EDUCATING BUILDING PROFESSIONALS FOR THE FUTURE IN THE GLOBALISED WORLD

INNOVATION

VOLUME 1

Editors:
Associate Professor Khoa Do
Associate Professor Monty Sutrisna
Mr Barry Cooper-Cooke
Dr Oluwole (Alfred) Olatunji
42nd AUBEA CONFERENCE 2018
Australasian Universities Building Education Association (AUBEA)

EDUCATING BUILDING PROFESSIONALS FOR THE FUTURE IN THE GLOBALISED WORLD

26 - 28 September 2018
Singapore

INNOVATION, VOLUME 1

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Dr Oluwole (Alfred) Olatunji

CURTIN UNIVERSITY
ACKNOWLEDGEMENTS

Conference Organising Committee

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Scientific Committee

Full papers accepted for publishing in the Conference Proceedings are subject to a blind peer review process. The 2018 Conference Committee gratefully acknowledges the generous work of the reviewers, who provide constructive and invaluable feedback within tight time frames to ensure the high standard of published papers. A full list of scientific committee is published on page x.
PREFACE

Over the last decade, Curtin University has grown from a research-capable university dominated by teaching into an innovative university increasingly recognised for research excellence. We have capitalised on our strong foundations of technical and applied research. We have used our relationships with key industry and Government partners to build impactful research collaborations. But equally important to our success has been our emphasis on innovation, knowledge-sharing and translating research into tangible benefits for society.

The benefits of this hard work and focus are there for all to see. Curtin now ranks in the top 1% of universities worldwide. This year, we were ranked 18th in the world’s Academic Rankings for World Universities. Ten years ago, we hadn’t cracked the Top 500.

But we are not content to rest there. Looking forward, our Research Strategy seeks to position Curtin as a strong technical and translation university. To do this, we must excel at connecting the university to the external environment to deliver value. We must continue to innovate and be agile in a time of digital disruption, rapid technological change and globalisation.

Curtin is proud to support the Australasian Universities Building Education Association (AUBEA) as it continues to prepare building professionals for a rewarding career in an increasingly global industry. Innovation is an important part of this preparation, providing resilience in the face of significant challenges, opportunities in disruption, and success through collaboration. By linking Sustainability, Innovation and Technology, the 2018 AUBEA Conference weaves together elements of the vision, principles, practices and tools that can help sculpt the building professionals of tomorrow.

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CONGRATULATIONS TO THE CONFERENCE ORGANISING COMMITTEE, SCIENTIFIC COMMITTEE, STREAM EXPERTS, AND CONFERENCE CONVERSANTS ON PUTTING TOGETHER A QUALITY PROGRAM FOR THIS, THE 42ND ANNUAL AUBEA CONFERENCE.

FOREWORD FROM THE CHAIR

It is with great delight I am writing this introduction for AUBEA 2018 Conference proceeding. Throughout the long history from its formation in 1975, AUBEA has been convening annual conferences successfully. This 42nd AUBEA conference, however, is the first AUBEA conference held in the Asia region. This represents the recognition of the significant roles played by the Asian region in the global building industry and building education. As soon as we received the mandate to host this conference, the organising committee immediately considered Singapore as a potential venue for the conference. Singapore as a place has inspired us to articulate the theme of this conference as “Educating Building Professionals for the Future: Innovation, Technology and Sustainability in the Globalised Market”. The theme embodies characteristics, challenges and opportunities facing the building education sector at the current time and beyond. We all know that the very nature of our building education sector calls for in-depth collaboration between industry and academia to educate building professionals fit for the future. Industry and academia are shaping the future of the profession together and it is highly celebrated in this conference through the selection of the prominent keynote speakers and stream experts, as well as the highly interactive conference programme.

I would like to take this opportunity to show my gratitude to my colleagues in the organising committee who have been working very hard to make this conference a reality. On behalf of the organising committee, I would also like to thank the AUBEA Council for entrusting us with the mandate to host the conference and also to show appreciation to the sponsors and partners of this conference that has supported the conference. We also would like to acknowledge the important contribution from the scientific reviewers who have been generously donating their time to review abstracts and full papers submitted to this conference to ensure the quality of the papers accepted, as well as the session chairs who are instrumental to the success of the delivery of the paper presentation sessions.

Last but not least, it is our aim to recognise excellence. Therefore, the organising committee have also set up various scholarships and awards in this conference. We have set up the AUBEA 2018 conference to provide a conducive environment and a platform for industry and academia to further collaborate in educating building professionals for the future. On behalf of the organising committee I would like to thank delegates for joining us in this celebration of learning and participating in this exciting conference.

ASSOCIATE PROFESSOR MONTY SURTISNA
Chair of AUBEA 2018 Conference

KEYNOTE SPEAKERS

Keynote Address

Educating for the future in Construction: An institutional perspective

PROF WILLIE TAN
Head, Department of Building | National University of Singapore

Keynote Address

Construction Industry in the Globalised Market

MR JOHN ANDERSON
Executive General Manager | John Holland’s South East Asia

Keynote Address

Educating for the Future in Construction: An institutional perspective

Professor Willie Tan is Head of Department, Department of Building, School of Design and Environment (SDE), National University of Singapore (NUS). He was the Program Director of the MSc (Project Management) program (2003-13) and Co-Director of the Center for Project Management and Construction Law (2005-7). He is an editorial board member of the International Journal of Project Management and Infrastructure Asset Management, among others. Professionally, he has chaired visit panels for Project Management Institute’s (PMI) Global Accreditation Center to accredit university programs in project management. He has served as a consultant in project management and infrastructure development in many countries in Asia and the Middle East.

Keynote Address

Construction Industry in the Globalised Market

MR JOHN ANDERSON
Executive General Manager | John Holland’s South East Asia

Keynote Address

Educating for the Future in Construction: An institutional perspective

Mr Phil Lazarus is an American Architect with over 20 years of experience leveraging the power of BIM on behalf of architects, engineers, contractors and clients. Involved with Singapore’s largest developments since 2006, Phil has been leading the change in promoting technology based innovation throughout Asia in his current role as Aurecon’s Digital Practice Leader. Phil oversees the activities of over 200 digital engineering staff. He leads Aurecon’s Singapore-based Centre of Digital Excellence, experting best practices for Digital Implementation to operations in Hong Kong, Thailand, Vietnam, China, and Indonesia.

Keynote Address

Construction Industry in the Globalised Market

MR JOHN ANDERSON
Executive General Manager | John Holland’s South East Asia

Keynote Address

Educating for the Future in Construction: An institutional perspective

Mr John Anderson is the Executive General Manager for John Holland’s South East Asia business region and has more than 20 years’ engineering experience gained through his work in Vietnam, Indochina, Sudan, Hong Kong, Singapore, Australia and Indonesia. His engineering experience includes civil and building construction, marine construction, environmental protection, structural-steel work, traffic management, viaduct construction, land/marine-foundation works, and planning and overall site coordination.
CONFERENCE THEMES

Educating Building Professional for the Future in the Globalised World

The overarching theme of the 2018 AUBEA Conference is ‘Educating Building Professionals for the Future in the Globalised World’ in recognition of the multiple and complex demands placed on an assessment in higher education. Some of these challenges are long standing, such as those relating to continuously synchronising education and industry practice. Other challenges are emerging as national priorities, funding arrangements and policy frameworks change.

Professor Joseph Ooi, Vice Dean (Academic), School of Design and Environment, National University Singapore
Professor Peter Newman
John Curtin Distinguished Professor, School of Design & the Built Environment, Curtin University
Professor Law Sui Pheng
Professor School of Design and Environment, National University Singapore
Professor Robert Amar
Head of Department, Dept. of Computer Science, University of Auckland

Innovative, technological and sustainable when it comes to construction and the built environment.

Mr Barry Copper-Cooke
Dr Oluwole (Alfred) Olutunji

The breadth of the papers presented is wide covering a vast array of subjects that pivot around the central theme of innovation. Performance in any industry is important and none more so than the construction industry, where none performance can come with high liquidated damages. One paper looks at the effect of cultural diversity on project performance, with a focus on its contribution to project success. On a similar theme of culture, the re-purposing of surveillance cameras is investigated, with the suggestion that they may be used to support urban densification in a sustainable way. The push for the densification of our cities cannot happen if the cost of construction is high, this then poses a challenge to industry to perform better and increase productivity while maintaining quality and keeping consumer costs at an affordable rate. One paper looks at the drivers and barriers to innovation along with identifying how government and industry can drive more innovations to achieve significant productivity performance. From an industry perspective to that of student work ready, students work ready one is of the primary focuses of education establishments. Two papers look at both these perspectives one focused on educating work-ready students and the other reports on student’s teamwork experiences during online study. This, I would suggest, is an important piece of work considering that more and more universities around the world are looking to delivering their courses online. How does this approach affect two important components of effective teamwork, communication and collaboration? I trust you will enjoy your time at the 42nd AUBEA conference hosted by Curtin in Singapore, a place that has proven to be innovative, technological and sustainable when it comes to construction and the built environment.

In the context of the built environment, technology plays a significant role in defining the overall systems that are opening new avenues in integration of the built and human environments. From real-time data that is instantly generated, and which enables constant analysis of implemented strategies, to the use of artificial intelligence to automate essential functions within the built environment through enhanced pattern recognition. The 42nd Australasian Universities Building Education Association (AUBEA) Conference aims to showcase the novel approaches that are implemented for integrating technology within the built environment, with focus on its adoption to further enhance the education of professionals in the field. It is throughout exhibiting and sharing of the most recent advances in technology integration within the built environment that we envisage an enhanced sector that is capable of bridging human and technology with its surrounding built environment worldwide. The “technology stream” of AUBEA this year hence provides a pivotal exploration and deep insight into future applications of intelligent technology in the built environment, helping to further ignite the adoption of effective technology within the field. Please join us for this unique experience in Singapore!

Mr Barry Copper-Cooke
Dr Oluwole (Alfred) Olutunji

Leads, TECHNOLOGY Stream
Curtin University, Australia

Mr Barry Copper-Cooke
Dr Oluwole (Alfred) Olutunji

Leads, SUSTAINABILITY Stream
Curtin University, Australia

In its broadest terms, the definition of ‘sustainability’ has been in a perpetual state of refinement since its inception some 40 years ago. It is generally accepted to be the ability to preserve, sustain and balance healthy environmental, economic and social systems, on an international scale. Next to this, exponential population growth and shifts to urban environments necessitates a sustainably responsible demand for construction and densification of cities. Construction has the capacity to make a critical impact on global sustainability agenda given that buildings in the first world contribute to more than forty percent of energy consumption over their lifetime. When we consider production of raw materials, construction, operation, maintenance and decommissioning—dissipation and decommissioning of buildings that are surrounding them. Technology has also meant that the capacity for educating building professionals for the future has advanced to an exceptional level, permitting the dynamics of an evolving industry to be rapidly transferred to its key players.
GENERAL INFORMATION

Conference plenary venue
The conference will take place principally in the Ramada Hotel.

Registration
Delegates can register from 08:00 am on Thursday, September 27. The registration desk is located in the foyer of the Ramada Hotel. The registration desk will be staffed throughout the conference to take general enquiries.

Presenter support
Presenters are asked to be in their designated room 5 minutes prior to the start of the session in their stream in order to load and check any files they require and to confer with the session chair.

For everyone’s benefit
To ensure everyone’s enjoyment of this event, please:

- Remember to turn off your mobile phones or set ‘silent mode’;
- Arrive on time for sessions;
- If you are presenting, keep to time limits and follow directions of the session chair; and
- Ask us if you have any questions or if you need assistance.

Assistance
Please don’t hesitate to ask Curtin conference staff or volunteers. Conference helpers are readily identifiable by their red coloured lanyards.

Meals
Full registration includes lunch, morning & afternoon tea and the conference dinner. Walk-in Single day registrations include lunch, morning & afternoon tea and the conference dinner on the 27 September or site visit on 28 September.

Tea, coffee and lunches will be served in the foyer of the Ramada Hotel.

The conference dinner will be held at the Ramada Hotel, with a reception commencing at 07:00 pm. If you travel independently to the venue, ensure you arrive in time to allow all guests to be seated by 06:45 pm.

Dress: Business Smart.

Proceedings
The website www.aubea2018.com.au will maintain an electronic copy of the proceedings. These conference proceedings (including abstracts and program) will also be supplied on USB to delegates on registration.

Photography
Curtin University will be photographing various parts of this conference. Your image and/or contributions may be photographed and used in printed or electronic publications as part of the conference archive and for educational purposes. If you have any concerns about this, please contact staff at the registration desk on the day.

Feedback
Please use the evaluation forms in your conference bag to provide us with feedback and suggestions for improving the next AUBEA conference. These will be collected on Friday, 28 September 2018. We also welcome your input at the registration desk at any time.

EDITORIAL

This section contains the abstracts and full papers presented at the conference. On behalf of the conference committee, we would like to acknowledge and thank the delegates that submitted papers for consideration under the conference themes of Innovation, Technology and Sustainability. Table 1 below shows the number of submissions and outcomes in each category.

Table below: AUBEA 2018: Submissions and outcomes

<table>
<thead>
<tr>
<th>Submission Format</th>
<th>Abstracts Received</th>
<th>Full Papers Received</th>
<th>Final outcomes (total)</th>
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<tr>
<td>Papers (Innovation)</td>
<td>46</td>
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<td>Papers (Technology)</td>
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<td>Papers (Sustainability)</td>
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<tr>
<td>Total</td>
<td>102</td>
<td>102</td>
<td>89</td>
</tr>
</tbody>
</table>

Full papers identified as ‘Full Paper – Peer Reviewed’ in the Conference Proceedings have undergone a blind peer review process, with de-identified feedback and suggestions for revisions provided to authors. All submissions were also reviewed by members of the conference committee review panel. We gratefully acknowledge the generous work of the reviewers, a national and international group of colleagues who contributed their time and expertise to provide review commentary, including constructive and valuable feedback for all submissions.

These proceedings are published by Curtin University under ISBN 978-0-9871831-3-2 (Print) & ISBN 978-0-9871831-6-3 (e-Book). We hope that this collection of papers will make a positive contribution to the ongoing discussion about those challenging issues that lie at the heart of assessment.

Disclaimer
The papers published in this Conference Program have been reviewed, edited and proofread to the best of our ability within the timeframe permitted. We acknowledge that there may be further proofing errors.

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Associate Professor Monty Sutrisna (Volumes 1, 2 & 3)
Mr Barry Cooper-Coake (Volume 1)
Dr Oluwole (Alfred) Olatunji (Volume 1)
Dr Ahmed Hammad (Volume 2)
Dr Chamila Ramanayaka (Volume 2)
Dr Emil Jonescu (Volume 3)
Dr Atiq Zaman (Volume 3)
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Austin Williams
Kingston University, United Kingdom

Peng Wu
Curtin University, Australia

Atiq Zeman
Curtin University, Australia
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Insights into the push factors of innovation adoption of professional services firms: the case of Ghanaian quantity surveying firms (QSF)
The bush university concept in Nowanup: a teaching place of learning from the land

Simon Forrest1, Eugene Eades2, Khoa Do3, Emil Jonescu4, Chris Leong5, Eileen Chan6, Monty Sutrisna7 and Belinda Gibson8

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Abstract:
The andragogy of constructivism theory for learning beyond the classroom is founded on the teaching principle of extending an adult learner’s constructed knowledge and skills, which have been neatly packaged and acquired in the classroom (Hildebrand 2008), to then be applied into practice to process the learnt in an authentic and meaningful way through a contextualised experience informed through real-world perspectives. The ‘real-world’ is considered the place where the application of theory is put into practice. It is rare and unique to have a real-world setting be transformed into a learning place. The Nowanup Bush University (NBU) project is the first Bush University concept to be developed in Australia. This paper presents the contextual design framework, by firstly, defining the aspirational brief for the spatial and scholarship concept of a NBU through the significance of the current existing six Nowanup learning circles (Karta-Wongkin-Jini), each is 1 km in diameter and were scribed onto the land through the replanting of native bush. The significance of these six learning circles is that they each represent the six Nyungar seasons and serves as a physical demarcation of a place. Moreover, they are a visually unobtrusive and unenclosed space that defines a gathering and meeting place for on-country learning – a breaking down of walls. This notion of breaking down of walls is both physical and metaphorical. It is a meeting ground without walls as barriers, of elders (teachers) and learners, of indigenous and non-indigenous peoples. This paper presents the current work-in-progress of the NBU project, and further, identifies the achievements and outcomes of the NBU project to-date and provides an anticipated long-term projection of outcomes for the design of a new university typology in Australia. The NBU seeks to extend beyond the traditional boundaries of what constitutes a university, and the findings seek to provide universities, academics and industry with a unique perspective on a model of collaboration that promotes design, culture and Scholarship of Teaching and Learning (SoTL) – principled on innovation, technology and sustainability.

Keywords:
Bush University, learning circle, beyond the classroom, indigenious, Australian Aboriginal

1 Introduction

What defines a good university? Most will say it would depend on the university’s 1) reputation, 2) history and 3) future direction. The line of inquiry in answering this question would, in most cases, lead back to a question of where the university is placed in the scale of rankings, and based on the research and scholarship performance index which are published annually at a regional, national and international level. University rankings are a mainstream system of acknowledging and rewarding high performance which directly strengthens the public image of prestige. Around the world, younger universities, of less than 50 years, stand out by "punching above their weight", but at the same time striking a careful balance of impact at a local level is imperative. For this, at all levels of the university, there is a clear vision to establish healthy and sustainable partnerships and alliances with a broad range of diverse local communities.

Curtin University in Western Australia, celebrated its 50-year anniversary in 2017 prompting the university to reflect on its many achievements. What has stood out as a distinguishing factor for Curtin University (CU) is that it prides itself on being a progressive university that is community-facing. By building trust through shared understanding, serving and engaging with the community and the Greater Curtin masterplan that blurs the physical boundaries between the university and the community serve as a robust integration model. CU has established and achieved its strategic image as a locally-influential university through the actions of its people who are visionary and pioneering, and their foresight, tenacity and bravery to serve the community through, and often, beyond their discipline fields of expertise. This historically is instilled through the culture of community engagement and empowerment which thrives evermore at Curtin and has paved forth a belief in formalising a partnership with Nowanup in Western Australia to co-develop a Bush University. The Bush University will be the first of its kind in Australia and will be achieved through a collaborative effort, Curtin University is part of a consortium of collaborators to include Gondwana Link, Greening Australia, Albany Council, Nyungar community of the South West and Friends of Nowanup Group.

A Nyungar point of view and principles to establish the terms of reference in which to take the vision of the Bush University forward was developed in 2017 through collaboration between Curtin University, Elder in Residence, Professor Simon Forrest and Nowanup Elder, Mr Eugene Eades. It is established that the NBU will be formed through the six Noongar seasons, geographically and pedagogically designed learning circles in Nowanup created by Elder Eades and Mr Justin Jonson (a restoration ecologist) seeks to unify the learning circles with Professor Forrest’s in-country scholarship of learning to the land. Bush University is therefore founded on the importance of the pedagogy of place (Wattchow and Brown 2011). The significance of learning in place, with place, and from place, in principle, does not seek to be an alternative to the established knowledge and skills of a contemporary learning classroom but offers an experiential learning environment that harnesses place as the critical component to teaching on-country. This endeavour, arguably, is in keeping with contextual learning, whereas to date it had to be taught in a de-contextualised, traditional classroom model.
2. The Story of Nowanup Bush University

The current Nowanup facilities are located in natural Mallee bushland where close to half of the property had been cleared for farming. Much of the cleared land has since been replanted with a mix with original flora species. Nowanup (Nyungar: Nyunk Nawainup), as it was recorded on early European maps documenting the area is a significant location both ecologically and culturally to the local Nyungar people. Through the vision of local elders, led by Elder Eugene Eades and supported by Greening Australia who owns and maintains the Nowanup property, the Nowanup location today is undergoing a transformational program of healing country-healing people (Gondwana Link Ltd 2017). One of the first projects was the design and construction of a Meeting Place. The project involved the contribution from young, at-risk Nyungar men. The healing country-healing people program has seen around 2,000 people participate annually and it is estimated that the Nowanup program has seen over 15,000 people participate since the program commenced (Gondwana Link Ltd 2017).

The camp program has attracted people and organisations, including members of the Stolen Generation, young Nyungar recommended by the courts, university groups, Wirrpanda Foundation, Department of Child Protection, school groups, corporate figures and many more (Gondwana Link Ltd 2017). Since 2016, the collaboration between Professor Simon Forrest (Curtin University, Elder in Residence) and Nowanup Elder Eugene Eades have since fostered the partnership between Nowanup and Curtin University. This partnership has focused on the vision for a Nowanup Bush University.

2.1 Vision

Cultural and ecological education done Nyungar way, from youngies to oldies, forging a traditional way forward in a westernised world (Gondwana Link Ltd 2017, 4).

2.2 Mission

The mission for the NBU is to build on the current strengths in the cultural and educational foundation which have been successfully implemented through the existing Nowanup programs to serve the community with:

- a teaching approach that is a pathway into Ranger jobs and land management for Nyungar people;
- an educational approach that strengthens the Nyungar culture for Nyungar people and supports a greater understanding of its essence and importance to non-Nyungar people;
- inspiration through the ecological and cultural perspectives of Nyungar way for the broader community to better manage their interactions with the environment (cultural survival as a means of cultural revival?)

Through Nyungar ways of learning and being on the land, the Bush University will help people from Nyungar and other cultures strengthen their relationship with an understanding of the country and each other. This is a living concept, one that will evolve further as it is implemented but will work through a close connection with country (Gondwana Link Ltd 2017, 5).

2.3 Initial program

Nowanup Bush University will include:

- formal training of students through being on-country and managing the many issues that arise;
- strengthened engagement of Nyungar people in managing their land;
- students from Curtin courses working, as part of their courses, to develop and document implementation pathways that meet the critical needs identified below;
- outreach to help people from other cultures understand and benefit from insights into Nyungar knowledge.

In essence, the Bush University will consolidate, strengthen and then significantly expand the Nyungar programs currently operating at Nowanup, under Eugene Eades, and in so doing underpin a rapid expansion of Nyungar land management that restores the health of large areas of Nyungar country, supports Nyungar leadership in land management across Nyungar country, and achieves substantial improvements in economic, social, cultural and health opportunities for Nyungar people, particularly youth at risk (Gondwana Link Ltd 2017, 5).

2.4 Nowanup Learning Circles (Karta-Wongkin-Jini)

The Nowanup six learning circles site was given the name ‘Karta-Wongkin-Jini’ by Elder Eades, meaning, place where people come together. The replanting process is an excellent demonstration of a successful culturally-informed ecological restoration project. It was planted in 2015 and was designed by Nowanup Nyungar Elder Eugene Eades and Mr Justin Jonson (restoration ecologist) and planted with the assistance of young Nyungar trainees (Bradby et al., 2016) see Fig. 1.

![Fig. 1. Eco-restoration design by Nowanup Elder Eugene Eades and Mr Justin Jonson](Image)
• Birak (Dec-Jan): Dry and hot. Also known as Season of the Young.
• Bunuru (Feb-Mar): Hottest part of the year. Also known as Season of Adolescence.
• Djeran (Apr-May): Cooler weather begins. Also known as Season of Adulthood.
• Makuru (Jun-Jul): Coldest and wettest time of the year; more frequent gales and storms. Also known as Fertilising Season.
• Djilba (Aug-Sept): Mixture of wet days with increasing number of bright, cold nights and pleasant warmer days. Also known as Season of Conception.
• Kamburang (Oct-Nov): Longer dry periods. Also known as Season of Birth.

3 Nowanup in collaboration with Curtin University by Design

In November 2017, the Site information for Nowanup to support design and development of The Bush University document (Gondwana Link Ltd 2017) was prepared for a design meeting with Curtin University. This document outlined the terms of reference for the proposed Bush University in Nowanup. The success of any good venture begins with a healthy and sustainable collaboration. Establishing shared values, aligned visions and core mission is only the beginning – people are at the heart of success. Given this, the document succinctly captured the evolution Nowanup since its acquisition through the property’s purchase by Greening Australia, supported in partnership with Gondwana Link. Nowanup has gained and continues to do so, with as much visibility as a significant cultural place for the Nyungar people but also a place which welcomes shared learning on-country.

3.1 Nowanup in Collaboration with Curtin University

The collaboration established between Nowanup Nyungar Elders, Greening Australia and Gondwana Link have established the strong collective partnership and identity for the NBU (National Bush University). A community formed through a universal aspiration that has been defined through Bush University and providing a purpose for people, program and practice. Curtin University historically was the Institute for the people of Perth. Having had humble beginnings as a technical institute – Western Australian Institute of Technology (WAIT). WAIT became Curtin University of Technology in 1987 (White 1996). Curtin since gaining the status of the university and becoming the third university in Western Australia. Curtin continued to establish itself as a higher education provider who prides itself as being strongly aligned and connected to industry and community. A great example of this is the Centre for Aboriginal Studies (CAS) which was established in 1983. Notwithstanding this, programs for Aboriginal and Torres Strait Islander people have been in operation since the 1970s. CAS continues to build knowledge and programs that advocate for the embedding of Indigenous culture across University Staff, students and visitors. Specifically, the in-country program has had an impactful contribution for the students and staff in the Discipline of Architecture. The importance of site investigation and contextual analysis of location and situational factors (such as seasons, orientation, geography and cultural aspects) forms one of the core design considerations at the inception concept phase and critical competencies for students in the architecture course. On-country provides a self-discovery and self-narrative-forming method that is culturally rooted in the Indigenous practice of walkabout – allowing the land (country) to speak, to lead and to connect you. A way of desensitising from the noise of where you have come from and connecting with being on-country. The Curtin University’s collaboration with Nowanup has created opportunities for the Discipline of Architecture to undertake further research into aspects of scholarship of designing of space and place (Ellsworth 2005), place activation and pedagogy of place with the focus on the already established framework of on-country and the self-discovery of walkabout and narrative. (Once rare) Research opportunities of significant value await design practices which stand to benefit from outcomes that will provide the architecture industry with value methods. To this end, the NBU project in collaboration with Curtin University has attracted the support of five architecture design practices to co-create by design, using elements of design thinking similar to that of the six design process developed by Hugh Dubberly (Wuiczec 2011, 148-149) to develop the framework to envision what NBU can be through architecture.

3.2 By Design (process)

In principle, the collaboration between Nowanup, Greening Australia, Gondwana Link and Curtin University to further develop on its concept design stage for Bush University has been agreed. Curtin University will sign a memorandum of understanding to form part of the consortia on the NBU project in late 2018. The consortia is a significant formalised gesture of collaboration which will further cement Curtin’s reputation as a community and industry facing University. It was therefore essential to provide an opportunity to create a Karta-Wongkin-Jini (gathering place/learning circle) project that would bring Nowanup, Greening Australia, Gondwana Link and Curtin University together through people and see that the NBU as a ‘fireplace’ to spark and flame ideas that could develop visibility and images of what is possible for the NBU bigger picture.

Traditionally when an aspirational brief is established, which the NBU bigger picture is, on the grounds of taking a concept into the possibility, the field of design and architecture are engaged to support the divergence of design thinking through the convergence of visualisation and taking the creative modelling into real possibilities. Design approach and using the design methods (Mootee 2013) of gaining insightful potential possibilities at the same time seeks to not to construct or limit the creative possibilities for design, through typical immediate limitations and constraints such as budget and stakeholder imposition, which are considered beyond to not impede the aspirational nature of this stage to cast futuristically (Kushner, M. 2015). In much the same way, in 2010, the City of Perth released its Urban Design Framework (UDF) documents essentially it was an aspiration brief. It was considered important that this aspiration required the support of big, bold and brave thinking through the imagery of big-picture thinking echoed through the UDF. The WHAT IF? Ideas for City of Perth project was a commissioned an Ideas Competition to support creative debate and to challenge current and established views of the city through design, while at the same time, consider the question of where might the City of Perth go in the next twenty years and beyond? (City of Perth 2010, 3). This method of creating Karta-Wongkin-Jini through a design Ideas Competitions was a relevant and successful approach for building a ‘community of practice’ for the NBU project and gain further expertise and engagement in the confidence of industry. This has diversified and established new critical in-kind partnerships beyond the core partners already involved with the project.

3.2.1 Ideas Competition

The NBU Ideas Competition provides the Karta-Wongkin-Jini space. The formation of five architectural project teams, with each project teams’ comprising of five architecture students (from both the undergraduate and postgraduate programs). The project teams collaborated with award-winning architecture practices in Perth WA, some with international esteem. At the same time, a committee was formed to support the ideas competition. A formal one-day Karta-Wongkin-Jini gathering was organised to bring together Elders from Nowanup, Friends of Nowanup, Greening Australia, Gondwana Link, Curtin staff and students and the five architecture practices. The Karta-Wongkin-Jini space provides a chance.
3.2.3 Site Investigation, Narrative & Metaphor

All project teams were provided with the opportunity to participate in an immersive on-country visit to Nowanup and staying on-country for three days. The trip entailed visiting significant Aboriginal sites, participating in reflection, journeying across the site and smoking ceremony. The project teams before being on-country for the site investigation phase were asked to undertake a pre-tour evaluation to develop an appropriate site investigation toolkit (Do and Siew 2006). Specific to the discipline of architecture, is the need to develop a wide range of sound teaching and learning methods of recording of place (Do and Siew 2005) through site investigation and understanding context to support methods of observational recordings, such as journaling, sketching and photography (Do and Siew 2006). The importance of place-responsiveness (Wattchow and Brown 2011) as outlined earlier in this paper cites the importance of education in the outdoors as does formative learning in its current dependency on an individual's ability for self-assessment and self-adaptiveness. This is something Spanish architect Enric Miralles describes through his practice as the act of investigating sites like that of an archaeologist who excavates the site by peeling back the layers of the hidden information to include geography, history, relics, sediments and rock. To uncover the stories immediately on the surface and below the ground (Caballero 2014, 155). Miralles adopts a technique of documenting the historical significance of site through architectural drawings that narrate the site and communicate a metaphorical evaluation of elements, concepts, drawings and writing (Caballero 2014, 155-180). His architecture is described as a journey punctuated with interpretive built elements geologically excavated and interpreted. Given this, the design project teams have adopted their own design narrative method (Lidwell, Holden and Butler 2015, 130-131).

3.2.4 Good Design is Communication

All project teams’ focus is on delivering Good Design for the NBU. The criteria for ‘Good Design’ is determined through the design co-creation process between the student team and the mentoring practice. The challenge for the project teams is to be able to deliver the project in a way that is not focused purely on the architecture (the built) but to develop clarity of ideas, appropriateness of concept application and to design a communication package through illustrations and modelling that encapsulates the good design strategies and principles (McCandless 2009), whilst providing the viewer with evidence of the quality in the spatial design from a 1st person perspective. Architecture and design are about pushing the boundaries of existing limitations by way of de-contextualising pre-set views and behaviours. Thus, shifting this trend is to adopt a user-experience perspective through the application of occupancy, behavioural and environmental affordance (Jonescu and Ghanim 2018).

4 Design Value Proposition

The Nowanup Bush University project has gained considerable momentum through the adoption of the architecture Ideas Competition (IC). The IC has provided a significant opportunity to create a shared space for all to contribute at the early aspirational stage of the project, and, it is evident that the NBU project provided those involved with the project with invaluable experiences. The project brought Indigenous and Non-Indigenous together academics, students and industry to a common ground through Karta-Wongkin-Jini, (familiar place to learn).
Students, staff, industry and the university have gained insightful understanding of: 1) Indigenous knowledge and language, 2) building resilience, 3) impactful collaboration, 4) sustainable future, 5) unique local place pedagogy and scholarship, 6) healing by the land, and 7) self-discovery.

5 Conclusion
The Nowanup Bush University is a unique platform founded on the living culture and traditional knowledge of the Australian Indigenous peoples. The notion of listening to the land through the immersive experience of being on-country seeks to reconnect Indigenous and non-Indigenous peoples to the significance of place-making, environmental healing and community resilience. To this end, the architecture Ideas Competition has offered an insightful design exploration and translation of the significant excavation of the stories of Nowanup. The design competition provided a significant opportunity for the establishment of a valuable collaboration teaching model of work-integrated learning (WIL) and has forged collective strengths of the design industry, architecture and interior architecture students and staff. Engaging in a co-creating of a collective visual narrative of possibilities for an Aboriginal place-making design for the Nowanup site. Designs for the spatial program was informed through the importance of teaching on-country and learning through Aboriginal narratives. The importance of Aboriginal on-country and culture, defines the unique local scholarship for the establishment of Nowanup’s place pedagogy – to be the Nowanup Bush University, where learning beyond the classroom, engaging the real-world and the wall-less (breaking down the walls) university – Nowanup Bush University is such a place.

6 Acknowledgement
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7 References


Video-based assessments for personalising learning in construction education

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Abstract
Personalised learning is critical to achieving excellence for universities, which entails maintaining an education system that is reactive to the diverse learning needs, aptitudes and interests of individual students, rather than imposing a ‘one-size fits all’ model, and ensures every learner achieves his/her highest potential. Pedagogical literature suggests that learning-oriented assessments that are engaging, authentic and relevant are an effective mode for personalisation. DigiExplanations is a novel approach that requires students to create short digital media to communicate their ideas to ordinary audiences. It offers an opportunity for research-based authentic learning by harnessing digital media that exist outside of their institution and their digital competencies to create personally relevant and interesting resources. The aim of the research was to investigate the effectiveness of DigiExplanations driven assessments for personalising learning in construction education. A case study strategy was adopted in the research. A first-year subject from the construction management degree was chosen as the case, which had a class of 159 students. A new assignment scheme was introduced for which students were required to develop DigiExplanations in groups of five. After the submission deadline, an online survey was conducted with the students to assess how the assessment approach facilitated personalised learning. The survey findings suggest that while the new approach achieved its intended aim, few students perceived it a cumbersome approach as it requires more efforts than traditional assignments.

Keywords: Personalised learning, assessments; pedagogy 2.0, DigiExplanations, construction education.

1 Introduction
In a rapidly changing world, education in any field of study requires effective teaching and learning strategies that would effectively adapt and suit those drastic changes and innovations. The tertiary education, which is the key doorway to the fast developing industry, demands education systems that harness a workforce with flexible and adaptive skills in learning the latest industrial innovations. According to Sampson et al. (2002) present education and training needs to cater for the knowledge-based economy. In order to fulfil these industrial demands, universities need to set apt learning outcomes, which are also named as graduate attributes by Biggs and Tang (2011), contextualised in their courses/programmes. The graduate attributes are creativeness, professional competence, problem-solving skills, communication skills, team work and life-long learning capabilities. In response to these demands, specialists have introduced an educational concept, called ‘personalised learning’.

Pedagogical literatures suggest that learning-oriented assessments that are engaging, authentic and relevant are an effective mode for personalisation. A study attributed to Glasser (1999, cited in Biggs & Tang 2011) indicated that most people learn 80% of involve student’s own exploration, research, experimentation, effective communication and presentation contribute to a more complete and comprehensive deep learning. The profound influence of assessment design on approaches to learning has been brought into the light by Gibbs (1999).

However, most of the traditional assessment methods limit to written reports or PowerPoint presentations that reduce learner enthusiasm, interactive learning and also restrict the learner and teacher engagements. Assessments could be made more beneficial if the presentation method of the content is made more attractive and interactive. More recently amidst the backdrop of technological advancements emerge the novel presentation method called ‘digiExplanations’ in that students create short digital media to communicate their ideas to ordinary audiences while satisfying assessment criteria. In this method, students are expected to harness suitable digital media that already exist on the internet or in other locations outside of their institution and their digital competencies to create personally relevant and interesting submissions; offering an opportunity for research-based authentic learning.

To this end, the aims of the study are: (1) developing an assessment model that leverages digiExplanations for construction education; (2) operationalising the assessment model; and (3) measuring its effectiveness for personalising learning for students.

2 Literature review

2.1 Defining personalised learning
Personalised learning, which is also known as ‘tailored learning’ or ‘learnacy’ (Burton, 2007) could be considered as the trendy approach in the world wide education lexicon. According to Sampson et al. (2002) this is due to the upsurge of the knowledge-oriented society and the knowledge-based economy in the present context. Personalised learning was also presented as ‘differentiated learning’ in 1990’s pedagogical discourses. According to Weston (1996), differentiation was a strategy used by educators to empower each student individually to achieve their own learning targets. Later in 2001, the Department for Education and Skills, UK (DfES, 2001, p.20) further discussed this as ‘individualised learning’, which promoted that every learner can be instructed in a unique way and pace which suits his/her aptitudes, needs and interests. More recently this is widely addressed as ‘personalised learning’, where Downes (2006) depicted it as a methodology, not an application, one that recognises personality and encourages the formation of communities of inquiry. Moreover, it argues that instructions ought not to be confined by place, time or any other obstructions, rather it should be customised to the individual learner’s needs, aptitudes, previous knowledge, interests, etc. (Sampson et al, 2002).

It is apparent from the above definition that personalised learning implies a drastic departure in education lexicon from traditional general and inactive learning environment to more personalised and active learning environments. Atwell (2007, cited in McLoughlin et al. 2013) characterised personalised in terms of learner participation, as the principles behind it imply that personalised learning offers a real opportunity for learners to participate fully and become co-creators of knowledge.
In summary, personalised learning aims to create an education system that is receptive to the varied learning goals of individual learners rather than imposing a ‘one-size fits all’ model (Bartle 2015). In this venture, educators are challenged to leverage resources that exist outside the formal institutional boundaries and the already known digital skills and interests of learners to facilitate authentic, active learning that is personally relevant to students (McLoughlin et al. 2013).

2.2 Characteristics of personalised learning

Hanover Research (2014) defined the fundamental features of personalised learning as: tailoring learning plans/paths to suit the needs of individual students; supporting students to realise their potential; engaging and motivating students by making learning activities authentic and relevant to their life, interest and goals; providing flexibility in how, what, when and where students learn; encouraging relationship between students, educators, institution and community; and preparing students to be life-long learners. Similarly, Keanny et al (2007) argued that personalised education has four features.

- Learner centred approach – it involves: (1) a well-designed approach that emphasises on the interests and learning needs and styles of students at the centre; (2) heavily engaging students; (3) meaningful assessment tasks for and from students; and (4) a commitment to reducing the achievement gap between students.
- Advanced use of ICT – using ICT infrastructure to: provide better diversity in learning methods; enhance individual interactivity between learners and educators; offer flexible learning beyond classroom, and facilitate student learning globally with external resources that exist on the Internet.
- Lifelong learning – involves developing skills and strategies to enable self-management of learning for employability (how to research, organise and present data; working in teams; learning to review and reflect; analysing, explaining, justifying and developing arguments).
- Communities of collaboration – develop and promote learning networks to underpin mentoring and knowledge building through connectivity.

2.3 Framework of personalised learning

Based on the characteristics identified in the literature (DfES 2001; Sampson et al. 2002; Bartle 2015; McLoughlin et al. 2013; Hanover Research 2014; Keanny et al. 2007), a framework for implementing personalised learning models is proposed, as shown in Figure 1. The framework encompasses three concentric rectangles, namely: learner, teaching, ICT and organisation. The framework postulates that the learner is the central focus of personalised learning and three key pedagogical components are essential to achieve the learner-centred education, with each component supporting the other.

The first rectangle explains four essential elements in teaching that are required to enable personalised learning (see Figure 1). They are:

- Flexibility and personal choice in learning: Teaching needs to provide flexibility and personal choice in what, how and where students learn. This mainly focuses on learners’ interest. Therefore, the course/subject structure and delivery mode should fit in to any environment, time or space.
- Pedagogical strategies for nurturing lifelong learning skills: Need to utilise strategies that train students for lifelong learning. Teaching the skills for learning is important as they would be of immense use even after graduation. In this fast-developing world, focused skills outdate fast and therefore students are required to keep learning new skills. It is therefore important to provide and nature learners with skills for lifelong learning. This could be through pedagogical strategies such as project-based learning, research-based learning, case study-based learning, inquiry-based learning, etc. These kinds of pedagogical strategies would train students as self-directed learners, where students are able to find their own tactics for learning and gaining new skills.
- Assessment for learning: Need to make assessments as a tool for teaching and provide feedback to reinforce further learning. For example, continuous constructive feedbacks on project-based assignments are helpful in student learning, where the comments could be utilised in additional learning and in revising the original task. Therefore, constructive comments could underpin students’ progress in learning.
- Community/network of learning: This is to go outside the classroom where learning can happen anywhere with anyone. It is to go beyond the traditional teaching and to direct students to an apt network relevant to the specific subject. This direction could be into a network of people or network of information such as forums, seminars, resource collection or even industry. Furthermore, networking could also be enabled through student group formation, where peer learning could take place.

![Figure 1: Framework for personalised learning](image)
be equipped with this kind of specific infrastructure in supportive of a unique teaching strategy.

- Policies: Organisational policy on teaching should facilitate these unique methods of teaching for personalised learning, whether it is through the allocation of proper budgets or encouraging staff through incentives, grants, etc.

- School structure: The above discussed unique pedagogical strategies for personalised learning require more resources, time and energy, which may not be feasible to be handled by a single person. Therefore, if the school structure encourages team based teaching or shared subjects, experts with specialised skills such as technical, contextual, media and delivery could work together to form a more comprehensive course that facilitates personalised learning.

- Partnership: The organisation can form partnerships with the industry to facilitate work-integrated learning which facilitates personalised learning. Organisational policies and facilities need to be aligned to harness partnerships.

3 Study Method

This research integrated “assessment for learning” in the first rectangle with “pedagogy 2.0” in the second rectangle in the above framework to facilitate personalised learning through a technique, namely “digiExplanations”. Pedagogy 2.0 is a model of teaching in that students are empowered by resources and networks that exist in the web 2.0 space to engage, communicate and create knowledge and thereby experience a high level of personalisation, ownership and control over learning. DigiExplanations offers a mechanism to bridge pedagogy 2.0 and assessments and involves learning tasks that require students to create short, interactive digital media to communicate to ordinary audiences while satisfying the marking criteria. The types of digital media developed for this purpose include: podcasts, digital stories, videos, slowmations (slow animations), video scribes or blended media. Further information on digiExplanations can be found on http://www.digiexplanations.com/

A case study strategy was adopted to operationalise the proposed pedagogical model and test its effectiveness for personalised learning. A first-year course, Construction and Property Economics, in the Bachelor of Construction Management and Property degree program was selected as the case. The research process involved two distinct stages, viz.: (1) implementing a digiExplanation-based assessment in the course; and (2) conducting a questionnaire survey to evaluate the effectiveness of the model for personalised learning. The ensuing sections elaborate on these stages. Case study combined with embedded questionnaire survey deemed the most suited strategy for this research because Cohen et al. (2011) argued that in educational research case studies can cause and effect (‘how’ and ‘why’); they reveal effects in real contexts and allow in depth understanding. Moreover, several previous studies in construction education have successfully adopted this strategy; for example, Kamardeen 2015; Kamardeen 2014; Kamardeen 2013.

4 Implementing a digiExplanation-based assessment for personalising learning

A group assignment was designed by the authors according to the proposed digiExplanations model and introduced at the beginning of the academic session. A brief description of the assignment is shown in Exhibit 1. Assessment criteria were made available to allow students understand the expected quality of submission and direct their efforts accordingly. The assessment criteria comprised: rationale for the study; depth and breadth of the discussions for the topic; appropriateness of media used in the discussions; creativity in the use of media (storyboarding); design of digiExplanation; quality of conclusion; and proper acknowledgement of materials used. Moreover, a progress review scheme was in place whereby groups’ progress was reviewed three times within 10 weeks, prior to final submission, and feedback was provided for improvement. Additionally, an online site of interactive resources on how to use technologies to create digital media was set up on the Moodle eLearning platform.

DigiExplanations for the Construction Industry

Scenario:
The NSW government aspires to set up a knowledgebase about the performance of the local construction industry to benefit small and medium sized builders, clients and investors. In order to achieve it, the government is intending on creating an e-portfolio. The government has decided to cover topics related to ten themes, including: Improving productivity in construction; Work health and safety in construction; Subcontracting practices in the construction industry; Cultural diversity in the construction industry; Sustainable construction; Construction trade unions; Financing methods for construction projects; Global construction markets; Disputes in the construction industry; and Ethics in construction business. In order to improve information richness and interactivity in presentation, the government has decided to leverage a novel approach, namely “DigiExplanations”, for creating the e-portfolio.

Task:
Students are to form groups of five and produce a 3–5 minute long digiExplanation on a topic interesting to them, using a video, slowmation, digital storey, videoclip or blended media form. Groups shall use their own technologies to create the digiExplanation: they can use computers with existing media, groups must make sure they are copyright free. They can use windows movie maker or imovie (for Mac); mobile phones; and/or still/video cameras. In creating these media, students can use their own images and videos or use existing ones that were created by others. When using existing media, groups must make sure they are copyright free. They can use google images and/or YouTube clips and integrate with their own images and videos to create an

Exhibit 1: Summary of assignment

The authors’ observations on the student learning process witnessed the following key characteristics during the course of the assignment: (1) All students were actively involved in the learning process and showed ownership for activities and contents they created; (2) Learning was largely driven by students and the lecturer provided only basic information or guidance; (3) Discussions and collaborations for problem solving within constraints were integral parts of their learning; (4) The task was felt challenging yet fun and enjoyable; and (5) Scholarly enquiry and information seeking/ research was a constant theme.

Though it was the first time for producing digital media or doing an assignment for that, students created media of reasonable quality. Their submissions can be found on YouTube with the search term of “BLDG1302”.

5 Effectiveness of the teaching model

After the submission of the assignment, an online questionnaire survey was administered with the students to evaluate the effectiveness of the teaching model for personalised learning. The questionnaire had three parts; the first part gathered background details of participants, the second part assessed how the digiExplanation approach satisfied nine qualities of personalised learning, on a 5-point ordinal scale consisting of strongly disagree, disagree, neutral, agree and strongly agree; and the last part received feedback on the overall learning experience, including written qualitative comments.
5.1 Survey participants

All 159 students in the class were invited to respond to the online survey, however only 108 of them participated, making a response rate of 68%. Table 1 shows the profile of survey respondents. Of the total of 108 respondents, around 80% were first year students. About 75% of the respondents were domestic students and about 36% respondents were from non-English background/English as Second Language (ESL) students. Over a half of the respondents had no work experience in the construction industry and around 20% of the respondents had more than one year’s work experience. Most of the students had used digital media before and among them more than 30% of them are frequent users.

Table 1: Survey participants

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Count</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Study Stage</td>
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<tr>
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<td>33%</td>
</tr>
<tr>
<td>2nd Year</td>
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</tr>
<tr>
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<td>24%</td>
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<td>4th Year</td>
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<tr>
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<tr>
<td>Work Part Time</td>
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<tr>
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<tr>
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<td>Frequently</td>
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<tr>
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<td>12 to 24 months</td>
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<tr>
<td>25 to 36 months</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>37 to 48 months</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>More than 48 months</td>
<td>6</td>
<td>6%</td>
</tr>
</tbody>
</table>

5.2 Survey results

Figure 2 illustrates the spread of responses to the questions asked to the students and their responses are summarised below.

- **Relevance:** over half of the students found the digiExplanation assignment was interesting and relevant to them. Only about 6.5% of the students were somewhat less interested in the assignment or found it irrelevant to them. About 37% of the students kept a neutral attitude on this issue.
- **Flexibility:** a majority of the students (more than 70%) considered the digiExplanation was a flexible way to present their work and ideas in a way they like. Only a small portion (less than 6.5%) of them thought the digiExplanation was not a flexible way.
- **Building on prior knowledge:** more than 70% of the students testified that the assignment model enabled them build on their previous knowledge on the subject whilst only a minority 5% disagreed and the rest was neutral.
- **Engagement:** nearly two-third of the students believed that the digiExplanation assignment was an engaging way to learn. Almost 30% of them were neutral and about 6.5% found it less engaging.
- **Collaboration:** over 70% of the students at least agreed that the digiExplanation assignment encouraged collaborative knowledge building and team work, while 22% students stood neutral and a few (about 7.4%) believed it was not a good way to facilitate collaboration.
- **Capitulate digital competence:** more than 60% of the students at least agreed that they could apply their previous digital skills in the assignment. While less than 10% of the students did not agree that their digital competencies were helpful in the assignment.
- **Harnessing Internet resources:** more than 65% of the students agreed that the assessment model fostered authentic learning that is meaningful to them by harnessing existing Internet resources. More than 25% of the students were neutral on this issue and less than 8% disagreed.
- **Self-managed learning:** nearly 75% of the respondents agreed the digiExplanation assessment encouraged self-managed learning of new knowledge. Only a small portion of the students (less than 5%) disagreed and 21% of them were neutral.
- **Feedback:** more than 60% of the students at least agreed that the progressive feedback provided helped them to realise their potentials. About 30% of the respondents remained neutral and less than 10% had negative responses and did not think progressive feedback was supportive.

Overall, the digiExplanation assignment received positive feedback. More than 84% of the students responded that they had a good personalised learning experience with it in the course, and within which, more than 30% of them rated the learning experience was “very good” or “excellent”. A correlation analysis was undertaken, as depicted in Table 2, to investigate which aspect of the above features better contribute to personalised learning experiences. Harnessing existing Internet resources, nurturing high student engagement and providing progressive feedback were regarded more important to personalised learning whilst personally interesting/relevant tasks, flexibility and building on prior knowledge were considered important.

Table 2: Correlation coefficients matrix for learning experience

<table>
<thead>
<tr>
<th>Learning experience (R)</th>
<th>Personally interesting/relevant</th>
<th>Flexibility</th>
<th>Building on prior knowledge</th>
<th>Engagement</th>
<th>Collaboration</th>
<th>Capitalise on digital competencies</th>
<th>Harnessing Internet resources</th>
<th>Self-managed learning</th>
<th>Progressive feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personally interesting/relevant</td>
<td>0.577</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.624</td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.545</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building on prior knowledge</td>
<td>0.519</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td>0.640</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration</td>
<td>0.465</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capitalise on digital competencies</td>
<td>0.291</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harnessing Internet resources</td>
<td>0.656</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-managed learning</td>
<td>0.467</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progressive feedback</td>
<td>0.624</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Furthermore, some direct quotes from students about the assignment model, which were found in the qualitative feedback, are as follows:

“It was very different to other assignments such as essays and reports thus making it more entertaining to undertake. It was great to collaborate in groups so knowledge from each individual could be shared, subsequently leading to more ideas and information being put forward. The use of technology was also a very positive learning experience which will be very useful in other university assignments and in the real world.”

“It allows for students to learn new skills not only with the use of computers, but researching, strengthens confidence and allows for current skills to be furthered. An all round effective method in learning a topic as a whole whilst developing other skills.”

“Very easy to learn from the digi explanations, easy again for ESL students who can watch the video if they don’t understand.”

“Adaptive learning, the use of multimedia allows us to exploit different methods and platforms/channels of communicating our topic across. Enables collaboration and actual team effort.”

“Make use of hobbies and multimedia experience in conveying or delivering research/report.”

“Interactive learning by bringing ideas across, through creative interpretation, on a globally recognised media stage (youtube).”

Qualitative feedback given by students was further analysed to get some insights into why some students remained in a neutral position in their responses to quantitative questions. Some challenges faced by students in undertaking this assignment were mentioned as reasons for that, which include:

- More work is required to produce a good digiExplanation than making a traditional report submission.
- Lack of prior skills in digital media creation in some group members, which burdens others.
- Inadequate contributions or delays by some group members make others hate group tasks as it pulls everyone down.
- Lack of examples of previous assignments as this was the first time the model was implemented.

However, overall most the students appreciated the novel approach to assignment, the level of engagement and enthusiasm nurtured by it and the new research and presentation skills they learnt. There were preferences from the students to see similar assignment methods implemented in other courses too.

6 Conclusion

Personalising learning is regarded as essential and trendy direction for attaining academic excellence and higher rankings for universities. Implementation of this agenda entails a well-thought-out framework that allows effective transformation of traditional pedagogical practices and institutional set ups. Utilising advanced and apt ICT strategies and technologies to support flexibility and personal choices in learning, gaining lifelong learning competencies, learning networks, and assessment-based learning, is a core ingredient for personalising learning for students. Identifying and leveraging right ICT strategies and technologies to satisfy the expected learning outcomes may be a challenge for lecturers. This research has demonstrated how a digiExplanation-driven assessment task was utilised to personalise learning in a large class of less-experienced, first year students. It was found that students perceive learning tasks that embody three features better support personalised learning, which are: harnessing resources that already exist on the Internet, the digiExplanation assignment facilitated collaborative knowledge building.
and with other students, and receiving progressive feedback for improvement. On the flipside, learning tasks that are excessively technically challenging and demand more work or hours than traditional tasks may not be received positively by students though they may be effective pedagogical strategies.

Lecturers should take some precautionary steps in order to reap the full benefits of this new assessment model. They should show some exemplary submission(s) to students, even if it involves them creating one, and plan the final submission date away from the busy period in the academic calendar.

Whilst the case study strategy that experimented with the new assessment model enabled a detailed investigation, the findings cannot be generalised to other disciplines or subjects. It may work better or worse in other cases, depending on the type of subject or knowledge taught. This inability to generalise findings may be regarded as a limitation of this research. Nonetheless, the case study can be considered as a past example to draw valuable insights for other lecturers.

The study has experimented with only a single combination (pedagogy 2.0 with assessment for learning) from the framework proposed in the paper and has demonstrated its soundness. Further studies may be conducted to test the other combinations of the framework.

7 References

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Hanover Research 2014, Best practices in personalized learning implementation, Retrieved from Arlington, VA.
Investigation of the empirical relation between student sketching, attendance and performance in construction education

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Abstract:
Traditionally students’ attendance and overall performance have been hypothesized to go hand in hand. In the current study, 195 students from non-engineering backgrounds were taught a core course of construction and their attendance vs performance results were empirically investigated. Further, the students’ attendance and performance were also assessed against tutors’ experience to highlight students’ performance in tutorials of novice vs experienced tutors. The assessment criteria of two quizzes each 20% weight, 1 assignment of 20% weight and a mid-semester exam with 40% weight were utilized with an attendance criterion of below 75% as low attendance. The result highlights that a clear difference of 14% marks exist between the students with less than 75% attendance and the ones with 75% and above. The students with low attendance averaged at 53.35% in terms of overall marks obtained whereas the good attendance students secured 67.40% marks on average. Furthermore, in terms of novice vs experienced tutors, students taught by novice and less experienced tutors not only displayed better attendance but also surpassed the experienced tutors’ students by a difference of 4% marks in terms of overall marks. Additionally, students with high marks in sketches secured higher overall marks as compared to the ones with lower sketch marks validating the hypothesis that students with better sketches have better imagination and perceptions, must have skills for construction managers and architects. This research gap and efforts are made to empirically analyse the relation between student’s attendance, tutors’ experience and overall academic performance. However, in context of construction course and students’ performance relative to their sketching, the literature is non-existent.

Keywords: Construction education, Experienced vs fresh tutors, Students’ performance, Students’ attendance, Sketching.

1 Introduction

Students’ attendance has been traditionally linked to higher academic performance. A report published by the University of Western Australia for the Department of Education, Employment and Workplace Relations (Hancock et al., 2013), stresses the importance of attendance for school going children. This report established the downfall in academic performance with lower attendance. Using NAPLAN tests, decline in academic performance was observed with any absence from school, and continued to decline as absence rates increased (Hancock et al., 2013). The authors used three criteria for such assessment: attendance rate, authorised absence rate, and unauthorised absence rate. Similarly, in a report by Hartley et al. (2016), none of the 42 investigated districts of the US have proper attendance monitoring and reward systems in place. The report recommended that these be introduced to incentivize the students for better attendance and subsequent better grades.

Various studies have encouraged the use of different engagement techniques for students to increase their overall performance. Lee (2014) upon investigation of 3,268 fifteen-year-old students from 121 U.S. schools concluded that behavioural and emotional engagement significantly predicts reading performance. The findings suggest that educators, policy makers, and research communities need to pay more attention to student engagement and associated enhancement ways. According to Gershenson et al. (2017), student attendance is a potentially important but understudied aspect of the educational process. The authors investigated the relationship between student absences and academic performance using longitudinal data for North Carolina to highlight that generally, student absences are associated with modest but statistically significant decreases in academic achievement in a linear manner. Various studies have discussed different ways of improving students attendance such as using flipped classrooms (Ryan and Reid, 2015), use of recorded lectures (Bos et al., 2016) and using incentives for attendance (Visaria et al., 2016). All these useful studies highlight the importance of student attendance for better educational outcomes. Yet, the field of construction education and specifically teaching the core construction courses to students from non-engineering background goes untouched. In terms of fields of construction and civil engineering, study of relationship between attendance and their performance as well as the performance of experienced vs novice tutors has not been assessed. The current study targets this research gap and efforts are made to empirically analyse the relation between students’ attendance, tutors’ experience and overall academic performance of the students. Furthermore, different studies have stressed the importance of sketching for students such as Ainsworth et al. (2016) for value of drawing in chemistry, biology and anatomy, (Masry et al., 2005) for computer and pen based sketching, and Melges (2016) for construction projects. It has been explored for mathematical drawings by Rellemann et al. (2017) who conclude that strategic knowledge of drawings and good sketching is positively related with good academic performance. However, in context of construction course and students’ performance relative to their sketching, the literature is non-existent.

2 Literature Review

Generally researchers, practitioners, policymakers and parents assume a positive relationship between academic success and school attendance. But, in terms of establishing the empirical evidence between input factors and their relation to academic outcomes, very few investigations exist that try to precisely assess the relationship between individual attendance and students’ achievements (Gottfried, 2010).

Massingham and Herrington (2006) investigated various aspects of students’ nonattendance of lectures and tutorials in University of Wollongong Australia. The study identifies relationships between attendance, participation and performance. The results of their study indicate that there are valid reasons for nonattendance that are both in the control of learners and teachers but if the students attend these classes, they will surely have benefits. Different researchers have explored and investigated the effects of student attendance on their performance in various fields. Deane and Murphy (2013)
explored its prospects in medical fields and concluded that among fourth-year medical students completing an 8-week gynaecology course, the relevant attendance at both clinical and tutorial-based activities is positively correlated to overall examination scores. They further concluded that 60% of failing students had lower attendance than the set limit of 80%. Similarly, Gershenson (2016) investigated the linkage among student attendance, student performance and teaching quality in North Carolina for primary school students to highlight that attendance has substantial statistical relation with students’ performance. Further, teaching quality and teaching tools and mechanism also dictate the students’ interest and attendance. In research conducted in South Africa involving 990 first and second year university students, the findings revealed that lectures which are an asset for construction and architecture students have a positive and statistically significant effect on academic performance (Nyatanga and Mukorera, 2017). The authors recommend using a more stringent attendance policy, varied assessment measures, and wider intervention strategies for enhancement of students’ performance.

In the research conducted by Gottfried (2010) for the Philadelphia School District and its urban elementary and middle schools, the author highlighted that positive and statistically significant relationships exist between student attendance and academic achievement for both elementary and middle school students. Further, using an instrumental variables strategy and fixed effects framework, their study estimated the causal impact of attendance on multiple measures of achievement, including standardized reading and math test performance and GPA. Similarly, Ladwig and Luke (2014) in their study of indigenous education policy in Australia highlighted that current federal government policy initiatives in Australian aboriginal education and social welfare reform are conventions based and assumes linear relationship between increased attendance and increased student performance. The authors empirically explored the relationships between patterns of students’ attendance and achievements in schools to highlight that reforms and policies around attendance have not, and are unlikely to, generate patterns of improved achievements. These useful studies have explored various aspects of students’ attendance and established relations with their performance in different fields, but this goes unexplored in field of construction. More specifically, the relation between attendance and student performance, and the tutors experience have not been explored in the field of construction. Furthermore, the research gap increases when construction course is taught to students of non-engineering background. Current study targets this gap and investigates the relationship between student attendance and overall performance as well as the relation with tutors’ experience.

Students were encouraged to attend the lectures and tutorials, but all materials including the tutorials and solutions were uploaded to an online platform called Moodle. Figure 1 shows samples of online materials. The availability of materials in different formats such as online sketches, videos, word and pdf files were available to students who were working during the semester and were not able to regularly attend the tutorials.

The analysis in this study is performed to investigate the relationship between student attendance and their performance in the construction course taught to students from different backgrounds. Further, results of experienced and novice tutors have also been compared to highlight the students’ results variation with tutors’ experience. This study is part of an ongoing investigation and in future, semi-structured interviews will be conducted to explore the underlying factors for this variation.

### Table 1: Student count and assessment breakdown.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>183</td>
<td>82.6979</td>
<td>25.72180</td>
<td>60</td>
<td>100.00</td>
</tr>
<tr>
<td>Assignment</td>
<td>180</td>
<td>15.7650</td>
<td>3.71431</td>
<td>90</td>
<td>20.00</td>
</tr>
<tr>
<td>Total Marks</td>
<td>183</td>
<td>66.6038</td>
<td>9.50362</td>
<td>24.75</td>
<td>49.00</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>183</td>
<td>9.3989</td>
<td>2.23119</td>
<td>90</td>
<td>10.00</td>
</tr>
<tr>
<td>Quiz 2</td>
<td>181</td>
<td>9.3224</td>
<td>1.68049</td>
<td>90</td>
<td>10.00</td>
</tr>
<tr>
<td>Attendance Group</td>
<td>184</td>
<td>1.7826</td>
<td>4.1300</td>
<td>1.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Students from performance clusters of high, medium and low. Thus, the distribution was fair and even in terms of students’ capabilities and understanding levels.

### 3 Research Methodology

The course was taught at the University of New South Wales, Kensington Sydney Campus to a class of 195 students. The course was designed for students of the Construction Management program as a core course, with different backgrounds. The course covers a wide range of concepts from strength of materials to concrete, steel and timber structures’ design. However, these concepts are the core of a series of courses in civil engineering with strong mathematics and physics background. The course involved one hour of lecture and two hours of tutorials every week. The lectures were conducted by the lecturer and the two hour tutorials were managed by six tutors. The tutors were distributed in such a way that three of them were experienced having more than five years of teaching and industrial experience whereas the remaining three were fresh graduates with little or almost no experience of teaching or the industry. Students were randomly assigned to the tutors based on performance clusters of their educational performance using an automated program. On average each tutor had 32-33 students with students from performance clusters of high, medium and low. Thus, the distribution was fair and even in terms of students’ capabilities and understanding levels.

The course content was distributed over a total of 13 weeks from 24th July 2017 to 31st October 2017. The assessments for the course comprised of 2 quizzes with 20% weight each, one assignment with 20% weight and one mid semester exam with 40% weight. The attendance limit is set at 75% for the current study. The details for the course are shown in Table 1. Further quiz 1 was conducted in week 4, mid semester in week 8, quiz 2 in week 12 and assignment was due by week 13. The participation in all criteria was more than 92%. Thus, 8% of the students missed the assessment who had dropped the course during its tenure.
Another objective of the current study is exploring the empirical relation between students’ sketching and their academic performance. For this purpose, students were asked to sketch two figures in one of the assessment modules. A total of 4 marks were allocated to the sketches: 2 each for one figure. Zero marks were assigned if the figures were not sketched. Figure 2 shows the sample sketches getting 1 to 4 marks as fig a, b, c, and d. These marks have been assigned based on the criteria in Table 2. The criteria include scaling, components, linking, structural stability, visualization and sketchers’ efforts. Yes or No are marked against a specific component and marks are added accordingly.

### Table 2: Sketch assessment criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Assessment Questions</th>
<th>No</th>
<th>Yes</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCALE</strong></td>
<td>a) Does the sketch fit properly on page? b) Are all the parts of the sketched object scaled accurately relative to each other? c) Are scaling factors (1:100 etc) specified? d) Are line angles consistent?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ESSENTIAL COMPONENTS</strong></td>
<td>a) Are all the required elements in place (columns, beams)? b) Is the load transfer mechanism shown correctly (from columns to beams and ground)? d) Are components correctly placed. f) Attention to details (column sizes, beams) g) No labels (no arrows, no text or irrelevant diagrams)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LINKING</strong></td>
<td>a) Are all elements are correctly linked? b) The support/ground is sufficient to carry the weight of the structure? d) Components are correctly placed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STRUCTURAL STABILITY</strong></td>
<td>a) Is the structure stable? b) Do the components show appropriate sizing for strength (moments and forces)? c) Do all components adhere to the law of physics?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VISUALIZATION</strong></td>
<td>a) Are proper colours used? c) Does the shading accentuate materials (different shades for columns, beams)? d) Avoid unnecessary artistic features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SKETCHER’S EFFORTS</strong></td>
<td>a) Is the sketch drawn with care (sharp lines)? b) Is the final product clean and presentable to a future employer? c) Is superfluous/unnecessary material left out - concentrates on key points? d) Does the sketcher show some artistic sophistication? e) Aesthetics (top, front, side views)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Student attendance, average marks and fail count.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Attendance Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>Failing Students</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attendance</strong></td>
<td>&lt;75</td>
<td>41</td>
<td>20.00</td>
<td>760.00</td>
<td>9</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>154</td>
<td>111.50</td>
<td>16056.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Marks</strong></td>
<td>&lt;75</td>
<td>154</td>
<td>102.32</td>
<td>14734.50</td>
<td>4</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>195</td>
<td>96.31</td>
<td>13869.00</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Assignment</strong></td>
<td>&lt;75</td>
<td>41</td>
<td>76.68</td>
<td>2967.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>154</td>
<td>96.31</td>
<td>13869.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Table 3, the average marks scored by students with less than 75% attendance are 53.35 which is very close to the pass mark of 50%. A total of 9 students among these 41...
were declared as failed as per the set criteria giving a fail ratio of 22%. On the other hand, only 4 out of the 154 students with attendance of 75% and above failed giving a ratio as low as 2.5%. The average marks for these students are 67.40%. Thus, a clear gap of 14.1% absolute marks is highlighted in this study among the students having below 75% attendance, and the ones with 75% and above. This indicates that a clear empirical evidence is established for students’ performance regarding their attendance. The Shapiro-Wilk Test was utilised and the Sig. value of the Shapiro-Wilk Test is below 0.05 (P=0.00). Thus the data significantly deviates from a normal distribution. The normal Q-Q plot was also produced showing that the data isn’t normally distributed since the data points are not mainly close to the diagonal line. Similarly, Mann-Whitney Test was utilised showing that the students who attended the tutorials regularly have achieved more marks on the exam (p=0.00). The results does not show any evidence to conclude that the assignment marks for both groups of students are different.

Further, it is imperative to discuss that only one of the 9 failed low attendance students missed the assignment. This assignment was a key component with 20% marks, yet the failure ratio is considerably higher than the students with good attendance. This is because of their lower performance in almost all assessment components. The assignment had a percent weight of 20%. On the other hand, among the four underperforming students in good attendance, 3 of them didn’t submit the assignment and would have clearly passed the course by a good margin had they submitted it.

Another key component of the study is comparison of the students’ performance with experienced and novice tutors. As previously mentioned, there were a total of 6 tutors involved in the course: 3 of them were novices while three were experienced. Table 4 shows the statistics for experienced and novice tutors. From Table 4, a clear lead can be seen for novice tutors as compared to the experienced ones. The overall average of students for novice tutors is 67.47 whereas for experienced it is 62.91 thus a difference of around 5% exists. This difference of around 5% exists for almost all assessment criteria except the attendance where it is around 7% thus further strengthening the argument of attendance affecting the overall students’ performance. On average, around eight students each of experienced tutors were reported to have short attendance whereas for novice tutors the number fell to only three on average. This indicates that the students enjoy attending and interacting with novice tutors compared to experienced ones. Similarly, a total of 7 students dropped the course for experienced tutors, whereas, for novice tutors, only 4 of them did so. A Kruskal-Wallis H test utilised showing that there was a statistically significant difference in students’ marks of different groups (e.g. tutorials) for Assignment, Final Marks and Quiz 1 as shown in Table 5. However, there

In addition to the above findings, the sketch marks as per criteria shown in Figure 2 were assigned. Table 6 shows that there is a considerable difference between the overall marks of students scoring 50% and below for the sketching activity and those scoring above 50% A total of 49 students scored 2 or below out of 4 and the average of their overall course marks is 58.925. On the other hand, students with marks above 2 amounted to 134 in total with an overall average of 72.38%. Thus, there is a considerable difference of above 13% between the overall marks of students with 2 and below marks in sketches and the ones with above 2 marks.

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Table 4: Comparison of students’ performance for novice and experienced tutors.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Experienced</th>
<th>Novice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (Overall)</td>
<td>67.79</td>
<td>70.09</td>
</tr>
<tr>
<td>Average (Mid)</td>
<td>94.81</td>
<td>56.93</td>
</tr>
<tr>
<td>Average (Quiz)</td>
<td>81.77</td>
<td>81.72</td>
</tr>
<tr>
<td>Average (Assignment)</td>
<td>85.17</td>
<td>91.36</td>
</tr>
<tr>
<td>Average (Attendance)</td>
<td>83.81</td>
<td>83.03</td>
</tr>
<tr>
<td>Dropped the course</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Short Attendance</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Average Attendance</td>
<td>62.91</td>
<td>62.67</td>
</tr>
</tbody>
</table>

---

Table 6: Students sketch marks.

<table>
<thead>
<tr>
<th>Marks</th>
<th>Average</th>
<th>Count</th>
<th>Combined Average</th>
<th>Count Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>43.53</td>
<td>5</td>
<td>58.92</td>
<td>49</td>
</tr>
<tr>
<td>1</td>
<td>68.50</td>
<td>7</td>
<td>58.92</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>64.71</td>
<td>3</td>
<td>72.38</td>
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</tr>
<tr>
<td>3</td>
<td>74.74</td>
<td>1</td>
<td>72.38</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>70.02</td>
<td>96</td>
<td>58.92</td>
<td></td>
</tr>
</tbody>
</table>

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Figure 3 plots the average marks of students with 0 to 4 marks in sketches. The trendline established using MS Excel shows an increasing pattern with increasing sketch marks. In general, students with 2 and below marks are scoring less than 70% marks whereas students with above 2 marks in sketches are getting above 70% marks on average. Thus, the hypothesis of students with more marks in sketches performing better overall as compared to the students with lower marks in sketches is validated. This can also be associated to the notion that students with better sketches have better imagination and better understanding thus performing better as compared to the ones with poor or bad sketches (Melges, 2016).
5 Conclusion and Further Research

The aim of this study was to investigate the relationship between student attendance and their overall performance. Further, comparison was made for the students result when tutored by experienced vs novice tutors. A total of 195 students in Construction Management program with different backgrounds were taught Building Structures, which is a core course of civil engineering. Their performance was assessed in comparison to their attendance and tutors’ experience. The results for 41 students having less than 75% attendance show average overall marks of 53.35 as compared to the students’ marks of 67.40% for students with 75 and above attendance. Further, a total of 22% from low attendance failed the course as compared to only 3% students with 75% and above attendance. Thus, clear empirical evidence is presented by the results of this study related to student attendance and their overall performance.

A total of 91 students with 75% and above attendance. Thus, clear empirical evidence is presented by the results of this study related to student attendance and their overall performance. Students need to regularly attend the lectures and tutorials to get better marks. This is also important for academic administrators to formulate strict attendance rules for better performances of students.

In terms of tutors’ experience, the novice tutors’ students outperformed the experienced tutors’ students by 5% in all assessment criteria on average, a main reason was the average 7% higher attendance by students of novice tutors. Thus, the students enjoy interacting with and attending the tutorials of novice tutors more. It is also evident by the fact that only 4 students of novice tutors dropped the course as compared to 7 students of experienced tutors. Further, a relation between students’ sketching and their overall performance exists which has been assessed for two sketches of four marks. Students scoring two or below marks are securing less than 70% in general and 58.92% on average. On the other hand, students with three or above marks scores above 70% overall marks in general and 72.38% on average. Thus, a clear empirical relation is observed between students having good sketches and their better academic performance. This stresses the need of improving student sketches and encouraging them to use their manual sketch skills for enhancing their vision and perceptions.

The current study is part of an ongoing investigation to assess the empirical relation between students’ attendance, sketches and their overall performance. It further compares the results of students taught by experienced and novice tutors. Since more information is required to be able to interpret the data and measure students’ perceptions, semi-structured interviews will be conducted from random students and tutors to identify underlying factors affecting the performance of students and tutors. The summary should then be followed by flagging relevant matters that may be relevant to this research but beyond the current research scope in the form of further research. For on-going research, this may include the next stages of the research that will be conducted by the researcher to complete the research, whilst for completed research this may include emerging new possibilities revealed during the research and/or potential for expansion based on the scope and limitation of the research set earlier.

6 References


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Learnings for construction project management personnel about offshore projects: a case study

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Abstract:
Involvement in the global construction project market is becoming more of a norm for designers and construction companies, no matter where the head office is located. As a result, practitioners need to be work-ready in order to be project leaders, consultants and managers on offshore projects, often at a relatively early stage of their careers. The experiences of industry and tertiary professionals also suggests that the challenges and opportunities presented by offshore projects, provide learnings that may also be applied to other construction projects, and should be included in construction sector training and development programmes. The paper and therefore the research question focussed on a qualitative case-study of an offshore tourist resort construction project involving a locally based New Zealand construction company that had recently completed the project. The methodology involved face-to-face interviews with the project management team personnel, as well as an integrated analysis of the project planning, procurement and communications’ documents. Several unique issues and consequent opportunities for innovative solutions were identified for improved practice and training, including managing limited site accessibility, challenging logistics, staffing the teams, plant and materials availability, and maintaining effective communications.

Keywords:
Communications, construction management, logistics, offshore construction projects, staffing relationships.

1 Introduction
The success of construction projects is highly dependent on management staff and the coordination of multiple consultants and tradespeople. These managerial responsibilities significantly increase when the project is located offshore. With an increasing number of remotely located construction projects worldwide, particularly within developing areas such as the Middle East, Asia, Latin America (Lin, 2010) and Australia (Baroudi and McAnulty, 2013), including environmentally sustainable developments such as eco-tourist resorts, the demand for construction practitioners to be involved on these offshore projects is increasing. This has enthused a growing research interest within the construction industry (Lin, 2010). Management of construction projects is complex in nature due to the uniqueness of each project and the multitude of stakeholders involved (Weippert et al., 2002). Previous literature has focussed on remotely located construction projects, where for example, Kestle (2009), defined a remote site project as being one that is separated geographically and/or has only limited seasonal, logistical or communications access, and found that the main challenges were in the areas of communication, increased management requirements, a lack of human resources and plant and materials, and experienced labour. It is clear that remote/offshore construction projects appear to have specific challenges that are not as commonly observed within urbanised areas (Baroudi and McAnulty, 2013). After undertaking a detailed literature review across a number of well recognised research data bases internationally, the objective of the research became, “How can the management structures and systems for offshore construction projects be further improved to be beneficial for construction management companies?” This has involved investigating the systems and structures that are currently used on offshore projects, and one in particular. This research may be of value for potential project management practitioners on the realities, and possible issues that may be experienced in the challenging environment of offshore construction projects.

2 Literature Review
Previous literature has suggested that there is a need for future research that focuses specifically on the realities of on-site remote construction projects, and creating realistic management frameworks for the use of construction industry practitioners (Kestle, 2009). Given the remoteness of these offshore projects the selected literature has been focused on discussing the challenges, improvement strategies and differing expectations regarding project outcomes for stakeholders and project management approaches.

2.1. The Importance of Effective Communication
Effective communication is essential for the success in any given construction project according to Weippert et al., (2002), but when the construction project is situated in a remote/offshore location, the need for effective communication systems is amplified, as government authorities and project architects/engineers are not able to visit site as frequently, to maintain face-to-face meetings, (Sambasivan and Soon, 2007). This results in an increasing emphasis on alternative means of communication between on-site management and supporting/project personnel (Sidawi, 2012). In addition, Kestle (2009) found that there are multiple limitations for effective communication on remote/offshore construction projects, with for example, a frequent lack of internet and telephone connections and/or a lack of reliability or compatibility. Kestle (2009), also identified the greater risk of miscommunication and information lost due to poor communication connectivity in remote site locations.

2.2. Effective Management Requirements on offshore remote projects
For the purpose of this research, construction management refers to the organisation, coordination, monitoring, control and reporting of all physical construction works. With a project located in a remote or offshore setting, there are differing management requirements, and the role a construction manager may have to undertake (Potangaroa and Khan, 2003). Not only does the construction manager have to manage all the traditional requirements common to all construction projects, but also those associated with the specific remote location. Additional factors regarding the management requirements, are for example, the impact of the construction project on the local community, and the potential language barriers. Potangaroa and Khan, (2003), found that on-site management is key for offshore construction projects, compared with having distant regional management, as on-site management is more effective. Case study results from the article by Lin (2010) have shown that on-site project administrators are favour ed over employing a local as they are more likely to mitigate managerial flaws and reduce project losses. However, mainland site engineers are less
likely to work effectively with local employees, and in combination with their high wages, are less likely to add value and improve the overall project performance.

2.3 Human Resources

Construction companies are struggling to source quality labour and human resources within urban areas. This problem is heightened according to Baroudi and McAnulty (2013), when recruiting people with the right skills for offshore construction projects. This is thought to be because contractors have particular difficulty attracting skilled workers to remote areas. The additional challenge associated with the allocation of local versus expatriate workers can create difficulties in regard to providing jobs, gaining local community loyalty and improving their economy. Although benefits are necessary for local communities there is a lack of skilled and experienced workers compared to employing non-local or expatriate workers. There is potential for a lack of productivity and motivation within offshore projects and it can have adverse effects on the individual staff member including fatigue, family stress, homesickness and in some cases lead to increased alcohol abuse. This is often resolved by the implementation of Fly-in/Fly-out (FIFO) arrangements, as used within remote regions of Australia, (Baroudi and McAnulty, 2013), and was implemented for offshore oil projects in the 1940’s (Houghton, 1993). There are increased expenses in association with the FIFO concept, including lodging, increased travel expenses between job and home base, and paying higher wages to local employees. According to Lin (2010) hiring local employees offers an alternative that is generally cheaper, but there is an increased risk as they are often not as skilled or experienced, potentially leading to greater project losses, and reduced quality of the overall project outcomes.

2.4 Plant and Material Availability

Plant and material availability is a critical risk for remote construction project completion. Not only will the procurement of materials locally be difficult, there is also a likelihood that the material(s) is/are not available to be sourced locally at all. Therefore, materials and plant will have to be brought in, often from overseas. Therefore, forward planning is essential to ensure correct quantities and materials’ specifications when ordering as lead times for materials and plant are often dramatically increased when procured for a remote offshore project (Cowie, 2002). Poor conditions and transport regulations can also be major barriers to the delivery of equipment and materials to remote projects (Sidawi, 2012). Sambasivan and Soon (2007) emphasised the fact that project success is risked with the possibility of transportation delays and/or limited materials and equipment.

2.4.1 The Lack of Infrastructure

Offshore construction projects are frequently hindered by the lack of infrastructure, such as access roads, power and telecommunication services, internet provisions, fibreoptics and water supply for example, (Kestle, 2009). The increasing demand in the construction industry for internet based communication and document sharing systems, means issues arise around maintaining up-to-date documentation (Brilakis, 2007). Road and highway regulation constraints in addition to limited access are often major issues affecting the delivery of materials and equipment to offshore projects. (Sidawi, 2012).

2.5 Increased Lead Times

For all construction projects there are a number of specialist or specific materials that have long lead times. For an offshore project though, supplies of all materials will have increased lead times. The transportation aspect of the lead time for offshore construction projects can often be calculated in months, rather than days or weeks for projects in urban areas. As a result, the risk of miscalculating the required material on site increases too, and construction companies often send too little or an excess of materials to offshore sites. Usman and Ibrahim (2015) noted that as suppliers struggle to deliver materials to site, the requirement for construction waste removal is also increased.

2.6 Increased Financial Risk

The usual and expected risks for stakeholders, contractors and sub-contractors associated with the construction industry are intensified when the construction project is located offshore. A frequent shortage of materials within these projects can be a major issue, making contractors reluctant to undertake these projects due to the unpredictable cost and availability of materials. Another risk is increased financial risk. Tam and Le (2016) suggested that the increased cost stems from the logistics of getting plant and material to site, which is sometimes greater than the actual cost of the materials.

3 Research Methodology

The most appropriate qualitative research methodology to answer the research question was a case-study approach, as the intention was to gain key insights by conducting an in-depth and detailed review of an individual case-study that had a few distinctive features, and could in turn have valuable implications for construction management practitioners. A case-study approach is useful when the researcher has little control over events or an ability /opportunity to change circumstances that naturally occur (Yin, 2003). It allows for a variety of multiple sources and data types as part of the investigation, and an opportunity to explain why certain outcomes occur, (Denscombe, 2008). A case-study lends itself to undertaking a holistic study of processes, relationships, successes and challenges within a particular real-world setting. This approach aligned well with the offshore construction project. The key limitations of this research related to the fact that this was just one offshore case-study, but the findings drew on several previous and relevant in-depth research publications into offshore and/or remotely located projects.

2 3.1 The Case Study

The selected case study was undertaken on a New Zealand project management company that had recently completed a remotely located construction project that involved the expansion of the existing resort facilities on an isolated south pacific island. The project comprised a 400m² 5star accommodation block, a 200m² conference centre, a new services and staff facility, commercial kitchen refurbishment and a drainage upgrade. All of this work was to be carried out whilst the resort remained fully operational for their tourist clientele. The project commenced with two shipments of all materials to undertake the site establishment work in August and September 2016. The construction period then ran from October 2016 to August 2017. It was completed on time and was ready for the NZ Prime Minister to officially open the new buildings. This, despite an 8.5 week delay of a materials’ shipment as the ship hit a storm and broke down, and the captain actually passed away too). The resultant was that the materials’ delivery sequencing was seriously affected. There was also a category 2 cyclone that caused a 3 day delay given the site was right on the coastline.

The case-study project was investigated from the main contractor’s perspective, and all of the findings were drawn from an analysis of the project programming, procurement and communications, and after interviewing the five key project management staff member including fatigue, family stress, homesickness and in some cases lead to increased alcohol abuse. This is often resolved by the implementation of Fly-in/Fly-out (FIFO) arrangements, as used within remote regions of Australia, (Baroudi and McAnulty, 2013), and was implemented for offshore oil projects in the 1940’s (Houghton, 1993). There are increased expenses in association with the FIFO concept, including lodging, increased travel expenses between job and home base, and paying higher wages to local employees. According to Lin (2010) hiring local employees offers an alternative that is generally cheaper, but there is an increased risk as they are often not as skilled or experienced, potentially leading to greater project losses, and reduced quality of the overall project outcomes.

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company’s personnel. The site was described as offshore due to its geographical separation from immediate logistical support, lack of locally available materials, and limited means of physical access. Throughout most of the construction stages, there was only one international flight a week to the island, restricting access for the mainland project staff. All materials and plant had to be transported to the island via a monthly shipment from New Zealand.

3 3.2 Data Collection and Document Analysis

Qualitative semi-structured face to face interviews were conducted with the five key project management company’s personnel, to hopefully gain a range of views and differing perspectives. Although the interviewees held different roles, all of the responses to the questions were relatively similar when identifying the struggles experienced, for example, throughout the offshore construction project period. The collected data were transcribed, codified, and tabulated, then collectively analysed and discussed in conjunction with the document analysis, to see how the data related or differed from the literature findings.

3.2.1 The Data Collection Instrument

Q.1. Management Structure

a) Describe in some detail the management structure used on the offshore/remote project (a) that you have been recently involved on.

b) Would an alternative structure have been more beneficial for the project(s) and why?

Q.2. Staffing Arrangements

a) What managerial staffing arrangements were utilised during the offshore/remote construction project (a) you have been recently involved on, to maintain effective managerial roles?; b) Would employment of local managerial staff arrangements have been more beneficial and why?

Q.3 Communication

a) In your experience, what types of communication systems/methods were/are used on offshore/remote construction project(s) and why are they selected for use?; b) Was a computer based communication system utilised on the offshore project you were recently involved on? If not, what was the reason for not having one on the project?

Q.4. Material and Plant Sourcing

Describe the actual processes used for managing the issues associated with the potential lack of plant and material availability commonly experienced on offshore/remote construction projects.

Q.5. Material and Plant Logistics

a) In regard to the logistical process of getting plant and material to site, did the management structure, communication system(s) and staffing arrangements work well and why?; b) If not, how could they have been improved?

Q.6. Other relevant comments

In addition to the semi-structured face to face interviews, a document analysis was conducted on the project programming, procurement and communications documents, to investigate the systems used and their effectiveness according to the interviewees. Variations to the programme, procurement and communications, and any delays and/or impacts on the case-study project were also investigated.

4 Findings and Discussion

4.1 Management Structure

All interviewees confirmed that a hierarchical management structure was utilised on the case study remote construction project, with a general consensus that an alternative management structure for the projects team may have made little difference to the project’s overall success. The hierarchical structure had been successfully used for all previous projects undertaken by the majority of this project team within the management company. However, one interviewee noted that they were new to the project team and the type of management structure. Pressure was experienced when communicating with senior managers and therefore an alternative structure might have reduced that sense of pressure. This finding differs from those by Sidawi (2012), who suggested that due to the introduction of electronic communication resources on offshore/remote projects that a more open management structure is possible, and offered a more effective process of sharing information and knowledge with the team. Similarly, Potangaroa and Khan (2003) suggested that on a remote/offshore project the construction manager has to not only manage the traditional project requirements, but also the impacts of the project on the local community, and the potential language barriers. Another interviewee noted that due to the project being largely set up and managed in a similar way to previous urban-based projects in New Zealand, logistics managers were not incorporated into the staffing team for the offshore project, thereby increasing the workload on other team members.

4.2 Staffing arrangements

According to the interviewees, the following staffing arrangements were those used for the duration of the case-study project by the New Zealand management company:

- Site managers (1x senior and 1x junior) Fly in - Fly out (7 weeks on, 1 week off),
- Project Manager flew in occasionally (approximately once a month),
- Site Administrator was locally employed,
- QS’ (junior and senior) were New Zealand based.

There was a mix of responses from the interviewees regarding the adoption of the FIFO arrangement for the site managers for this project, believing that:

- There was a negative financial impact on the project when the employees’ salaries, costs of flights, accommodation, food allowances and costs of compensation were considered.
- The FIFO arrangement is expensive but the alternative would be to employ a local as the full time site manager, but this could have had a greater negative financial impact, as the ‘local’ would be less experienced, leading to potential project losses. This finding was fully supported by Lin (2010) in the literature findings.
- A full-time remotely based site manager would have been better for the project, as the FIFO arrangement time period of 7 weeks on the island was too short, leading to information loss.
- 7 weeks was a long time for site managers to be away from their families.
- A site manager on-site full time is beneficial for the project, however FIFO is a better arrangement for the site managers.

4.3 Employment of locals

The general response from all interviewees was that employment of locals as managers on-site would be financially beneficial, given their local knowledge and familiar methods of communication throughout the construction of the project. However, all of
the interviewees suggested that locally employed management staff would definitely require training prior to the project commencing.

The specific views expressed by the interviewees were that:

- Local employment of site management staff could be an option if they had sufficient support from FIFO managers, and a sound communication plan to ensure clear communications between NZ based managers and the site manager.
- The employment of one local site manager (to reduce the financial impact of two FIFO site managers), and maintain one FIFO site manager to lead the site team. Lin (2010) supported this by indicating that hiring locals is often cheaper, but that there is an increased risk of them being less skilled and experienced, resulting in reduced quality, time overruns and the potential for increased financial losses.
- A local site administrator was hugely beneficial for communications, local knowledge and the relationship with the local community.
- Multiple locals were employed throughout the project for roles such as labouring on site or catering and cleaning for the FIFO managers and subcontractors.

4.4 Lack of plant and material availability

All of the interviewees noted that the most challenging aspect of the entire project was the procurement of plant and materials and the associated logistics of actually getting the materials to site. For example:

- The process of procurement included standard processes, with the addition that all materials, whether concrete, timber, finishing materials and fixings et cetera, were required to be shipped to the island.
- The implications of once a month shipments highlighted the need for forward planning and ordering materials three months prior to when they were actually required on site. It was forward planning that the project management team struggled with the most, and this supports Cowie’s (2002) comments on the absolute need for thoroughly detailed and sequenced forward planning on offshore projects.
- Management’s decision for procurement to be the main contractor's overall responsibility, to ensure that specified materials and correct quantities were delivered to the island. This reduced the risk of re-ordering incorrectly delivered or short-supplied materials. As a result, subcontractors were signed up on labour-only contracts.
- The lack of effective communication led to a disconnect between construction and procurement teams, creating unnecessary pressure for the project team, and meant that some materials were delivered out of sequence, increasing the demand for on-site storage (not allowed for in the budget), and potential for a financial loss on the project.
- The plan was to have all the construction materials delivered to the island before the ‘cyclone season’.

However, due to unusual weather patterns a cyclone in the Pacific Ocean caused delays to the second to last shipment of materials which impacted on the project programme incurring a 3 week delay. This finding fits with Usman and Abraham’s (2015) finding that climatic delays need to be factored into the lead times for materials’ availability.

It was originally planned to employ a logistics manager but due to the shortage, management struggled to employ someone. As a result it became a part of the QS’ responsibility and meant the project team had to share and cover the additional workload. All of the interviewees noted that:

- Employment of a logistics manager would have benefitted the project. Issues experienced throughout the project were: timing of material deliveries; the quality of the material when it arrived on the island due to damage during shipment, and incorrect materials being ordered or supplied and needing to be replaced. A logistics manager would have carried out the required checks before the materials were packed into containers for dispatch to the site.
- A better communication system would have benefitted the logistical process. For example, being able to communicate on a more regular basis; share documents such as the construction and procurement programmes between the team to ensure alignment; ensuring materials were delivered to site when required to reduce storage requirements or delays due to late supply.

4.5 Communication

According to the case-study planning and procurement documents, an ICPM (internet-based construction project management) approach was planned for the offshore case-study project. The views expressed by the interviewees were that:

- ICPM was selected as the main communication channel for the project to create a common database for documentation, and to hopefully improve collaboration and communication between team members. This approach was supported in the literature by Sambasivan and Soon (2007); Alshawi and Ingrigie (2003), and Stewart and Mohamed (2004) where project team members (for example, architects and engineers) are regularly located at distance from the offshore site during the project, and that a web-based project management system be considered, to support project personnel.
- During site establishment the site team struggled to find sufficient internet connection. However, it was just enough for basic communication such as emails, but insufficient for downloading or sharing larger documents such as drawings.
- Poor connectivity forced the abandonment of ICPM and the team reverted back to emails and phone conversations as the primary means of communication.
- Email correspondence and communication was slow compared to the ICPM system causing delays on site when urgent design clarifications were required.
- Information was often lost or miscommunicated because it was being double handled between site managers and senior managers, then senior managers to the consultants.
- The establishment of an alternative such as using a satellite or wireless internet connection was deemed too expensive for a project of this size. The ICPM approach is only effective if all project members use it, and before it was abandoned, several of the project team members chose not to use it anyway.

Brilakis (2007), and Kestle (2009, 2011), identified and acknowledged the possible limitations of communication access due to issues such as a lack of infrastructure internet provisions /reliability. This is causing major barriers to communication on a number of remote/offshore projects. Overall the findings identified that an online communication system is more likely to be used on a large scale project but only if an alternative form of internet connection can be shown to be financially viable for the stakeholders and clients.

5 Conclusions and Recommendations

The experiences of industry and academic research suggests that the challenges and opportunities presented by offshore projects provide learnings that may also be applied
to other construction projects, and be included in construction sector training and development programmes. The research question was focussed on a qualitative case-study of a recently completed offshore tourist resort construction project involving a locally based New Zealand construction company. The literature review and analysis initially concentrated on the selected topic of offshore projects and associated keywords, where the terms identified in the literature were: communication, increased management requirements, lack of skilled labour resources, and issues about plant and materials availability. Interviewees shared first hand experiences of the management structure and systems used on the recently completed offshore case-study construction project, including the differing staffing arrangements on offshore construction projects to maintain effective managerial roles within project teams. Literature findings drew comparisons between the FIFO arrangement of current employees of construction companies and the employment of local personnel to fill the remotely based management roles, and suggested that locally employed managers are financially more beneficial compared to FIFO arrangement for the project with regards to cost of flights and accommodation. The effectiveness of such arrangements though were limited to the skill and experience of local employees, with the potential for an increased risk of project losses, reduced quality and poor project outcomes. Interviewees supported these findings by suggesting that the optimal staffing arrangement is the employment of local’s as managers with the support from FIFO management staff. It is evident from this case-study that construction practitioners interested in offshore construction projects need to consider changing from traditional hierarchical management structures and systems to make those projects more beneficial for the construction management company and the stakeholders.

The lack of plant and material availability was another key factor investigated throughout this research, and it is clear that in more remote locations, the availability of specific materials is often limited and therefore construction practitioners are required to adopt alternative means of procuring materials. The literature and interviewees identified issues of needing to ship materials, and the increased lead times as a critical factor for practitioners to consider. Interviewees discussed the processes adopted for the case-study project that included making the supply of all materials the main contractor's responsibility, to ensure the specified materials were ordered, and correct quantities delivered to reduce the risk of causing project delays.

The final issue discussed in this research was about the communication system(s) used on offshore projects as identified by interviewees and in the literature as a key factor for the success of a project. Online communication systems were the preferred method of communication where all project members can access a central database for all channels of communication and documentation sharing. However, it was highlighted by most of the interviewees and in the literature, that due to the reliance of such systems on sufficient and reliable internet connectivity, they are not often used on remotely located projects. The implementation of alternative internet connections is possible but currently too expensive to establish for most offshore projects.

6 5.1 Recommendations

The following recommendations outline some of the key issues practitioners need to consider based on the above findings in relation to the research question “How can management structures and systems for offshore construction projects be improved to be more beneficial for construction management companies?”

1. Employment of local personnel to fulfil some of the managerial roles to support FIFO management staff, in order to gain the benefits of local relationships, local knowledge, and ease any communication and language barriers.
2. Establish a logistics manager to support the procurement process of plant and materials. The role being to manage the coordination and additional workload of getting the right materials to sites when needed.
3. Establish effective, accessible communications systems for all project personnel.
4. Establish alternative means of internet connection to support the use of online communication and document sharing systems.

Future Research could be on how to improve offshore infrastructure, and the use of satellite or wireless internet connections and drones, at a viable cost.

7 References

Abstract:
The international literature on higher education emphasises the importance for academics and professional staff to develop their disciplinary teaching and learning practice. The global corporatisation of universities however has increased expectations on staff to grow student numbers, research publications and external income. This has led to a segregation of research focused academics and a growing cohort of industry professional and casual teaching staff with limited higher education training. Teaching staff in built environment degree programs such as building construction and engineering tend to focus on ‘what’ content is being taught, rather than ‘how’ teaching facilitates learning contexts for students and demonstrates expected unit and course skills outcomes.

To investigate these trends, this research reviewed the higher education literature and relevant international studies on increasing quality teaching and student learning.

Findings highlight that the development of a personal teaching philosophy statement (TPS) and teaching profile provide an important link from individual educational development to enhancing teaching and learning.

The authors propose an innovative and strategic approach to address and align the professional development of teaching staff in built environment programs. This includes: Embedding the value of teaching and learning practice into employment, workload and performance reviews; peer support and educational training to support students’ technical and skills learning outcomes reflecting faculty and institutional goals; rewarding quality teaching and learning as valuable practice and basis for research and scholarship. This approach encourages capacity building across teaching teams, institutional engagement in the degree program and educational outcomes for future building professionals.

Keywords:
built environment education; teaching philosophy; teaching and learning

1 Introduction

1.1 Higher education international and institutional context

Internationalisation and digitisation of higher education teaching and learning has created global employment opportunities for academics and mobility for students alike (Hattingh, Thompson, Williams, & Morton, 2015). The predominant career-long academic tenure at one or two institutions has given way to fixed term or short-term employment and contracts with specialisation of research, teaching and administrative roles (Bennion & Locke, 2010; Locke, 2014). The increasing complexity and fragmentation of the academic workforce is enhanced by the separation of management...
funding and academic rewards and recognitions for individual and institutional research output as key drivers for reputation and career success (Fanghanel & Trowler, 2008). Current constraints to institutional change management are emerging and appear to be on a number of levels, such as the university reward systems for staff and faculty leadership geared towards discipline-focused research outputs, rather than teaching innovation or educational publications (De La Harpe, Radloff, & Wyber, 2000; Watty, 2003).

In this context, it is becoming important to strengthen institutional connections from corporate strategy via faculty management to measurable student learning and skills outcomes in individual disciplines and courses (Borrego & Cutler, 2010; Hoey, 2008; Ruge & McCormack, 2017). More recently, researchers’ concerns about the lack of alignment between skills assessment and students’ acquisition of work-based professional and lifelong skills, also highlighted by industry and employers, have expanded the research in this field (Bunney, Sharples, & Howitt, 2015).

1.2 Assurance of quality student learning outcomes

The critical role of graduate attributes in student learning is also reflected in their prominence in national quality assurance activities (Barrie, 2004; Oliver, 2013). In Australia, since 1998, quality assurance audits are undertaken by the Australian government through the Tertiary Education Quality and Standards Agency (TEQSA). These reflect the international trend of governments setting standards, tightening funding and expecting universities to report and perform against national and global rankings (Bowden, 2000). As a result, quality assurance measures in higher education have now started to pervade many aspects of academics’ teaching and research activities. Today’s expectations of higher education providers include assurance of teaching quality and graduate learning outcomes for future student employability (Tam, 2014; Tomlinson, 2012). For more than a decade understanding the effectiveness of good teaching and learning at universities has been identified (Fitzmaurice & Coughlan, 2007; Prosser & Trigwell, 1999; Schönwetter, Sokal, Friesen, & Taylor, 2002). Traditionally, engagement has been left to the individual lecturer based on disciplinary expertise without questioning the educational pedagogy or review of assessment and demonstrated student learning outcomes. Yet in the current international higher education context going forward at the current rate of change, the connectivity to good teaching and learning within higher education policy, processes and practices is at risk of being left behind.

These changes in the higher education sector have for individual academics resulted in higher performance expectations of increased numbers of student recruitment and completion with engagement with stakeholders for research funding and achievement of targets on high-ranking publications (Locke, 2014). In this context of systemic and disruptive change academics are required to broaden their expertise in teaching, research and stakeholder engagement. For the employing institutions managing an international and diverse cohort of expert employees, questions of underlying beliefs, values and expected contribution are emerging as critical factors to ensure continuity and sustainability. To investigate these trends, this research reviewed the higher education literature and relevant international studies on increasing quality teaching and student learning.

2 Research Context

2.1 Re-valuing teaching and learning for higher education

Detailed insights into the personal contexts and motivations of teaching academics who have experienced these institutional changes were undertaken in the late 1990s (Hill, 2000; Mcinnis, 2000; Winter & Sarros, 2002). A number of studies reporting on such implementations, found that academics and teachers do not respond well to teaching and learning initiatives imposed by the institution or faculty if there is lacking interest in the implementation (De La Harpe et al., 2000; Summion & Goodfellow, 2004; Watty, 2003). Findings also showed a decrease in, or lack of, institutional support for teaching at lecturer levels, where increased workloads had a negative effect on work motivation and performance. Winter and Sarros (2002) elaborate that ‘academics in teaching only roles and teaching and research roles reported significantly lower levels of organisational commitment compared to academics in more senior administrative roles’ (p.248). This confirmed previous work by (Boyer, 1990) who had already pointed out that academics with teaching focused roles and responsibilities were provided fewer opportunities to gain institutional recognition and rewards. In order to address this gap and support the educational development of staff, initiatives to reintegrate the scholarship of teaching and learning (SoTL) in North America and Teaching Quality in Australia and the UK took place in the 1990s (Chalmers, 2011). Over the last two decades these fields have been growing through national educational organisations, scholarships and university teaching and learning awards to enhance recognition of individual academic and discipline teams (Fanghanel & Trowler, 2008; Huber, 2004; Young, 2006). Therefore critical questions in relation to the transformation of the academic environment and of how the academic profession can move forward balancing the need and recognition for disciplinary or ‘discovery’ research in relation to SoTL and enhance teaching and learning outcomes for students, the institution and the communities affected (Bair & Bair, 2011; Cashmore, Cane, & Cane, 2013; Chalmers, 2011).

2.2 Teaching philosophy for personal practice and professional development

Investigating the international literature for higher education, the starting points for the development of a teaching philosophy were shaped by the seminal works of Van Note Chism, Goodyear and Allchin, as well as Atkinson and Schönwetter (Atkinson, 2000; Chism, 1998; Goodyear & Allchin, 1998; Schönwetter et al., 2002). Prior to the publication of frameworks for a teaching philosophy statement developed by these scholars, the literature lacked ‘conceptual models that also offered operational dimensions and a process for generating and evaluating teaching philosophy statements’ (Schönwetter et al., 2002, p. 83). Since then, Teaching Philosophy Statements (TPS) have been widely adopted for employment, promotion and are adapted for disciplinary and institutional purposes. Indeed, TPS are seen by some authors as ‘central to how practising academics teach’ (Fitzmaurice and Coughlan, 2007, p. 39) because they provide a ‘cornerstone’ (Coppola, 2002, p. 448) for individuals’ reflective and scholarly teaching practice.

Teaching philosophy statements can be defined in various ways but, put simply, they are written statements of why teachers do what they do—their beliefs and theories about teaching, about students and about learning, all of which underpin what and how they teach (Fitzmaurice, 2007, p. 39).

However, in order to do so the teacher or academic has to engage, reflect and describe their personal values and identity, which is a complex process and indeed a lifelong journey, crossing roles, emotions, passions and courage (Akkerman & Meijer, 2011) .
Reflection and self-development of individual pedagogical and philosophical basis or purpose for teaching and learning (Schonell et al., 2016). The pedagogical concept, TPS or teaching profile addresses personal beliefs, values and goals. It supports inquiry, reflection and self-development of individual pedagogical and philosophical basis or purpose for teaching and learning (Schonell et al., 2016). The pedagogical concept, longer term reflective process and scholarly practice of developing a TPS also addresses the increasing issues experienced by academic in the current higher education context where good teaching and the scholarship of teaching and learning are undervalued.

3 Research Methodology

As the educational and institutional landscape is subject to rapid and frequent change, the way in which these changes are supported can influence learning experiences and outcomes. A review of three frameworks used to evaluate success of teaching and learning strategies identified that the different perspectives of stakeholders involved, such as students, staff and institutions, are critical when supporting quality teaching and student learning (Mackintosh, Beard, & Macedo, 2017). These frameworks use different indicators to demonstrate how the strategies employed in higher education address the needs of the student, staff and institutions. The impact of these strategies is evaluated using tools such as student and staff surveys, learning analytics, graduate outcomes and financial performance. However, current evaluation tools are limited in the way in which they address the impact that governance decision making processes can have on teaching and learning success and outcomes. This paper seeks to find alternative methods of supporting quality teaching and student learning in built environment education by involving staff as active partners rather than a passive workforce.

3.1 A reflective and practice focused approach

Critical thinking and reflection are the skills that support the ability to respond to and adapt to change. As previous experiences inform our understanding of the world and our beliefs, the relationship between reflection and meaning perspective (i.e. the frame within which meaning takes place), is complex (Adams,Turns, & Atman, 2003; Loughran, 2002). According to Mälkki (2010, p. 46), ‘reflection refers to becoming aware of and assessing the taken-for-granted assumptions within one’s meaning perspective, to construct a more valid belief’. Critical self-reflection is essential to establishing one’s own position of and within local and global communities. Self-reflection, the metacognitive application of critical thinking to one’s own thinking, feelings and actions, involves the assessment of assumptions. Such reflection can create tension, as it challenges the very mechanism by which meaning is made. Reflection is not a purely rational process, but can be threatening and emotionally charged (Mälkki, 2010, pp. 47-47). Such tension is often felt in educators, when required to reflect on their teaching practices as part of their professional development. Supportive strategies and active involvement can assist the educator in recognising and overcoming concerns and tension. Reflective practices are often supported by communities of like-minded peers coming together to share experiences and review each others’ practices, (Kennelley et al., 2013) leading to transformation (Aitken, 1999, 15), or a change of practice (Kitchenham, 2008; Mezirio, 1997). The dynamic interaction within these communities results in the collective development of knowledge, language and skills as, through social interactions, experiences are interpreted in different ways and new meaning is made. This new or revised interpretation of experience also called ‘perspective transformation’ (Taylor, 1997, p. 49) is important as it is this transformation that influences further action and interpretation of future experiences. The meaningful communication and collaboration with others that can occur within communities of reflective practice can result in a shared benefit for all involved and mitigate the challenges often felt by individuals working alone.
4 Findings and Discussion

4.1 Teaching and learning in built environment degree programs

A national research study on construction education in Australia identified a number of concerns, including the lack of educational training and increasing number of sessional staff, who are primarily industry practitioners, as well as the significant gender imbalance and ageing profile of lecturers and professors (Williams et al., 2009). Informal interviews by the researchers suggest that the building and construction educators’ approaches to teaching and learning predominantly fall into Barrie’s (2007) teacher-focused content delivery approach. Here the focus is on a traditional transfer of ‘what students should know’, by passing on current technical knowledge in relation to a specific course area. In contrast, the educational philosophy of the learner-focused teaching approach (Harvey & Kanouvouas, 2008; McCabe & O’Connor, 2014) provides scaffolded learning experiences and assessments that can enhance the students’ skills development and learning engagement. This also recognises the important findings by Holmes and by Wood who investigated an architectural course, where students through their learning and assessment sought to position themselves and their emerging identity in the higher education and future career contexts (Holmes, 2001; Wood, 2006). One of the first longer term research studies on student skills development in building and construction management demonstrates the shift from the ‘what of learning content to the ‘how’ of student learning and skills development (Ruge & McCormack, 2017). Findings highlight the importance of a ‘constructive, explicit and reflective’ teaching approach engaging students in their own generic and professional skills development. In Australia, higher education progress is closely linked to Government funding, which at this point rewards research and publication outputs more than innovation and time investment in quality teaching for graduate learning outcomes (Gale & Parker, 2013; Marginson, 2002). The overall institutional capacity, resources and development of staff skills to affect significant change in teaching and learning is currently lagging behind and therefore a concern for government, universities and industry alike.

Findings from the literature identified themes, which relate to the constraints and potential opportunities for educators striving to develop and position themselves in their discipline and institution. Schönwetter (2002) identified, that a TPS serves the individual academic in: clarifying what good teaching is; providing a rationale for teaching; promoting personal and professional development and encouraging the dissemination of effective teaching (p.85). An alternative way of supporting this is the development of teaching and learning workshops focused around and supporting staff in developing a teaching profile and their philosophy in order to build the case studies to be used in the future (Schonell et al., 2016). The aim of these workshops is to create the peer groups and networks that support a collaborative learning environment for staff (Kennelly et al., 2013). As initial step to apply the research findings, the authors are facilitating two teaching and learning workshops at school level for built environment staff to develop their TPS and teaching profile. These workshops will include and encourage cross disciplinary learning and collaboration as part of the annual professional development program for academics and contract staff.

4.2 Strategy to develop a Community of Reflective Practitioners

The authors propose an innovative and strategic approach to address and align the professional development for teaching staff in built environment programs. This includes: embedding the value of teaching and learning practice into employment, workload and performance reviews; peer support and educational training to support students’ technical and skills learning outcomes reflecting faculty and institutional goals; rewarding quality teaching and learning as valuable practice and basis for research and scholarship. This approach encourages capacity building across teaching teams, institutional engagement in the degree program and educational outcomes for future building professionals. The workshops are seen as a critical first-step in the process of creating a Community of Reflective Practitioners (CoRP) in Built Environment programs, and are being developed as a case study for ongoing research.

4.2.1. Development of teaching profile and educational awareness

The professional development workshops planned for Built Environment educators and professional staff will enhance educational awareness for pedagogy, reflective practice and facilitate the preparation of personal teaching profiles. These workshops will provide a transition and linkage between ‘discipline language’ and ‘educational language’ and become part of the school’s professional learning program for academic staff. The format and content will respond to the discipline specific needs and skills development of individuals as they reflect on their personal teaching philosophies and practices. Sharing the insights of these reflections exposes individuals to other points of views and approaches, and as staff work collaborative to address common problems and share successes, the foundation of a longer term teaching and learning community of reflective practice is formed within the school. Making the peer review experience a positive one with linkages to continuing improvement, reflection, innovation and initiative.

4.2.2. Engaging faculty management to actively support the CoRP

Providing peer support and educational training for staff to support students’ technical and skills learning outcomes reflects the faculty and institutional goals and quality of student learning outcomes. Developing methods such as qualitative fieldwork that supports data collection of teaching practices, and using case studies to align teaching practices with student outcomes supports discipline focused teaching academics in contextualising their findings. This will enable school and faculty teaching and learning initiatives to respond to discipline specific requirements, and assure relevance of graduate outcomes in the diverse and complex built environment industry.

4.2.3. Reward and recognition

The teaching profiles developed by staff as an outcome of these workshops will increase the visibility of SoTL and educational practice within the schools. The data collected through varying research investigations will contribute the evidence required for future institutional reward and recognition programs. Rewarding quality teaching and learning as valuable practice forms the basis for research and scholarship. The reflection on practice re-focuses the academic analysis from the preparation of learning content to the reflective practice of teaching and learning. The case studies developed through this research will provide valuable background to theory and practice with potential inter-disciplinary and cross-institutional impact.

5 Conclusion and Further Research

This research identified current trends in the higher education context and the emerging teaching and learning skills gap of academic and discipline staff to meet institutional and student learning expectations. In particular Built Environment degree programs in Australia have maintained a technical content focused teaching approach partly due to the lack of institutional support to develop learning focused educational skills. In international educational practice and research, the development of a teaching...
philosophy statement and teaching profile are well established. This research identified the strategic opportunity for staff to better understand their own practice through the development of a TPS and their personal teaching profile. The development of a community of reflective practice for built environment educators is proposed as integral part of a continuing professional development program with peer support. As part of the University professional learning program a series of educational workshops is developed for teaching staff in built environment programs. The educational workshops target the following key outcomes

1. To embed the value of teaching and learning practice into faculty employment, workload and performance reviews. A central part is the development of a personal teaching profile based on reflection and educational awareness that connects the ‘discipline language’ with the ‘educational language’.

2. To support educational training for staff on how to support students’ skills and learning outcomes reflecting faculty and institutional goals. This process is guided by the proposed Community of Reflective Practitioners (CoRP), where teaching and learning initiatives receive peer support in their development, research and continuing reflective practice.

3. To reward quality teaching and learning as valuable practice and basis for research and the scholarship of teaching and learning within the schools. The data collected through varying educational research investigations will expand the preparation of learning content as part of the reflective practice for quality teaching and learning outcomes.

This proposed approach encourages capacity building across teaching teams, institutional engagement in the degree program and evidence based data collection and research for the long term educational outcomes of graduates and future building professionals. This research is presented at the AUBEA 2018 Conference for feedback at the early development stage. The project builds on established national and international higher education research and practice. The focus on the educational context for built environment degree programs in Australia has highlighted the particular challenges and therefore tailored response needed to support educational development in learning and teaching. The researchers invite other built environment schools interested to join the development program to contact the authors for more information and cross-institutional research collaboration.

6 References


Gale, T., & Parker, S. (2013). Widening participation in Australia in higher education.


Abstract:

Students’ pre-course perceptions of a subject provide insight relative to their understanding and appreciation of a subject and challenges that the lecturer may encounter. The purpose of the study reported on is to determine the pre-course perceptions of construction management students towards the subject Geometric Drawing, based upon a self-administered questionnaire survey conducted in a South African university. A survey of students occurred at the inception of the subject at first year level. The salient findings include: Visual communication is perceived as more important than graphic, oral, and written communication whilst Structures, Construction Management, and Project Management predominate in terms of the extent Geometric Drawing will assist students with the undertaking of construction management activities. The results indicate that students regard Geometric Drawing competencies as important for Construction Managers. Based upon the findings conclusions are that students have a degree of understanding and appreciation of the Geometric Drawing module prior to exposure thereto, and they understand and appreciate the importance and role of the modules to their programme and disciplines. Recommendations include that research be conducted on an annual basis, and a preparatory lecture module ‘The role and importance of Geometric Drawing’ should be evolved for first time Geometric Drawing students.

Keywords:

Construction Management, Geometric Drawing, Perceptions, Students
BSc (Construction Studies) students at Nelson Mandela University, register for the two-semester subject, Geometric Drawing, in their first-year of study. The purpose of the subject is to develop a ‘good’ three-dimensional perception capability. A fundamental requirement is that the student becomes familiar with geometrical drawing and drafting techniques, conventions, and skills. In terms of learning outcomes, by the end of the course, the student must:

- be familiar with basic drafting equipment;
- be aware of good drawing practice;
- be able to produce drafted drawings with reasonable skill;
- have a basic knowledge of three-dimensional geometry;
- be able to interpret and perceive form when reading various types of orthographic and 3D projections;
- be able to produce the different kinds of orthographic and 3D projections, and;
- be able to tackle problem-solving exercises using descriptive geometry.

However, students have encountered difficulty passing the subject upon the first attempt. Furthermore, anecdotal evidence, and meetings with class representatives indicate that Geometric Drawing students encounter difficulty in terms of interpretation, and developing drawings. Table 1 below presents the pass rate for the years 2009 to 2017 including the mean for the subject.

Table 1. Pass rates for the years 2009 to 2017 for Geometric Drawing

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<tr>
<td>Pass rate (%)</td>
<td>52.1</td>
<td>54.5</td>
<td>65.5</td>
<td>55.6</td>
<td>70.0</td>
<td>59.0</td>
<td>63.0</td>
<td>62.3</td>
<td>48.9</td>
<td>56.3</td>
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The literature indicates that students commence courses with pre-conceived notions with respect to the courses, possibly influenced by normative views of members of the larger campus community (Heise, 1979, 2002, in Francis, 2011). Furthermore, results of prior research have shown student attitudes toward a course before the start of the semester affect student course evaluations (Barke et al., 1983 in Francis, 2011). Research conducted by Barth (2008) in Francis (2011) relative to student evaluations, using factor analysis, determined that prior ‘interest in the subject matter’ has a significant impact on the overall course ratings.

Given the aforementioned, and the Department of Construction Management’s focus on ‘learning and teaching’ research in addition to general assessment of courses, programmes, and related interventions, a self-administered survey was conducted among students registered for the subject Geometric Drawing at the commencement of the presentation thereof.

The objectives were to determine the:

- importance of various forms of communication;
- extent Geometric Drawing will assist students with understanding and performance relative to other subjects; and,
- extent Geometric Drawing will assist students with the undertaking of construction management activities.

2 Literature Review

2.1 Importance of Geometric Drawing

A study ‘The practice of construction management Phase 2’ conducted among non-student members of the Chartered Institute of Building (CIOB) (Southern Africa), determined, inter alia, the frequency at which 78 knowledge areas and 45 skills are used relative to the three levels of management. In terms of skills, graphic communicating achieved importance indices (IIs) and ranks relative to the three levels of management as follows: operational – II = 2.15 (23rd); middle – II = 2.29 (25th), and top – II = 2.27 (28th), and mean – II = 2.23 (24th). All the IIs are > 2.00, the midpoint of the range, which indicates the use is frequent as opposed to infrequent (Smallwood, 2006).

According to a range of authors cited by Azodo (2017), engineering drawing helps engineering students develop their spatial ability, design competence, and expertise needed for problem-solving prevalent in the engineering profession. Field (2004) contends that knowledge of drafting develops communication in two dimensions (2D), and thinking in three dimensions (3D). He advocates that students require understanding of some solid geometry through drafting and courses in plane geometry, which cover applied geometry, as well as logic, to overcome the difficulties students experience in moving from two dimensionally dominant interactions into three dimensions through the principles of drafting to interactive solid modelling.

A survey conducted by McLaren (2008) determined that industry practitioners, faculty, and students believe there is value in learning how to construct technical drawings using a pencil, and that the “haptic experience of pencil and paper line production and layout, combined with the discipline of using orthographic and axonometric projections appears to engender a deeper appreciation of accepted conventions.” These conventions seem to serve as an aid to developing visualisation skills required when engaged in mentally transposing images. All sample groups were able to identify what learning derived from manual technical drawing. This learning identified fundamental knowledge, standards, and conventions and techniques, as well as describing terms of personal gain. The development of these transferable skills and attitudes was categorised by McLaren using Bloom’s taxonomy of learning domains model (Bloom, 1965, in McLaren, 2008):

- General cognitive development: problem solving; thinking skills; spatial awareness, and visualisation skills;
- psychomotor development: coordination; control; accuracy, and neatness, and affective development: motivation; artistry; care, and personal satisfaction.

2.2 Perceptions and Attitude

Azodo (2017) contends that attitude is one of the most important elements in the learning environment necessary for understanding and improving the educational processes. Goodykoontz (2008) states that student attitudes are mostly affected by four external factors, namely the teacher, teaching style, classroom environment, assessments, and achievement, and one internal factor, individual perceptions and characteristics.

However, according to Poon (2007), students’ ability and previous knowledge, workload (time spent), teaching content, and teaching strategy also affect the outcome of students’ learning process and attitudes. Felder and Brent (2005) contend that a deep approach towards learning in students can be engendered through arousing the learners’ interest in a subject through the provision of background information with respect to the subject, as inadequate background knowledge and lack of interest discourage students’ developing a deep approach towards learning.
A study conducted among engineering students in Nigeria by Azodo (2017) determined that the students had prior knowledge of the subject and involved practices from varied sources. Colleagues and friends, and the introductory class constituted sources of information of the necessity of the subject. However, they were neutral as per whether their experience is different from the pre-knowledge about the subject and difficulty of the subject. Azodo (2017) states that the findings concur with those of Igbinomiwanhia and Aliu (in Azodo, 2017) who observed that lack of technical drawing education at the secondary education level affects students when undertaking the subject at the tertiary education level. The findings also indicate that the students are negative about the relevance of the subject to the engineering profession. Azodo (2017) concluded that the lack of knowledge of the importance of engineering drawing militated against the whole essence of studying engineering drawing, and that this challenge needs emphasis and re-emphasising of its importance in the engineering profession, so as to stimulate students’ to interest towards the subject.

3 Research Methodology

The researchers employed a quantitative design to collect data to determine the pre-course perceptions of construction management students towards the Geometric Drawing module. The intention of the research is to provide input into the department’s efforts to overcome challenges that the lecturer had previously encountered from students as to the relevance of geometric drawing to construction management. Research questions captured students’ insights relative to their understanding and appreciation of the subject and its relevance to other subjects as well as the importance of different forms of communication, particularly in assisting students with the undertaking of construction management activities upon completion of their degree. Twenty-six students from a net enrolment of fifty-seven students completed a self-administered questionnaire during the introductory lecture for the subject, which equates to a response rate.

The questionnaire consisted of four closed ended questions, three of which were five-point Likert scale type questions. A measure of central tendency in the form of a mean score (MS) between 1.00 and 5.00 was computed based upon the percentage responses to the points on the scale to enable interpretation of the responses and to rank variables where necessary. The responses were weighted as per the figures recorded within parentheses: not important / minor extent (1); less important / minor extent (2); important / some extent (3); more important / near major extent (4), and very important / major extent (5).

4 Findings and Discussion

Table 1 presents the importance of four forms of communication for construction managers in terms of a scale of 1 (not) to 5 (very), and a mean score (MS) between 1.00 and 5.00. It is notable that all the MSs are > 3.00, which indicates that in general the respondents perceive the forms to be more than important, as opposed to less than important. Visual predominates, and given that the MS (4.65) is > 4.20 ≤ 5.00, it is perceived as more than important to very important / very important. Visual is followed by graphic, oral, and written, the MSs of which are > 3.40 ≤ 4.20, which indicates the perceived importance is between more than important / very important - more than important. The second ranking of graphic, the subject of the study, correlates with the contentions of the NCCA (2000), Liu and Hein (2007), and Bisharat (2004).

Table 1. Importance of four forms of communication for construction managers

<table>
<thead>
<tr>
<th>Form</th>
<th>Unsure</th>
<th>Not</th>
<th>Some</th>
<th>Major</th>
<th>Very</th>
<th>MS</th>
</tr>
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<tbody>
<tr>
<td>Visual</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.7</td>
<td>19.2</td>
<td>73.1</td>
</tr>
<tr>
<td>Graphic</td>
<td>7.7</td>
<td>0.0</td>
<td>0.0</td>
<td>15.4</td>
<td>15.4</td>
<td>61.5</td>
</tr>
<tr>
<td>Oral</td>
<td>7.7</td>
<td>0.0</td>
<td>3.8</td>
<td>7.7</td>
<td>26.9</td>
<td>53.8</td>
</tr>
<tr>
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<td>3.8</td>
<td>7.7</td>
<td>15.4</td>
<td>38.5</td>
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</tbody>
</table>

Table 2 indicates the extent to which respondents perceive Geometric Drawing will assist them with their understanding and performance relative to ten subjects. It is notable that 8 / 10 (80%) of the MSs are > 3.00, which indicates that in general respondents perceive Geometric Drawing will assist them with their understanding and performance relative to the ten subjects to a major, as opposed to a minor extent. It is notable that only 2 / 10 (20%) MSs > 4.20 ≤ 5.00, which indicates the perceived extent is between a near major extent to a major extent / major extent - Structures, and Construction Management. 4 / 10 (40%) of the MSs are > 3.40 ≤ 4.20, which indicates the perceived extent is between some extent to near major extent / near major extent - Project Management, Materials & Methods, Site Surveying, and Production Analysis / Quantities. The remaining 4 / 10 (40%) MSs are > 2.60 ≤ 3.40, which indicates the perceived extent is between a near minor extent to some extent / some extent - Environment & Services, History of the Construction Industry, Property Economics, and Building Economics.

Table 2. Extent to which respondents perceive Geometric Drawing will assist them with their understanding and performance relative to ten subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>U</th>
<th>Minor</th>
<th>Some</th>
<th>Major</th>
<th>Very</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>11.5</td>
<td>23.1</td>
<td>65.4</td>
<td>4.54</td>
</tr>
<tr>
<td>Construction Management</td>
<td>7.7</td>
<td>11.5</td>
<td>3.8</td>
<td>33.1</td>
<td>53.8</td>
<td>4.29</td>
<td>2</td>
</tr>
<tr>
<td>Project Management</td>
<td>5.8</td>
<td>3.8</td>
<td>7.7</td>
<td>42.3</td>
<td>34.6</td>
<td>4.00</td>
<td>3</td>
</tr>
<tr>
<td>Materials &amp; Methods</td>
<td>11.5</td>
<td>7.7</td>
<td>15.4</td>
<td>42.3</td>
<td>23.1</td>
<td>4.08</td>
<td>4</td>
</tr>
<tr>
<td>Site Surveying</td>
<td>7.7</td>
<td>7.7</td>
<td>19.2</td>
<td>26.9</td>
<td>38.5</td>
<td>3.81</td>
<td>5</td>
</tr>
<tr>
<td>Production Analysis / Quantities</td>
<td>11.5</td>
<td>7.7</td>
<td>11.5</td>
<td>19.2</td>
<td>34.6</td>
<td>3.70</td>
<td>6</td>
</tr>
<tr>
<td>Environment &amp; Services</td>
<td>12.0</td>
<td>8.0</td>
<td>20.0</td>
<td>24.0</td>
<td>20.0</td>
<td>3.23</td>
<td>7</td>
</tr>
<tr>
<td>History of the Construction</td>
<td>15.4</td>
<td>11.5</td>
<td>26.9</td>
<td>19.2</td>
<td>15.4</td>
<td>3.18</td>
<td>8</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property Economics</td>
<td>22.1</td>
<td>11.5</td>
<td>19.2</td>
<td>11.5</td>
<td>30.8</td>
<td>3.85</td>
<td>9</td>
</tr>
<tr>
<td>Building Economics</td>
<td>34.6</td>
<td>3.8</td>
<td>23.1</td>
<td>26.9</td>
<td>9.0</td>
<td>3.88</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3 indicates the extent to which respondents perceive Geometric Drawing competencies (knowledge and skills) will assist them with nineteen construction management activities. It is notable that only 9 / 19 (47.4%) MSs are > 3.00, which indicates that in general respondents perceive Geometric Drawing competencies (knowledge and skills) will assist them with the activities to a major, as opposed to a minor extent. It is notable that only 3 / 19 (15.8%) MSs > 4.20 ≤ 5.00, which indicates the perceived extent is between a near major extent to a major extent / major extent - resolving design problems, setting out buildings, and preparing site layouts (Planning). 5 / 19 (26.3%) of the MSs are > 3.40 ≤ 4.20, which indicates the perceived extent is between some extent to a near major extent / near major extent - programming and scheduling (planning), temporary works design e.g. scaffolding, measuring quantities, and estimating. 6 / 19 (31.6%) of the MSs are > 2.60 ≤ 3.40, which indicates the perceived
extent is between a near minor extent to some extent / some extent - resolving construction problems, plant & equipment planning, subcontractor management, quality management, materials management, and cost control. 4 / 19 (21.1%) MSs are > 1.80 ≤ 2.60, which indicates the perceived extent is between a minor extent and a near minor extent / near minor extent - productivity management, health and safety management, labour management, and information management.

The extent to which respondents perceive Geometric Drawing competencies will assist them with resolving design problems (1st), setting out buildings (2nd), preparing site layouts (planning) (3rd), programming and scheduling (planning) (4th), temporary works design (5th), and resolving construction problems (9th) correlates with the contentions of Liu and Hein (2007), and Bisharat (2004).

Table 3. Extent to which respondents perceive Geometric Drawing competencies (knowledge and skills) will assist them with nineteen construction management activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Response (%)</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolving design problems</td>
<td>3.8</td>
<td>0.0</td>
<td>5</td>
</tr>
<tr>
<td>Setting out buildings</td>
<td>0.0</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Preparing site layouts (Planning)</td>
<td>0.0</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Programming and scheduling (Planning)</td>
<td>7.7</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Temporary works design e.g. scaffolding</td>
<td>7.7</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>Measuring quantities</td>
<td>4.0</td>
<td>12.0</td>
<td>5</td>
</tr>
<tr>
<td>Estimating</td>
<td>7.7</td>
<td>15.4</td>
<td>5</td>
</tr>
<tr>
<td>Outlining the scope of work</td>
<td>15.4</td>
<td>3.8</td>
<td>4</td>
</tr>
<tr>
<td>Resolving construction problems</td>
<td>15.4</td>
<td>3.8</td>
<td>4</td>
</tr>
<tr>
<td>Plant &amp; equipment planning</td>
<td>7.7</td>
<td>23.1</td>
<td>5</td>
</tr>
<tr>
<td>Subcontractor management</td>
<td>19.2</td>
<td>23.1</td>
<td>5</td>
</tr>
<tr>
<td>Quality management</td>
<td>7.7</td>
<td>3.8</td>
<td>4</td>
</tr>
<tr>
<td>Materials management</td>
<td>15.4</td>
<td>34.6</td>
<td>5</td>
</tr>
<tr>
<td>Cost control</td>
<td>11.5</td>
<td>42.3</td>
<td>6</td>
</tr>
<tr>
<td>Productivity management</td>
<td>7.7</td>
<td>34.6</td>
<td>6</td>
</tr>
<tr>
<td>Health and safety management</td>
<td>11.5</td>
<td>30.8</td>
<td>7</td>
</tr>
<tr>
<td>Labour management</td>
<td>11.5</td>
<td>34.6</td>
<td>6</td>
</tr>
<tr>
<td>Information management</td>
<td>19.2</td>
<td>30.8</td>
<td>7</td>
</tr>
<tr>
<td>Resolving disputes</td>
<td>30.8</td>
<td>46.2</td>
<td>7</td>
</tr>
</tbody>
</table>

34.6% of the respondents registered for Engineering Graphics and Design at secondary school, and 65.4% did not, whereas 12.0% registered for Woodwork, and 88.0% did not. Engineering Graphics and Design is a recommended subject in terms of registering for the BSc (Construction Studies) degree.

5 Conclusion and Further Research

Meetings with class representatives indicated that Construction Studies students in the Geometric Drawing subject encountered difficulty in terms of interpretation, and development of drawings within the class negatively affecting their ability to pass the subject. The results reinforced this with students encountering difficulty passing the subject at the first attempt. A perception had developed within the Department of Construction Management that students commenced the course with pre-conceived notions with respect to the course, possibly influenced by peers repeating the subject alongside a new cohort as well as the views of members of the larger campus community. Literature on the subject would suggest that this is a common phenomenon amongst student groups, particularly if their understanding of the relevance of the subject to their career is constrained. Prior research has also shown that student attitudes toward a course before the start of the semester affect student course evaluations (Francis, 2011).

Perceptions are thus a strong indicator of performance and amongst this cohort of students there are notable positive perceptions, which indicates that ‘perceptions’ with respect to the subject are not necessarily the challenge in terms of improving the pass rates over a period. These students performed better, doubling the pass rate of their peers three years prior and improving by ten percent over the two subsequent years, when the researchers did not administer the questionnaire. This may indicate that the administration thereof influenced students’ attitude towards the subject although this group of students had a degree of understanding and appreciation of the subject prior to exposure thereto. They understood and appreciated the importance of graphic communication, and the role and importance of the subject to their programme and discipline.

Visual communication is important to Construction Managers (Smallwood, 2006; McLaren, 2008), a finding confirmed by the students who rated it as very important for communication as a whole. Furthermore, in general, respondents perceive Geometric Drawing will assist them to a major extent with their understanding and performance relative to ten subjects, with Structures, Construction Management and Project Management perceived to be benefitted the most. This finding underscores the rationale for the inclusion of Geometric Drawing in the undergraduate programme, namely to assist students with their understanding and performance relative to several subjects through horizontal and vertical integration. What was notable was the results from the questions with respect to respondents’ perception as to Geometric Drawing competencies (knowledge and skills) assisting them with construction management activities, with only 9 / 19 (47.4%) achieving a MS greater than three. This appears to indicate that students’ understanding of the role the subject plays in day-to-day activities on a project need enhancing, possibly through better integration of those skills into reports generated from site visits conducted as part of the ten subjects included in the survey.

Recommendations include that on an annual basis a survey occurs at the commencement of the course and that a preparatory lecture module ‘The role and importance of Geometric Drawing’ be evolved for first time Construction Studies Geometric Drawing students. Furthermore, research to determine the challenges experienced by students, including potential interventions to address those specific challenges, is conducted with students who have repeated the subject. Finally, a need exists to incorporate greater cross subject implementation of knowledge and skills studied into project reports.
6 References


Learnings from a collaborative academia – construction sector bespoke study programme – a reflective case study

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Abstract:
The construction industry is known as a competitive, fragmented and often adversarial work environment. Maintaining high levels of productivity and profitability within such an environment frequently requires a diverse range of skills and experience. Published research investigating the application of integration, collaboration, and organizational learning has demonstrated that leveraging these concepts can begin to address fragmentation, increase integration and encourage innovative thinking thereby providing the opportunity for productivity gains within the construction industry. Two years ago a first tier New Zealand commercial construction company approached a tertiary provider to consider tendering for its management training programme. The primary aim was to focus on introducing the principles of lean construction and integrated project delivery to over 300 middle management onsite construction staff over the next 5 years. The company wanted a delivery approach that would have the greatest possible impact on staff in terms of engagement and knowledge transfer. A bespoke training programme of study was developed and delivered collaboratively with the company, for 50 managers in 2016 and another 50 in 2017. The tertiary provider drew on the latest innovations in construction education, and combined that with the partnered company's culture vision for the wider sector potentially. Feedback has been positive and constructive from the construction company partner, the programme participants and the academic staff on the programme.

Keywords:
academia-industry, collaboration, construction sector, innovative thinking, organisational learning

1 Introduction
Maintaining high levels of productivity and profitability within the construction industry, frequently requires innovative and front-foot responses. Perhaps, as suggested in published research, leveraging the concepts of collaboration and organisational learning, fragmentation could be reduced by increasing integration of the design and construction project team participants, stakeholders and specialist trades. The aim being to enable opportunities for productivity gains within the construction industry. With this in mind the research question became, “How does the collaborative industry-academia partnership work in achieving training with high staff engagement and effective knowledge transfer?” The main focus being on how a bespoke training programme for the construction company partner was jointly developed and delivered, and the literature that informed and that process.

The New Zealand Construction industry has been experiencing a significant period of growth during the last 7 years, driven primarily by the Christchurch earthquake rebuild,
the demand for housing, particularly in Auckland, and increased net gain immigration. At the same time there has been ongoing discussion between government and industry regarding how to manage the lack of skilled capacity within the construction sector, which has further constrained productive capacity (PWC, 2016). The lack of capacity has further increased the demand for skilled labour, causing resultant increased pressure on all, a number of key stakeholders. These include, but are not limited to, having a culture that encourages KS, and how it communicates. Trust based inter-organisational relationships are a common feature of the construction sector.

2.1 Sector Identity

The construction sector is frequently referred to as being a fragmented, sometimes confrontational and a predominantly competitive work environment (Egan, 1988; Latham, 1994). This could be said to be particularly true in the New Zealand market, which is comprised of a few large-scale construction companies, but is primarily a plethora of small and medium enterprises, whether construction companies or related labour sources and suppliers within the construction sector supply chain. There is a noticeable lack of integration on the majority of projects currently, increasing levels of outsourcing occurring to meet deadlines, and a significant lack of skilled resources available. Risk and opportunity are going hand in hand at the moment in this sector. The fragmentation occurs horizontally and vertically in particular. This is realised for example, in the ongoing practice of single stage competitive bidding for work, though this has been mitigated to some extent on some projects with the adoption of alliancing, and other mechanisms such as integrative governance (and risk sharing), and the management of boundaries using boundary spanning for instance. As noted by Fellows and Liu (2012) boundary spanning on projects involves bridging and connecting with external organisations, forming project teams and coordinating interdependent work efforts within and across organisational boundaries. This approach is now being seen by a few of the large-scale and confident construction companies in New Zealand as a market opportunity, as a means to achieving their company vision of being a leader in the field and achieving an increased market share. This was one of the main reasons why the particular construction company approached this tertiary provider to set up a collaborative training partnership (Laing et al., 2017).

2.2 Collaboration and Organisational Learning Practices

In order to be competitive in the construction sector, companies need to adopt practices that ensure continuous development and improvement. Collaboration and organisational learning are practices that are the focus of attention for companies looking for a competitive advantage. Collaboration is based on the concept of building relationships with stakeholders (both internal and external) by building trust (Cheung et al., 2015). The trust relationship is established and enhanced via an organisation's culture and how it communicates. Trust based inter-organisational relationships allow for a greater level of performance in supply chains (Dellufo, 2011). Building trust processes contributes to higher levels of collaboration and team integration (Baiden et al., 2006). This has been shown to increase the performance of Architecture, Construction and Engineering (ACE) project delivery teams (Franz et al., 2016). Organisational learning is a process that helps expand on what a trust built collaborative relationship affords by openly sharing knowledge and understanding (Cheung et al., 2015). The combined process of collaboration and organisational learning means greater opportunities are created for innovative solutions to complex problems. The ability to solve complex problems, such as those found in the construction sector, are enhanced further via incorporating models such 'Systems Thinking', as suggested by Senge (2003) and looped learning (Wong 2015), which advocates organisations and individuals adopt learning practices. A key component of organisational learning involves the ability to express and share understanding via knowledge sharing (KS) practices. By communicating one's knowledge, an opportunity can be created for knowledge growth among participants. Knowledge sharing is shown to help organisations create a competitive advantage through increased productive practices (Abu Bakar et al., 2012; Wang and Ko, 2013). Navimipour and Charband (2016) research into the knowledge sharing relationship literature has recognised a number of key mechanisms for this process. These include, but are not limited to, having a culture that encourages KS, leadership support, project teams' recognition of the value of KS, and a willingness of participants to engage in KS. These practices are enhanced when interdisciplinary and inter-organisational engagement is supported and rewarded (Zhang et al., 2013). Organisations involved in KS practices can also benefit from understanding how knowledge is successfully transferred.
Construction projects can be seen as unique in that many of the parties involved are separated in terms of time and location during the life of a project. Understanding how to transfer knowledge in this context is key to leveraging learning. Knowledge management has two broad categories, being 'explicit' and 'tacit' knowledge. Explicit knowledge is generally easy to manage via record keeping and information systems. Whereas, tacit knowledge is more challenging to engage with, and manage, as it is held in the minds of individuals. The ability of individuals to draw on both explicit and tacit knowledge at the right time has the greatest impact on knowledge transfer success (Bagheri et al., 2016). Research has demonstrated that it is through the mechanism of integrated project teams (IPT) in construction that the opportunity for knowledge transfer is at its greatest potential (Zhang et al., 2013).

### 2.3 Industry-academia relationships

Key drivers that create successful industry-academia partnerships result from the time invested in establishing a construction company's actual needs and the tertiary provider's willingness and ability to form a meaningful training relationship (Schofield, 2013). Those involved in a partnership need the right mix of construction industry experience, management, research and teaching expertise, from diverse construction management backgrounds, and in addition, shared common drivers such as increasing productivity and collaboration in the construction industry (Laing et al., 2017). Patterson (2016) identified the importance of effective communications in developing trust and loyalty during the first phase of relationship building, and that collaborative relationships should be built on the principles of partnering where trust is developed through open communications. There are many barriers to academic-industry collaboration, as it requires a higher level of commitment and activity (Tumbas et al., 2016), and there are always resourcing risks and challenges (financial as well as staffing, and differing drivers/priorities). Laing et al. (2017) found that in order to achieve a collective approach, the key for the construction company and the tertiary provider was that each was actually prepared to listen, adapt and offer suggestions. As a consequence, the relationship is based on a pro-active problem solving approach by both parties.

### 2.4 Collaborative Learning and the Living Curriculum approach

Tertiary providers have an ongoing desire and need to find, create and implement new and innovative ways of facilitating real-world learning for programme enrollees (Guerrero et al., 2016) whether at trade, middle management or senior management levels. The construction sector is ever-changing in the demands and expectations from stakeholders and clients in particular. Construction sector companies whether individually or collectively engaging architectural, engineering or construction staff have to ensure that they are trained in-house as well as further developed into an innovative, front-footed, effective, and forward looking team. There are currently several learning methods employed by tertiary providers. Collaborative learning is the predominant method. This involves a workshop approach in high tech computer-rich, integrated group-friendly teaching spaces, and online resources. Participants work as interactive groups /teams in a problem-solving mode with the facilitator as a constant mentor, critic and guide (Davidson and Major, 2014). The term Living Curriculum is not unique to tertiary providers as it is used widely by many educationalists where learning is reframed as a complex social conversation (Keesing-Styles et al., 2014). The thinking is formed from a belief that people learn best by constructing their own understanding and solutions to problems through discourse with peers and the broader community. The ‘Living’ aspect emphasises the dynamic nature of the approach that grows and changes by responding to the needs of the students, (Birchmore and Kestle, 2011), and in this particular research work that community was the construction company, and their selected participants on the bespoke programme. This collaborative, and flexible approach to the bespoke programme had ‘Lean’ as an overarching theme to all of the 6 modules and this fitted well with the outcomes sought by the construction company for their interdisciplinary middle management staff.

### 3 Research Methodology

An interpretive case study research approach was conducted from the perspective of the main contributors to the industry-academia relationship as it provides a broad opportunity to develop a comprehensive view of the elements involved from the perspective of those involved, according to Liu and Fellows (2015). This stage of the industry-academic partnership process was essentially concerned with building on the work already published by Laing et al. (2017) which focussed on the procurement process of setting up the industry construction partnership with the tertiary provider in 2015/16. The principles of a bespoke programme of study were designed and developed collaboratively with the construction company and the modules were jointly delivered. Each of the four company cohorts of 25 participants have been middle managers from across New Zealand, and were selected by the company's senior management in 2016 and 2017 (and now in 2018). Each module has had a lead academic deliverer/facilitator receiving piloted workshop based workshops. The company's senior (on-site or specialised) staff were provided to facilitate a section of each of the modules to work alongside, and collaborate with the academic(s). This approach provided the company's perspective and relevant live project examples to support and underpin each module's focused theme. Participant evaluations, using anonymous evaluation forms, were then conducted by the tertiary provider and the construction company, at the end of each of the 6 modules on the bespoke programme, and for the overall programme. Using qualitative data coding techniques (Fellows and Liu, 2009) the evaluation responses were coded against the literature themed sub-headings. The collected data was reviewed and reflected on by the tertiary provider academics and the construction company management.

### 4 Findings and Discussion

Evaluative feedback received from the programme participants in 2016 and 2017 are the main findings of this case study research. In addition, a quote from the construction company partner after four cohorts have been through the bespoke programme in 2016/17 is included here, together with the reflective evaluations on the participants' feedback and the learnings from the academic staff:

#### 4.1 Construction company partner feedback

"We chose to partner with the tertiary provider to deliver our programmes as we believe they are an institution that provides a practical and collaborative approach to learning in the construction space. The facilitators at the tertiary provider have done a great job at developing and delivering relevant content to our employees, whilst ensuring they have an engaging learning experience. We particularly liked the delivery staff’s ability to be ‘pracademic’."

(quote from the construction company partner's leadership personnel March 2018).
4.2 Participants' feedback

The overall programme of 6 modules was evaluated by the participants using anonymous course evaluation forms that asked questions such as:

- What aspects of the programme have been most valuable to you in your work? Do you have any comments on the programme content? How has the programme impacted your job / role? Which, if any, modules or learning do you think would be beneficial to a much greater range of participants?

The data was codified from the participant feedback and then presented under the following sub-headings to compare the findings, and establish the overall level of support for the collaborative bespoke programme's aims.

4.2.1 Sector Identity

“I think the course content as a whole reflects the overall company philosophy of collaboration”; “Made me feel that I was on the company’s long term plans”; “I feel like I am on a path that is structured to help my development”; “I’ve understood for a very long time that business is about good relationships, and now I’ve made the connection that people make good relationships happen.; “I am more aligned with colleagues, which being relatively new to NZ has helped me understand further how the cogs turn within the company culture”.

4.2.2 Collaboration

“It has given me confidence when approaching tasks like planning, communication with subcontractors, risk management and Lean Construction”; “I’m getting better engagement with my project team and subcontractors through properly listening and understanding their point of view”; “I also conduct myself differently when talking to subcontractors and when trying to resolve an issue or a conflict”; “Collaborative working ideas have helped improve working relationships with other staff and subcontractors”; “I personally learnt a lot about myself and how I can improve with the first module on effective communication and conflict management. It has definitely influenced my behaviour and the way I go about daily duties”.

4.2.3 Organisational Learning

“It was clear that the tools which are already provided are not being utilised to their full potential, so it was a good experience to learn more about some of the systems tools we already have access to; “Especially the technology focus areas.”; “Have put a lot into practice already, and am aware of other aspects that need to be put into practice. The programme has also opened up my eyes to many new ways of doing things - e.g. last planner”; “Have been given exposure to alternate ways of thinking and incorporate that into my work. Have made contacts and correspond with others outside my region. Surprised that the issues I face are very similar across the company”; “It was good because it taught you things e.g. risk management from the site managers point of view. There were also things I haven’t been exposed to in my job. We learnt about them and the right way to do it.”.

4.2.4 Knowledge Sharing

“Sharing knowledge and experiences with peers, and senior colleagues in the business, as well as learning about leading techniques was great”; “Meeting other members of the company and discussing the way they do things in other regions compared with what we do”; “Meeting new staff has enabled me to increase my network base so I have others to discuss similar issues/projects with”; “Really good to hear from other staff and projects and discuss issues, and solutions.”.

4.4.5 Collaborative Learning

“The effective communication module - I took a lot away from this, and have put many aspects learned into every day practice - have definitely seen positive results from this, especially in my own team members and subbies”; “Meeting peers within the company who share broad experience and knowledge, sharing our work stories and scenarios”; “Meeting company staff, was the most beneficial, but the communication/collaboration and risk management were the items studied that I will use on a daily basis. Other topics, whilst useful to increase my knowledge, will not be used as much”; “Talking/sharing experiences with other teams, and the presentation from other industry experts. Each subject has provided me with new skills and a better level of understanding which can be used when communicating with my team, subcontractors, and consultants”.

4.3 Reflections on the bespoke training programme

Schofield (2013) reviewed a wide range of potential barriers that face those entering an industry-academic collaboration. On reflection, a credible point of contact for both organisations proved to be a key success factor and was a key stipulation by the construction company. This worked well and became a cornerstone of the programme. The Programme Curriculum Advisor (PCA) specifically appointed by the construction company for this partnership with the tertiary provider, was an experienced academic and highly experienced Construction Manager. This offered an opportunity to tailor a bespoke programme that fitted the construction company's commercial needs, and the tertiary provider's academic drivers. Feedback on the programme and the collaborative relationship has been positive for the construction company partner, and academic staff.

4.4 Reflections on the participants' feedback

When reviewing the evaluation results from participants there was a general consensus that the programme is adding value individually and collectively, and has a strong level of support. Engagement in learning is positive and the majority of participants are applying their learnings back on site, by working and thinking differently. Generally, the feedback connects with literature discussed. Comments regarding sector identity, collaboration, learning and teaching pedagogy support the findings from recent and earlier research. In line with Fellows and Lin's (2012) research on boundary spanning, there is commentary from participants that relationship building and connecting with the construction company's strategy on collaborative practices is being adopted and is being given a higher level of priority. Remarks like “I’m getting better engagement with my project team and subcontractors through properly listening and understanding their point of view” connects the learning to literature by Baiden et al. (2006) on increased collaboration and team integration and that of Delhomme (2011) findings on how collaborative behaviour can create better performance. Organisational learning and knowledge sharing practices are clearly occurring with the participants. Cheung et al. (2015) noted the value of collaborative approaches and the opportunity for increasing productive practices, commentary such as “The programme has also opened up my eyes to many new ways of doing things - e.g. last planner” an example of the consensus in combination with the tertiary provider connecting organisational learning. The value of knowledge sharing as discussed by Abu Bakar et al. (2012); Wang and Ko (2013) was a significant and positive outcome for the construction company with...
significant commentary evidence such as “Really good to hear from other staff and projects and discuss issues, and solutions” coming from participants.

4.5 Reflection on the construction company partner’s feedback

The company was looking for a delivery approach and team that would have the greatest possible impact on staff in terms of engagement and knowledge transfer, and to work collaboratively together in developing the programme and the delivery. It would appear in the quote received from the company leadership that their expectations have been met, and even exceeded both from the point of view of the collaborative relationship that is ongoing into a third year, but also the added-value for their staff and the company projects currently underway.

4.6 Academics' reflections on the programme and collaboration with the construction company partner

The academics delivering on the bespoke programme have been engaged on successful government funded programmes and delivery models, but this collaborative partnered model needed out-of-the-box thinking. This was the first significant step toward a different delivery model in conjunction with a construction partner who had strong foresight and vision for their company's future and the sector. It offered the opportunity to engage with applied research and influenced the way company staff introduced new ways of working and thinking on their current projects. Engaging with the construction company has been a great experience in terms of seeing the challenges the industry currently faces, and how they were generally receptive and enthusiastic about the learning opportunities being presented to them through the programme. It created the opportunity to combine overseas experience and theoretical knowledge with the local industry context. This collaborative industry-academia relationship has also assisted in understanding why certain new technologies and processes, common overseas, have not yet been adopted or implemented that widely in New Zealand. 'Complex conversations’ being one of the main pillars of the ‘Living Curriculum’ pedagogy adopted by the tertiary provider (Keesing-Styles et al., 2014), was a natural process with these industry professionals, and the company’s co-facilitators with the cohort participants, where local examples were shared, creating rich and analytical conversations. The participants acknowledged how to make a shift in what is often an adversarial environment to create a collaborative and more open sector, that benefits all the players. In the last module of the programme the participants present team proposals and strategies for improving company and individual outcomes to the construction company’s senior leadership personnel. This is often the most rewarding time - seeing how their thinking has changed and how they are engaging with the construction company’s challenges.

5 Conclusion and Further Research

The research question: “How does the collaborative industry-academia partnership work in achieving training with high staff engagement and effective knowledge transfer?” focused on how the bespoke training programme for the case study construction company was jointly developed and delivered with the tertiary provider by drawing on the local context in construction education, and consisting that with the partnered company’s culture vision for the wider sector. The discoveries of the research and its impact are that, academia and the construction industry can work collaboratively despite all the challenges suggested in the literature, if you have two parties willing to commit to common goals, listen to each other’s needs, be flexible and recognise the differing ways of working. This included acknowledging and taking the risk on new technologies and new delivery models. In addition, collaboration was a strongly shared vision by the tertiary provider and the construction company partner for the sector going forward, so as to be more productive and provide enhanced value to the construction company, the staff, clients and stakeholders. The next stage of this research is to conduct an action research study regarding whether any significant changes have occurred in the industry partner’s staff and management practices and what they are, following the delivery of 3 years of participants on the bespoke training programme.

6 References


Students’ teamwork experiences in online study mode: a case study of Central Queensland University

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Abstract:
Teamwork skills are among essential graduate attributes and expected learning outcomes in built environment programs. Student teamwork is challenging, takes time and patience, and above all, fair assessment of its outcomes has proven to be complex. In online study mode, where team members are distributed across different locations and face-to-face interactions are limited or non-existent, communication and collaboration as two components of effective teamwork become even more challenging. This paper reports on students’ teamwork experiences in three units of Bachelor of Building Design course offered at Central Queensland University from November 2016 to June 2018. The three assessment items examined in these three units required teams of students to carry out a collaborative research on a topic related to building design and construction. As an assessment requirement, students were asked to reflect on their teamwork experiences and include in their individual submissions a statement about their teamwork processes i.e. divisions of teamwork tasks, lessons learned, and challenges they encountered with. A thematic analysis of a total number of 65 students’ comments identified a number of barriers to effective teamwork in online study mode including issues with communication and time management as well as important factors which influence team processes including team formation strategies and structures of assessment tasks. The results of the qualitative data analysis were then examined in light of the findings of existing literature on determinants of team effectiveness in virtual teams. The paper concludes with a discussion of how design educators should set up an assessment item with teamwork components, systematically support student teamwork processes, and fairly assess their teamwork outcomes, specifically for online study mode.

Keywords:
Building Design, Design Education, Distance Learning, Online Study, Student Teamwork

1 Introduction

Teamwork skills are among important graduate attributes for architects, designers, and engineers (Building Designers Accreditation & Training of Building Designers Association of Australia, 2018; Royal Institute of British Architects Education Department, 2011) and have been stated as expected learning outcomes in university courses and programs in different disciplines. Student teamwork is challenging, takes time and patience, and above all, the fair assessment of its outcomes i.e. the product and processes has proven to be complex (Richard Tucker & Abbasi, 2015; R. Tucker et al., 2014; Wilcoxson, 2006). Students’ attitudes towards teamwork in educational settings are mostly negative which may be due to past experiences with ineffective teams.
particularity related to unequal contributions of team members and their perceptions of unfair assessment that did not reflect individual team members’ differing contributions to the teamwork product and process (Pfaff & Huddleston, 2003; Ro & Choi, 2011; Rudawska & Szarek, 2014; Richard Tucker & Abbasi, 2016; Wolfe, 2008). Teaching practices and curricula often fail to provide required support throughout the teamwork process and explicit teaching of teamwork skills (Abbasi & Tucker, 2016; Main, 2010; Richard Tucker & Abbasi, 2012). Communication and collaboration as two components of effective teamwork become even more challenging in online education where team members are distributed across different geographic locations and cannot meet, communicate, and collaborate face-to-face.

While there has been much research and effort to address challenges of student teamwork in traditional face-to-face education delivery i.e. guides and manuals developed to support students and teachers in teamwork processes (Clack, 2017; Richard Tucker, 2016; Richard Tucker & Abbasi, 2015; R. Tucker et al., 2014), little research has focused on online education delivery and challenges and factors specific to this mode of delivery (Jaques & Salmon, 2007). CQU as one of the leading online education providers in Australia realised the needs to address the challenge of student teamwork in online study mode and to identify strategies to effectively teach teamwork skills, systematically support student teamwork, and fairly assess teamwork outcomes.

This paper presents a study of students’ teamwork experiences in three units of Bachelor of Building Design at Central Queensland University (CQU) that is offered to students in distance education mode. The aim of the program is to provide career advancement and personal enrichment for students who are not able to attend university in an on-campus mode due to different reasons i.e. work commitments, locality, and other constraints. Students are often individuals with prior trade, certificate or diploma tertiary qualifications who are already employed in the industry and seeking to improve their qualifications for future advancement. They mostly choose a part-time load of two units per term to achieve a workable balance amongst the demands for work, social, family, and study commitments.

2 Research Methodology

Students’ reflective statements about their teamwork experiences from three units of Bachelor of Building Design program offered completely online at CQU from November 2016 to June 2018 were examined. For all the units under study, the teamwork submission was composed of two parts: an individual written report and a brief team presentation. An assessment rubric was provided by the educator addressing the criteria against which students’ submissions were to be assessed. Each team member received the same team mark for the team presentation while individual reports were assessed separately and the sum of these two marks formed a student’s total mark for the teamwork assessment. This meant that each team member received an individualised mark to ensure fair assessment of the teamwork.

For each individual report submission, students were asked to write a paragraph or two reflecting on their teamwork experiences and respond to the following questions:

- What do you think about your teamwork experience? Was it beneficial?
- Did you learn anything from working with another person?
- What were the challenges of working with another person when compared to working individually?

65 students’ reflective statements about their teamwork experiences were recorded.

Table 1. Number of students’ reflective statements about teamwork experiences in the five case study units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Term &amp; Year of offering</th>
<th>No. of students’ statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>Term 3, 2016</td>
<td>9</td>
</tr>
<tr>
<td>Unit B1</td>
<td>Term 3, 2016</td>
<td>24</td>
</tr>
<tr>
<td>Unit C</td>
<td>Term 1, 2017</td>
<td>15</td>
</tr>
<tr>
<td>Unit B2</td>
<td>Term 3, 2017</td>
<td>7</td>
</tr>
<tr>
<td>Unit C2</td>
<td>Term 1, 2018</td>
<td>10</td>
</tr>
</tbody>
</table>

2.1 Unit A, Teamwork Peer Review and Evaluation, 2016

For Unit A, ten students were engaged in teamwork in the final assessment or assessment three. The first assessment required students to develop a client and project brief for a residential aged care facility. Students then further developed these into a completed design and prepared design drawings in assessment two. In assessment three, students were asked to pair up with another student and conduct a teamwork review and evaluation of a client brief, project brief, design and design drawings for a Residential Aged Care Facility submitted in two earlier assessment items by one of their fellow students. The educator assigned a submission to each team on a random basis ensuring that each team is not evaluating one of the team members’ submissions. Student teams were asked to review the submission in terms of addressing all the relevant issues addressed in the study guide including responses to BCA and relevant national guides and local authorities’ requirements. Students were required to address both strengths and weaknesses of their peer’s work they are evaluating and make recommendations for possible improvements.

2.2 Unit B1, Teamwork Research, 2016

For unit B, 25 students were engaged in teamwork for the second assessment item. The first assessment was an individual assessment item and students chose two readings from the set readings in the Resource section of the unit, critically reviewed them, and submitted a written report summarizing their understandings. In assessment two, Teamwork Research, students were required to: (1) form a team with up to four other students; (2) select a building type i.e. residential spaces, healthcare facilities, and educational facilities; and (3) study different spatial issues and factors related to human-environment interactions in the building type that they selected.

2.3 Unit C1, Teamwork Research, 2017

For unit C1, 15 students were engaged in teamwork for the first assessment item, Teamwork Research. The purpose of this assessment item was to give students the opportunity to explore and report on barriers to BIM adoption in Architecture, Engineering, and Construction (AEC) industries. Students were required to: (1) form a team with up to four students; (2) search relevant academic journal papers to identify 10 barriers to Building Information Modelling (BIM) adoption in AEC industries and explain why and/or how each barrier influences BIM adoption; and (3) determine three barriers to BIM adaptation in AEC industry which they argue are the most important ones from the 10 barriers and explain their reasons.
2.4 Unit B2, Teamwork Research, 2017
For unit B2, a number of changes were made to the previous year’s offering of the unit, Unit B1. A total number of 9 students were engaged in teamwork for the second assessment item which had a second part in addition to the teamwork component, ‘an individual portfolio no.2’. The first assessment was modified from a ‘critical reading review’ of two readings to ‘an individual portfolio no.1’ requiring students to (1) review, summarise the key points, and critically analyse research papers and reports through Reading Activities; and (2) complete a set of spatial design Exercises to better understand the practical implications of the set readings for topics 1 to 4 of the unit. The individual portfolio no.2 which was to be submitted alongside the teamwork research focused on topics 5 to 7 of the unit. Due to the number of enrolment that year, two teams were formed for this teamwork research: one team with 4 members and another one with 5 members. The educator also created two Teamwork Forums, one for each team, to communicate throughout the process. The aim was to give the educator an opportunity to monitor team processes and provide assistance for student teams if they needed it.

2.5 Unit C2, Teamwork Research, 2018
For unit C2, in addition to creating Teamwork Forums for teams, the topics of the teamwork research were changed when compared with the previous year’s offering of the unit (Unit C1). 11 students were engaged in teamwork for the first assessment item, Teamwork Research. The purpose of this teamwork research was to explore and report on answers to one of the two topics offered to students: (1) prefabrication in the Australian residential construction sector; and (2) post occupancy evaluation (POE) of buildings. Students were required to: (1) form a team with up to four students; and (2) search relevant academic journal papers to answer the questions of their selected topic.

For the first topic, as the minimum requirement, students needed to examine: (1) benefits and outcomes of prefabricated construction; (2) drawbacks, challenges, and barriers associated with prefabricated construction; and (3) some of the successful (or otherwise) case studies of prefabricated construction in the residential sector. For the second topic, as the minimum requirement, students needed to examine: (1) benefits and outcomes of Post Occupancy Evaluation (POE) or Building Performance Evaluation (BPE); (2) some of the approaches, methods, and tools used to conduct POE or BPE; and (3) some of the case studies of POE or BPE in two building types i.e. residential buildings, office buildings, retail facilities, healthcare facilities, and libraries or other educational buildings.

3 Findings and Discussion
Thematic analysis of 65 students’ reflective statements identified some of the challenges of teamwork in online study mode. The two main challenges of online teamwork remain as; (1) challenges resulted from individual differences in terms of knowledge, skills, backgrounds, preferences, attitudes, expectations, and commitment levels; and (2) difficulty in communication and coordination of tasks exacerbated by geographical distances. Interestingly, except from three students’ references to dissatisfaction or negative experiences with teamwork, all students’ statements explicitly pointed to positive experiences with teamwork in the case study units. In one student’s words,

... we did quite well considering our time restraints and communication barriers and we communicated effectively through e-mail, the forum and on the phone.

References were made to students’ already held negative attitudes to teamwork that appeared to be mainly resulted from previous bad teamwork experiences. As one student pointed, “teamwork exercises are not entirely useful nor successful and serve only to increase work load and stress levels on the participants.” Another student also referred to having “reservations about teamwork projects as communication and information compilation is generally quite a hard task.” However, students appear to be well aware of the benefits of teamwork with 27 references made to this theme. Thematic analysis also determined some of the factors that might have contributed to students’ positive teamwork experiences. Two main determinants of positive teamwork experiences were found to be division and coordination of the teamwork tasks among team members (23 REF) and effective communication (16 REF).

3.1 Students’ views on challenges of teamwork
From a review of students’ statements, three themes were identified as challenges of online teamwork. Table 2 lists these themes and the number of references made to them. In addition to these themes, three students’ statements also pointed to two other challenges they faced: leadership issues or the quest for powers; and workload from the same and other units. One student described the leadership issue as follows:

... the disparate expectations were difficult to work with. For example, one member of the group took the initiative and stated they would do a draft ... however a few days later a nearly completed draft showed up, which was a little confronting as I would have liked to participate more in the overall research.

The conflicting commitments and study workloads were specifically stated by students enrolled in B2 who had to complete another individual portfolio component alongside their teamwork research.

<table>
<thead>
<tr>
<th>Themes</th>
<th>No. of REF</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuals’ different knowledge, skills, backgrounds, preferences, attitudes, commitment levels, and expectations</td>
<td>15</td>
<td>23%</td>
</tr>
<tr>
<td>Difficulty in communication and coordination of tasks</td>
<td>13</td>
<td>20%</td>
</tr>
<tr>
<td>Timing of the assessment item with teamwork component</td>
<td>6</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

3.1.1 Individuals’ different knowledge, skills, backgrounds, preferences, attitudes, commitment levels, and expectations
Individual differences appear to be an important factor contributing to challenges of online teamwork. In one student’s words, “the main challenge in working with another person is wanting to move forward but being unable to, having to be patient and waiting to hear back from some team members.” Some team members like to complete the tasks early while others leave things to the last minute. This prolongs the process of completing the assigned tasks in a team when compared with working individually. Individual differences affecting teamwork processes and products can be in terms of individual team members’ capabilities, knowledge, preferences, expectations, and attitudes that they will bring in with themselves. When working individually, each individual knows his/her own capabilities and if the work is not completed in time or is not up to standard, it is the individual’s personal responsibility. Working with other individuals and not knowing their capabilities can lead to unpredictable outcomes. Team members may however overcome this challenge by being adaptable and...
organised recognising their strengths and weaknesses and providing support to each other.

3.1.2 Difficulty in communication exacerbated by distance (team members being in different location) and time difference

13 students’ statements addressed the difficulty to effectively communicate ideas due to not being able to meet in person with the team members:

The team communicated well through email and the online forum, however what was discussed in about 10-11 emails/forum posts over the course of a week could have been discussed in about five minutes if we had been able to have a face-to-face discussion.

In some instances, the time difference between states made it even more difficult to schedule a team meeting. In one student’s words, teamwork was even more challenging “when attempted via email communications across the country, through different time zones and working commitments of the team members.” The communication barriers and lack of face-to-face meetings appear to have influenced time management and coordination of tasks in some student teams:

... the greatest challenge faced would most certainly be the time management factor. Because of the distance, responding to queries is delayed, sometimes a day or two later forcing any plans to structure the work to be delayed ... The lessons learned from this experience is to develop a strategy immediately and always set time aside to come together and clarify questions.

3.1.3 Specific challenges related to the time of year for the teamwork

Students enrolled in the five case study units also referred to the timing of the assessment item with teamwork components as a challenge they faced. As the assignment period included the Christmas period, It appears that students find it difficult to organise themselves with other priorities taking precedence and resulted in a later start to the assignment than would have been preferred. As one student pointed, There is an inherent difficulty in getting everyone together at what is generally a hectic time of the year when people are focused on Christmas and the holiday season ... it took 3 weeks from the initial group member correspondence via email to our first meeting.

3.2 Students’ views on the benefits of teamwork

Students’ statements about their teamwork experiences highlighted their awareness of the benefits of teamwork regardless of its common challenges with 27 references (41.5% of the total statements) to some of the benefits of teamwork. Students viewed reduced workload and exposure to various points of view and specialities as two main benefits of teamwork. One student stated “the teamwork experience have the benefit of sharing ideas and it breaks the study up from the conventional method of working on assessments individually.” Another student added that working as a team encouraged him “to take initiative in exploring the task and understanding it in order to ensure our communications were concise and fruitful” and “to see how someone else carries out the same task and be able to learn together, drawing on their experience.”

While working individually allows full control over timeframes to complete tasks and freedom over perspective direction, it significantly increases the workload. Having team means the workload is significantly reduced. The unique study habits, presentation ideas, and collaborative mediums brought to the table as ideas by the various members also enhance the work submitted. From the challenging process of teamwork, students are also able to improve teamwork and collaboration skills. Students are able to look at the same question from different angles, to think outside of the box, bounce ideas of one another to provide a more in depth analysis of the topic, and incorporate new technology to enable efficiency. Finally, students’ statements showed they acknowledge the necessity of teamwork assessment tasks to prepare them for the future career within the design and construction industries. As one student wrote,

Teamwork is essential. As humans, we can spend all our time discovering technological improvements but essentially, all businesses are about managing people and teams. Working in a group such as this is therefore definitely beneficial for preparation of the future and working within the industry.

3.3 Factors determining positive teamwork experiences

From students’ reflective statements on their teamwork experiences in the case study units, five main themes were identified as factors that determine positive experiences and satisfaction with teamwork. Table 3 presents these themes and the number of times they were found within students’ statements. One student’s statement highlights these five themes:

... it is my opinion that our team of four members worked very well together. One of our team members set up a group project page in ‘Asana’... I found it terrific in keeping in contact with everybody and sharing information. The team split up all of the topics and contributed evenly... Everybody was keen to share and pool resources and skills with multiple Skype meetings and online Asana conversations.

Table 3. Themes in relation to factors determining positive teamwork experiences in online study mode

<table>
<thead>
<tr>
<th>Themes</th>
<th>No. of REF</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Division and coordination of the tasks among team members</td>
<td>23</td>
<td>35.4%</td>
</tr>
<tr>
<td>Effective Communication</td>
<td>16</td>
<td>24.6%</td>
</tr>
<tr>
<td>Efficient Collaboration</td>
<td>15</td>
<td>23.1%</td>
</tr>
<tr>
<td>Motivation and Engagement of all team members</td>
<td>12</td>
<td>18.5%</td>
</tr>
<tr>
<td>Equal contributions from team members</td>
<td>7</td>
<td>10.8%</td>
</tr>
</tbody>
</table>

Other factors that students referred to as determinants of team success and positive teamwork experiences included: (1) manageable team size (4 REF); (2) leadership and roles clarity for team members (3REF); and (3) team cohesiveness (2 REF). In small teams with two to three members, coordination and division of tasks among members appear to be easier. In one student’s words,

due to the team being comprised of only two members, the clear demarcation of the work required by both members allowed for the ease of the dissemination of the information and the compiling of the presentation materials

In addition, when a team had specified a leader to monitor team progress and hold everyone responsible about handing their assigned tasks, the team experiences appeared to be positive. Finally, team cohesiveness, described as presence of little to no conflict and team members having the same levels of experiences and capabilities, was stated as a success factor in student teamwork.
3.3.1 Division and coordination of the tasks among team members

The mostly referred factor in determining students' positive experience with their teamwork assessment is evenly delegating tasks or dividing the workloads, clearly setting the expectation levels or acceptable quality of task submissions, and completing them by the deadlines set by the team. As one student pointed out, "with any collaborative work, assigning specific tasks to each individual team member at an early stage is an important key to success." Similarly, another student added:

What mainly determined the success of the team was that all team members had clear ideas about the tasks assigned to them; there was no confusion as to who was undertaking which task and when tasks are to be completed.

3.3.2 Effective Communication

The second mostly referred factor that determines positive teamwork experiences was effective communication. Under this theme, references were made to team members being "easy to communicate" or having "excellent communication" which ensured the smooth running of the assessment tasks or team members being able "to listen to each other’s views and opinions" or keeping "a clear line of communication" all the times. In one student’s words, “communication was the key in completing group tasks and throughout this assessment, each person had a high level of communication which made the task easier to complete.” Another student pointed to the use of "Asana"1 for team members to keep in contact with each other and share information, in addition to making use of Zoom meeting rooms2, exchanging emails, and using the teamwork forum set up by the educator. Finally, one student suggested, "the use of the Zoom meeting room certainly helped us as it allowed us to collectively discuss the project in real time.”

3.3.3 Efficient Collaboration

Efficient collaboration among team members was the third theme that emerged from students’ statements. Students referred to the ways that they used technology to share information and collaborate on tasks. As one student stated, We used a ‘google drive’ to transfer group contributions allowing all team members access at any time to current documents ... this method of collective storage is another element of success ... especially with distance involved ...

3.3.4 Motivation and Engagement of all team members

Students referred to motivation and engagement of all team members as another factor that resulted in satisfaction with teamwork processes. When team members were keen to contribute their fair and equal share to teamwork tasks, were all cooperative and made themselves available for team meetings, and had the hard working attitude, teamwork ended up to be a rewarding experience. In one student’s words, ... it was beneficial, as [name hidden] is a knowledgeable and enthusiastic student who is determined to do his best. This is helpful as there are things that I can learn from him, but also his enthusiasm tends to ‘rub off’ on to me as well.

3.3.5 Equal contributions from team members

Equal contribution from all team members was another theme that emerged from students’ statements. In one student’s words, “division of the labour for the group work was achieved without dissent and everyone involved did their fair share of the labour.”

4 Conclusion and Further Research

So what did we learn from the review of students’ reflective statements and what would be the implications of these findings for teaching practices? Three key lessons learned from this thematic analysis of students’ statement are as follows:

4.1 Pay close attention to the design of the assessment item

For Unit A, the assessment description only asked students to review the assigned brief, design, and drawing based on the relevant issues addressed in the study guide and throughout the unit tutorials including responses to BCA and relevant national and local authorities’ requirements and guides. It was not clearly specified that addressing which aspects or dimensions are the minimal requirement of the assessment submission. Students pointed to the difficulty in dividing the tasks and assigning them among team members. A clearer assessment description which explicitly lists the assessment tasks or minimal requirements of the submission may assist students in the teamwork processes, if the team members decide to divide the tasks. In developing this list, educators may need to consider the team size and how the team may divide the tasks among themselves. It should be noted that in some teams, students may decide to adopt a different approach than dividing the tasks: each team member may review and complete the assessment tasks and then the team may come together to discuss each members’ contributions.

4.2 Examine alternative modes of communication and collaboration

Educators should encourage students to make use of alternative modes of communication and collaboration that may be more effective for online study mode. It is important to encourage students to make use of technology to assist them in collaborating online e.g. use of shared drive or a Google drive.

4.3 Adopt a teacher-assigned team formation strategy

In all the five units, students were given the freedom to choose their teammates. The only restriction in place had to do with the number of students in a team. A Group Choice module was created in the Moodle page of the unit and students would access that to pick their teams (e.g. Team A, Team B, and etc.). In these case studies, two problems occurred. As there was no due date set up to join a team, it took almost a few weeks and in some cases, two weeks before the assessment due date, for certain students to join a team. This created a degree of concern for a team whose members had already started collaborating and would suddenly be faced with a newly joined member. In two occasions in two different units, one student was left with no team due to the issue with a mismatch between the total number of teams, the total number of students, and the size limit. In online delivery mode, it is then strongly recommended that educators set up teams using a number of predetermined criteria.

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1 Asana is a web and mobile application designed to help teams organize, track, and manage their work: https://en.wikipedia.org/wiki/Asana_(software)
2 Zoom meeting rooms are platforms which include video conferencing, content sharing, and integrated audio: https://en.wikipedia.org/wiki/Zoom_Video_Communications.
5 References


Jaques, D. and Salmon, G. (2007), Learning in groups: A handbook for face to face and online environments, Routledge, Abingdon.


Abstract:

More educators are using gamification to enhance learning due to the many benefits such as improved learning, engagement, problem solving, and social interaction skills. However, gamification within project management education is not well understood. The aim of this study is to determine the extent of gamification in PMI-accredited university project management (PM) programs and whether it provides an educational environment to better prepare graduates for future challenges in practice. 10 PMI-accredited university programs participated in this exploratory study. A two-step data collection method was used where participants completed a short 8 question survey followed by a qualitative interview. Approximately 20% of PM programs sampled used some form of gamification. Surveys collected from program leaders suggest that gamification can improve student motivation, engagement and confidence when exploring complex project management problems. A summary of best practices for project management students and educators follows a review of the results and implications for educators when applying gamification. The implications are divided into learning and teaching categories.

Keywords:

Gamification, Multiple Lives, Simulation

1 Introduction

Nearly a quarter of today’s global economic activity takes place through projects, and project-based organizations (Bredillet, et al. 2013). The importance of project management is also reflected by an expected creation of 15.7 million additional project management jobs between 2010 and 2020 (PMI, 2013). The educational landscape has risen to meet the demand for project competence with a growth of programs (Alam et al., 2008).

Educators might add gamification to their courses. Surprisingly, this term is relatively rare in project management research even though a considerable literature has grown up around gamification for educational purposes (Mekler et al. 2015). Simply, gamification mimics game playing as a strategy for learning; elements of games are applied to non-game activities. For example, simulations, games, and role playing are examples of gamification. Given the belief that employing gamification can contribute to improve project management education, this study aims to determine the nature and extent of gamification applied in PMI-accredited university project management programs.
2 Literature Review

In their critique of project management education, Winter et al., (2006) suggest that educators can do more to prepare students. Córdoba & Piki (2012) suggested a group-based approach with real-life components to motivate and engage students. Ojiako et al., (2011) used project-base modules to foster critical thinking and problem-solving. Similarly, Ramazani & Jergeas (2015) call for an educational environment where students are exposed to project (problem-based) situations. One such teaching method that can approximate these workplace challenges is gamification (Hung, 2017).

Our literature review identified only one paper that connected project management education or training with gamification. Here, gamification was used during a two-day course for project managers. It concentrated mainly on training evaluation, indicating positive results and an increased understanding of the impaired content (Briers, 2013). Some discussed simulations, blended learning and other project management education techniques, however, they did not connect it directly with gamification (Geithner & Menzel, 2016). Gamification in project management is a relatively novel teaching modality.

Outside project management education, several researchers reported positive results such as increased student engagement when gamification is used. Lee & Hammer (2011) traced this effect back to the gamification design principle of the ‘freedom to fail’. Camilleri et al., (2011) increased student engagement using leaderboards and competition. O’Donovan et al., (2013) gamified a computer game development course and observed higher student engagement, increased attendance, and higher academic performance. Likewise, Charles et al., (2011) report increased learning, lower failure rates, while Dominguez et al., (2013) claimed that gamification helped to develop practical competencies. These researchers claim gamification has a positive impact in an educational environment. Despite the optimism, some authors note that empirical evidence for gamification benefits is still limited, and further research is needed (Dicheva et al., 2015; Mekler et al., 2015).

Conversely, some have criticized gamification approaches that focus on badges, levels or leaderboards (Bogost, 2011a, Kapp, 2012b). Robertson (2010) stated that an approach like this means ‘taking the thing that is least essential to games and representing it as the core of the experience’. In her point of view, such approaches would be better described as ‘poinification’ and distract from the main purposes of gamification. Some authors have argued that gamification brings only short-term benefits (Hamari et al., 2014; Koivisto & Hamari, 2014). Initially, gamification generates excitement; however, after some time students may get used to gamification and their interest may decrease. Other authors report adverse effects from social comparison and competition (Christy & Fox, 2014).

A further challenge is reported by Dominguez et al., (2013) who experienced difficulties when evaluating student performance in their gamified course due to the need to provide rapid feedback to students. Nevertheless, our literature review unveiled numerous papers and studies that report benefits from gamification. The challenge for instructors remains to identify which principles and mechanisms will work best in their specific context. One of the biggest challenges for the future research of gamification, is designing empirical studies to gain valid and reliable results remains (Hamari et al., 2014; Seaborn & Fels, 2015). However, what we know about gamification in project management training and education is limited. Therefore, the focus of this exploratory study is to better understand the nature and extent of gamification in project management education and training.

3 Method

A mixed method approach was taken to investigate gamification in project management education and training to increase the reliability and validity (Voss, Tsukritsis, & Frohlich, 2002). 56 universities offering project management programs endorsed by the Project Management Institute (PMI) via their Global Accreditation Centre were invited to participate in this research with 10 returning responses (Table 1).

Table 1: Utilization of Gamification

<table>
<thead>
<tr>
<th>Method</th>
<th>North America</th>
<th>Latin America</th>
<th>Asia 1</th>
<th>Asia 2</th>
<th>North America 1</th>
<th>North America 2</th>
<th>North America 3</th>
<th>North America 4</th>
<th>North America 5</th>
<th>Australia 1</th>
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<th>Australia 3</th>
<th>Australia 4</th>
<th>Australia 5</th>
<th>North 1</th>
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</thead>
<tbody>
<tr>
<td>Project Mode</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Source of Gamification</td>
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<td>Y</td>
<td>Y</td>
<td>N</td>
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<td>Y</td>
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<td>Y</td>
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<tr>
<td>Basic - PC</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
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<tr>
<td>Basic - Non-PC</td>
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<td>Multiple Lives</td>
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<tr>
<td>Digital Badges</td>
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</table>

In the first step, participants completed an eight-question survey designed to evaluate their attitude towards gamification in project management programs (Table 2).

Table 2: Survey Questions

1. Are you aware of the concept of gamification?
2. Do you use elements of gamification in your program? If yes, please describe which elements and how they are used. If not, please continue with Question 6.
3. If you are using elements of gamification, when did you start with their implementation?
4. What do you try to achieve with the use of gamification?
5. What experiences did you make with it?
6. Do you plan to make use of the concept of gamification in the future?
7. If not, why do you think using elements of gamification will not be useful in your program?
8. Would you be willing to participate in a subsequent semi-structured interview? If yes, how should we contact you?

In a second step, interviewing was used to gain further insights after the survey results had been analyzed. Interviews took place in the form of semi-structured conversations to better understand the mances of their quantitative survey answers. Thus, a short quantitative survey was used to get a high-level understanding of the nature and extent of gamification in project management training and education followed by semi-structured interviews.

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4 Results

Ten institutions participated in the study (see Table 1). Since the data had to be made anonymous (for ethical reasons), each university is only represented with its geographical region. The column program mode explains whether the academic program is offered on-campus (C), in hybrid mode (H), or 100% online (O).

Only one participant answered that he is not aware of the concept of gamification. Even though, all other participants responded that they are familiar with gamification, each had a slightly different, definition of gamification. Participants responded that they learned about gamification while reading journal articles, attending presentations and by searching the internet. Five participants use gamification in their programs (3x America, 1x Australia, 1x Latin America). The other half responded that their institutions do not use gamification in their project management programs. Our research participants reported that their barriers to using gamification include a lack of knowledge and anecdotal experiences from instructors who were not as successful with gamification as planned. The following sections describe how our research participants use gamification in project management education and training: i) digital badges, ii) simulation, and iii) multiple lives.

4.1 Digital Badges

Two universities reported using digital badges to gamify their project management programs. One university grants performance badges within a single course, whereas the second university grants badges over the whole degree for each PMBOK® Guide (PMI, 2013) knowledge areas. A second finding is that some instructors award badges immediately after the student performed the assignment task, while others were awarded upon graduation. Both instructors try to achieve similar goals with digital badges: motivate the students to participate and to achieve good results. The university granting the badges at the end of the degree also have two additional motivations in using the badges. First, some badges can only be earned when the student attends additional pop-up classes. However, one of the participants indicated that underperforming students lose interest in badges very quickly.

4.2 Simulations

Simulations can be classified into two broad categories: computer-based simulations and non-computer-based simulations (e.g. role playing). Computer-based simulations can be further subdivided into simulations that are commercial off-the-shelf simulations and custom simulations usually developed in house by the instructor.

4.3 Computer-based Simulations

Four research participants reported they used computer-based simulations. Two commercial project management simulations were developed. SimulTrain and Sim4Projects. Furthermore, one participant used web-based project management tools to collaboration online. Only one university developed a custom-made simulation called Risky Business. In Risky Business students proceed through a series of decision making scenario’s. SimulTrain and Sim4Projects both simulate midsize projects. Students have to plan the projects by acquiring resources and assigning project team members to project activities. These simulations expose students to events that could arise in real projects. Students have limited time to make decisions that creates an environment of emotion and stress typically found in real projects. It takes up to seven hours to complete SimulTrain, whereas Risky Business can be completed within one hour.

In most simulations, project performance is tracked against typical performance indicators such as cost, time, and quality. Both Risky Business and SimulTrain offer learning reports at the end of the simulation to provide feedback to students. The universities using Sim4Projects as well as web-based tools incorporate debriefing and reflections in the form of class discussions, presentations and reports after the simulations are completed. SimulTrain is used in a voluntary pop-up class, which is not part of the university’s curriculum, so performance is not formally assessed.

In other simulations, lecturers grant a grade based on individual or group reflection. Students may be asked to prepare an interim management report summarizing project progress as well as their plans for project completion. The lecturer plays the project sponsor and leads a debriefing on what the students did well and what they might do differently. At the end of the simulation, students give another presentation: the final status report, a project audit report, and their reflections on the learning experience. Finally, in the case of Risky Business, the overall score of the student is translated directly into a grade which accounts for ten percent of the Risk Management subject.

The participants who experienced the simulations reported very positive student feedback. The research participants reported that students enjoyed the simulations and felt highly involved. The participants believed that the simulations increased students’ project management knowledge and confidence they could apply this knowledge in practice. Students told their instructors that the simulations were an excellent way to experience many of the components of project management in a real-world scenario. Only a few students critiqued that the simulation took too long and there was pressure to make decisions.

4.4. Non-Computer-based Simulations

Two research participants used role playing to simulate project experiences in their courses. One participant reported that students have been very positive to role playing even though it provides challenges and uncertainties. At another university, the concept of role play is used to simulate a negotiation. Students work in groups of four and prepare a negotiation scenario with opposite positions including information not available to the opposite party. After some preparation, the two groups negotiate with each other in the front of the whole class and ends after ten minutes. The lecturer provides feedback about what was done well and about possible improvements.

4.5 Multiple Lives

One participant allows his students to resubmit assignments after receiving feedback. The participant described this opportunity like having multiple lives in a computer game where the player can retry a level if he failed to pass it. It has been his experience that most students take the opportunity to resubmit an assignment after they have received feedback.

5 Discussion

The literature review and data collected in this study show that gamification has not been widely used in project management education and training.
5.1 Digital Badges

Digital badges are frequently used in the gamification of classrooms (Hanus & Fox, 2015). In this study, some used badges to encourage performance at the task level while others at the course level. Others used digital badges to reward attendance rather than performance. Given the research results of Abramovich, Schunn, & Higashi (2013), it might be questionable if the badges lead to an increase in student motivation and subsequent performance. Nevertheless, one participant reported that the badges led to a greater participation rate in optional pop-up classes. The increased participation rate confirms the results of Barata, Gama, Jorge, & Gonçalves (2013), who also achieved increased attendance and participation through gamification.

5.2 Simulations

The most significant difference reported in the simulations is in the level of importance given to debriefing sessions. One university emphasizes debriefing and students must present their insights and lessons learned from their simulation experience. In contrast, other research participants did not use debriefing sessions. Millis & Hertel (2002) state that reflection enables students to integrate experience into their lives as a foundation for future learning, thus increasing the likelihood of knowledge and skill transfer in a professional setting. Therefore, simulation debriefing appears sensible since students may not have incorporated all the learnings from the simulation.

Some participants also required their students to submit a written reflection of their experience or to give a presentation. A reflection helps students to organize and share their thoughts and emotions that they might not want to share in a large group discussion (Millis & Hertel, 2002). These personal reflections are supported by the developer of SimulTrain, who recommends that students should prepare a report and present them to the class (STS Sauter Training & Simulation SA, 2017).

One simulation challenge lecturers face is evaluating student performance. The following assessments have been described by the research participants: (1) no specific assessment, (2) assessment simulation scores, and (3) assessment based on debriefing session and reflection.

All participants described students’ simulation experiences as positive. Students have been engaged, worked together in teams and learned to reflect on their learning experience. Furthermore, students mentioned they liked to be challenged with real-life project scenarios of uncertainty. Participants also mentioned their students felt more confident applying what they learnt. These findings align with Pagano & Blu's (2014) study where students felt more confident about what they learnt through simulations. What became apparent is that students faced real challenges in a safe environment where they could test their project decisions without harmful repercussions.

5.3 Multiple Lives

The idea of having lives and allowing students to redo an assignment or task is based on the gamification design principle of freedom to fail (Dicheva et al., 2015). The concept is like continuous improvement and may contribute to improved learning. However, there is no agreement that repeating an assignment is a good thing (Kapp, 2014) while other have suggested freedom to fail encourages exploration (Oxford Analytica Ltd, 2016).

6 Conclusion

Within this study ten institutions in the United States, Australia, Latin America, and Asia shared their gamification insights in project management training and education. As the study unveiled, there is potential for a broader application of gamification in project management as only half of the participating institutions claimed to use gamification. Simulations were the most employed tool, and various approaches by universities to use them were discussed. Gamification was also used with digital badges and multiple lives. All participants reported mostly positive effects from using gamification in their classrooms. Benefits that have been realized comprise an increased participation rate, higher student engagement, as well as experiencing the project context and complexity, resulting in more confidence in applying project management knowledge, tools and processes in a real-world scenario.

Gamification can contribute to meet the actual demands of industry in project management education. One benefit it can deliver is the possibility for students to experience real-world scenarios in simulations (computer based and non-computer based). If those simulations are employed together with the educational gamification design principle of freedom to fail and sufficient possibilities to debrief and reflect on the learning experience they can provide, then valuable insights may prevent students making expensive mistakes in their future roles as project participants. Furthermore, gamification can help students to understand the project context. Students who participated in a gamified course and experienced project context and complexity already during their studies may have an advantage compared to students who have been taught project management exclusively through lectures. Courses and programs that employ the concept of gamification provide students with teamwork knowledge and experience. The implementation of the design principles of the freedom to fail and rapid feedback may help students to increase their capabilities respecting critical reflection and continuous change. Perhaps an added benefit to educators is that gamification has the promise to bring lifelong lessons into the classroom that are recognized by the smiles that accompany the intense gamification experience.

6.1 Limitations

As with most project management research, this research has limitations. The results of the study generally support earlier gamification research findings albeit in areas other than project management. The sample was also limited to include only those institutions accredited with PMI; therefore, there are institutions not affiliated with PMI that were not contact that may be using gamification in novel ways and would have like to participate in this research.

6.2 Further Research

This exploratory study suggests that gamification in project management education and training is in its infancy and is ripe for research. First, it would be insightful if this study could be repeated but with a larger sample size to confirm the results and perhaps to uncover new data about gamification in project management training and education. Additional qualitative interviewing may uncover further insights and extending the research focus with a Delphi study might help to generate a consensus of the type of gamification most beneficial in project management training and education. Additional research could be directed at the barriers of introducing gamification into project management education and training. More research could be completed from a student’s perspective of gamification; for example, are certain learning styles better suited for
gamification? Researchers might look at whether some gamification techniques are better suited for education rather than for training purposes (and visa versa). Finally, once gamification is more widely used in project management education and training, research can be directed towards understanding the efficacy of gamification.

6.3 Implications

There are implications that can be separated into teaching and learning. An early choice for the educator is to develop the appropriate gamification for the class size and learning objectives. Role playing might not be appropriate for large classes, but online, individual experiences with gamification will be more appropriate. For the teacher, developing a gamification lesson or course may likely take longer than a traditional PowerPoint lecture. However, successful gamification can provide lifelong lessons and increase engagement. Teachers need to allocate sufficient time to prepare gamification lessons. Additionally, greater teacher satisfaction might be achieved if administrators acknowledged the effort and innovation required to provide gamification in lessons. As noted in the literature and in our results, educators should be wary about how points are awarded so that the focus is on achieving learning outcomes rather than on pointification.

Educators should add a debrief opportunity to gamification. Longer experiences may have a mid-point debrief while shorter gamification experiences might only have a debrief at the end of the game. The key is to debrief and do it soon after the gamification experience ends to be explicit about learning outcomes. And where appropriate, link gamification learnings with the needs and expectations of business. There might be an additional step where the students update their CVs with these new skills and knowledge. Not all students learn the same way which is why student-centred learning has been an important construct in education. Therefore, there may be some students who do not like simulations, some who do not like team work, some who prefer lectures, some who like team work, etc. The point is one may have students who do not perform well in simulations. Therefore, multiple learning modalities should be used throughout the course. Finally, one of the benefits of submitting multiple drafts of an assignment (Multiple Lives) is that this process can be extended to business: i) include others when you develop project management assets; ii) include a feedback loop to improve the project asset; and, iii) feedback is a good thing!

7 References


Measuring project success: conceptualizing a new approach applicable to all project types

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Abstract:
There is much confusion about what constitutes a successful project, since often the criteria applied are not made clear at the outset and the boundaries for what is to be included in the evaluation become blurred. To overcome this problem, a new approach (called \textit{i3d3}) is conceptualized for measuring project success based on the objectives of multiple stakeholder groups, and conducted at multiple assessment points in time. It also enables a method for comparing success between projects regardless of type, size or location so that differential performance outcomes across a portfolio of projects become manifest. It is concluded that there are generic criteria applicable to any project type, although the detail of the evaluation may require specific customization to capture the pertinent characteristics involved. A single score can be computed to identify success and to rank projects on a common scale. This paper sets out the framework for achieving such an outcome and establishes the foundation for future tool development and testing.

Keywords:
purpose success factors, benefit realization, collective utility, stakeholder satisfaction, multiple criteria decision-making

1 Introduction

Measuring the success of completed projects has always been a perplexing challenge. The traditional view of project success is associated with time, cost and quality objectives (Carvalho et al., 2015). This view comes from Martin Barnes’s ‘iron triangle’ consisting of the core project constraints that he introduced in 1969, in which a project is considered successful when the actual cost and time are very close to the initial planned budget and schedule, and all deliverables meet the requirements agreed by all stakeholders involved in the project (Langston, 2013; Berssanetti and Carvalho, 2015). However, due to changes in the global business environment and market demand, these criteria are seen by some as too simple to deal with the requirements of project stakeholders (Toor and Ogunlana, 2009; Alzahrani and Emsley, 2013).

Is it possible to compare the success of a doghouse and an opera house, or a new aircraft with a refurbished apartment building, or a telecommunications tower with relocating an organization to bigger premises across town? All of these things are projects and all of them have the objective of being successful interventions that realize benefits to stakeholders within society. These benefits are not necessarily financial, but may provide social, political or environmental advantage. How do we know what represents the best use of our time and resources in terms of creating collective utility to those affected by our actions?
The aim in this paper is to propose a framework for measuring project success that is agnostic to type, size or location. So theoretically we should be able to compare a doghouse with an opera house, for example, even though the former is small, inexpensive and could be finished over a weekend, while the latter is large, expensive and may take a decade to complete. The collective utility of the doghouse might lie with its owner (the dog), while the collective utility of the opera house might give pleasure to a large cross-section of the community.

Recent research by Albert et al. (2017) provides a good starting point. They undertook a structured literature review on the topic of the evaluation of project success. They examined similarities in the assessment of project success in different fields of application, and claimed this was the first review of its kind despite project success being a widely scrutinized topic in project management research. Based on six different fields of application, they extracted characteristic project success criteria. They based their work on the assumption that project success includes project management success, product success and performance over time. What they discovered was a world of inconsistency. Their key conclusion was that “a generic model to describe project success should be developed to provide a common guideline for assessing” (Albert et al., 2017:18).

2 Literature Review

Numerous researchers have proposed diverse types of models to develop a more robust approach to understand project success and what criteria are reliable enough to be used during the deliberations. Some of these studies have been conducted based on the perceptions of different stakeholders involved in the project such as clients, project managers, investors, project team, community and so forth. For some researchers, success is a subjective phenomenon, and is dependent on the perspective of those who are measuring it, because intangible criteria mean different things to different people.

Müller and Turner (2007) found that project managers themselves are possibly the most project success. They stated that project performance is a subjective phenomenon, and is dependent on the perspective of those who are measuring it, because intangible criteria mean different things to different people.

Müller and Turner (2007) found that project managers themselves are possibly the most influential variable for project success realization. Each industry or organisation, project manager or team, potentially can form their own definition of success (Chan and Chan, 2004; Jia and Iyer, 2006; Berssaneti and Carvalho, 2015).

For instance, Frödell et al. (2008) investigated project success from the construction client’s perspective, and their findings showed that factors such as user’s participation, commitment to the project, high standard of quality consideration among the construction workforce and team working are of significance in achieving success. Savolainen et al. (2012) considered project success and failure from the supplier’s perspective. They found that the criteria for software development success from the supplier perspective can be summarized as: (1) customer satisfaction, (2) short-term business success for the supplier, and (3) long-term business success for the supplier. Yamin and Sim (2016) examined the success of international development projects from the local project team’s perspective and found that monitoring, coordination, design, training and institutional environment have a significant relationship with project success. Davis (2017) proposed a new multiple stakeholder model that takes into account all stakeholders’ opinions in judging project success and recognising its principal dimensions.

Radučkovíc and Sjekavica (2017) argued that project success differs from project management success. Their study gave definitions of project management success and reviewed different models of quantification. Although success criteria may vary from one project to another, Langston (2013) introduced a model using six generic key performance indicators (KPIs) that can be measured objectively as ratios of the core constraints that he described as scope, cost, time and risk to enable comparison of projects in terms of delivery success regardless of type, industry, size or time. Carvalho and Rabechini (2017) proposed a project sustainability management research model and verified its positive impact on project success dimensions, although the magnitude of this effect was shown to be moderate. Berssaneti and Carvalho (2015) defined the key variables that impact project success. In their research, time, cost and technical performance are deemed as the core dimensions of project success and they found that project management maturity is significantly related to these factors. Cheng et al. (2010) proposed a more scientific approach based on artificial intelligence to evaluate project success by employing a fast, messy genetic algorithm, a support vector machine and K-means clustering.

In a construction context, extensive studies have emphasised the importance of identifying critical success factors (CSFs) for measuring success (Cook-Davies, 2002; Fortune and White, 2006; Alias et al., 2014). Alzahrani and Emsley (2013) studied project success by focusing on the effect of contractor’s attributes from a post-construction evaluation perspective. They identified a number of CSFs such as turnover history, quality policy, adequacy of labour and plant resources, waste disposal, size of past projects completed and company image as the most significant factors affecting project success. Yong and Mustaffa (2012) recognized the significance of human-related factors such as competence, commitment, communication and cooperation towards the success of a construction project. Toor and Odet (2009) stated that factors related to project planning and control, project personnel and client involvement were critical for the success of large-scale construction projects from the construction professional’s perspective. Most of these studies have adopted research approaches that first extracted sets of success factors based on reviews of relevant literature and project characteristics, and then validated them quantitatively or qualitatively through questionnaire surveys (Yu and Kwon, 2011). However, a crucial limitation is that it is difficult to prioritize, categorize and reduce the factors to a more manageable number. Hence, a compelling model encompassing all CSFs has yet to be developed (Mir and Pinnington 2014; Stefanovic, 2008) and indeed may be impossible.

Project success is intricately interwoven with project performance, and a countless number of studies have used KPIs to measure this factor to evaluate project success. Chan and Chan (2004) developed a set of KPIs comprising time, cost, quality, functionality, user expectations and satisfaction, measured both quantitatively and qualitatively, by undertaking a comprehensive review of the literature, and then verified the practicality and usefulness of these KPIs using case studies. Ofori-Kuragah et al. (2016) offered nine KPIs for Ghanaian contractors to measure project performance towards success. These KPIs in order of relevance were quality, client satisfaction, cost, time, business performance, health and safety, environment, productivity and reputation. For Mphahlele (2015), overall stakeholder satisfaction, cost, time and quality turned out to be important KPIs for measuring project performance on innovative building technology projects. Mir and Pinnington (2014) recommended that project management itself was the most significant individual variable contributing towards the success of any project. They concluded that performance measurement is essential for organisations to enhance project success. Achieving project success goes beyond delivering the project to the satisfaction of the client (Williams et al., 2015). This implies that a successful project has to be acceptable to a wide range of stakeholders, including the owners or sponsors, regulatory...
authorities, project developers and end-users. As such, project success involves the integration of stakeholder needs from the beginning to the end of the project (Heravi et al., 2015). According to Davis (2014; 2017), different stakeholders have different perceptions and factors of project success. The result of her research indicated that “all stakeholders do not value all dimensions of equal importance to achieve project success and therefore, relevant dimensions varied between stakeholder groups with different perspectives in the literature” (Davis, 2017:615). The requirements for each stakeholder group needs to gathered together and put into consideration in ensuring that the right project is done right to deliver its stated objectives (Kerzner, 2017).

Time is a significant criterion when gathering information and when making informed opinions about any project. Turner and Zolin (2012) developed a model of predicting performance indicators for managers to study the perception of success by stakeholders. They showed that the perception of success does change over time. From this they concluded that to gain an understanding of how to achieve a successful project, one must integrate the opinions of various stakeholder groups over multiple time frames.

3 Proposed Conceptual Framework

The literature demonstrates there is much controversy about what makes a successful project and who should be the judge. Do all projects share potentially common criteria, or is every project different? When should the success of a project be determined and is it even measurable at all? What are the critical success factors that lead to favourable outcomes?

To explore these questions, it is first necessary to consider a project to be broader than the typical definition used by project managers who view the end of a project as being when it enters its operational (post-delivery) phase. Otherwise, project success is framed by the design and delivery processes that were involved in its creation, and fails to consider the impact of the project once it is handed over to the project sponsor or client. Impact is not just financial return, but should include social, political and environmental consequences as well. At any rate, clearly time is critical to gather information and make informed opinions about project impacts.

The key to success is measuring benefit realization. Benefits are both tangible and intangible, and in the latter case, they can be resistant to objective measurement. They must also be viewed as societal, which means that although some stakeholders may win and others lose, successful projects provide positive collective utility to society. This cannot be determined at the point a project is available for its intended use. A period of evaluation time is necessary during the post-delivery phase. For example, in the case of built assets, this is commonly referred to as post-occupancy evaluation.

Time, therefore, plays a fundamental role in measuring project success. There are three generic phases that underpin the life of all projects: pre-delivery, delivery, and post-delivery. Although there is a range of labels used in different contexts, they share a common sequence of (1) develop/plan, (2) execute/control and (3) operate/utilize. End of life is part of post-delivery. We don’t need to wait until then before we can finalize our judgment about a project’s success, because if we did, then the verdict will have little interest to any of its former stakeholders.

During each phase, different sets of stakeholders have higher power and interest towards evaluation of project success. Different criteria apply too. For a project to be successful, it must do so across all three phases. Often design-related criteria (such as functionality, beauty, etc.) are mixed with delivery-related criteria (such as on time, within budget, etc.), making it difficult to know whether the designer did a good job or the project manager did a good job. Even where success in both these areas is clear, what do the project recipients (such as end-users or customers) think? Any measure of success must surely take account of how successful projects are at realizing their initial vision for the target audience.

All of these ideas and considerations have led to a proposed new framework for measuring project success. Its key characteristics are that it has three time phases, different sets of primary stakeholders (who perform the evaluation of success), different criteria per phase that ideally should be generic across all project types, different methods of evaluation per phase, and an overarching focus on measuring benefit realization that leads to positive collective utility. The proposed framework, known as I3D3, is shown in Figure 1. Its title references the three generic phases (renamed as initiate, implement and influence) and the three generic objectives of these phases (design, deliver and delight). It should be noted that stakeholder communication across each phase is critical to ensure that common purpose and vision is maintained. Project success is simply characterized, with the wisdom of hindsight, as ‘doing the right project right’.

Each phase of the proposed framework will now be explored in further detail.

3.1 Project Initiate

The key stakeholders in this phase are owner/sponsor and shareholders. Their focus concerns creating a design that will maximise the potential benefits. Success factors can be viewed as a quadruple-bottom-line evaluation to determine if the project is feasible, useable, achievable and sustainable (in that order). The objective here is to do the right project. A balanced scorecard approach can be used to evaluate success on a fixed scale (-100 to +100).

A successful project should be feasible. Its intended cash flow should be positive (benefit-cost ratio should be greater than 1). It may involve a trade-off between short-term expenditure and long-term income, and therefore needs to forecast future economic conditions that the project must negotiate. Even projects that do not seek to make a

Figure 1. Proposed I3D3 Framework

<table>
<thead>
<tr>
<th>Project Initiate</th>
<th>Project Implement</th>
<th>Project Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>(benefit/plan phase)</td>
<td>(execute/control phase)</td>
<td>(post-delivery phase)</td>
</tr>
<tr>
<td>owner/sponsor</td>
<td>regulatory authorities</td>
<td>client/end-user</td>
</tr>
<tr>
<td>initiate</td>
<td>implement</td>
<td>influence</td>
</tr>
<tr>
<td>design</td>
<td>deliver</td>
<td>delight</td>
</tr>
<tr>
<td>realize</td>
<td>make</td>
<td>satisfaction surveys</td>
</tr>
<tr>
<td>project</td>
<td>project</td>
<td>post-delivery</td>
</tr>
<tr>
<td>success</td>
<td>success</td>
<td>success</td>
</tr>
<tr>
<td>do the right</td>
<td>do the project</td>
<td>do the right project</td>
</tr>
<tr>
<td>project</td>
<td>right</td>
<td>right</td>
</tr>
<tr>
<td>benefit</td>
<td>realization</td>
<td>collective utility</td>
</tr>
</tbody>
</table>

planned virtual reality satisfaction surveys

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financial return usually need to consider financing sources or sponsorship to get them off the ground.

Feasibility is important, but only if projects are useable. Design solutions should add value, such as improving our standard of living or making people safer or more productive. Projects should have purpose. While not all projects can contribute high-level social outcomes, they must at least demonstrate local community support. Successful design is not a top-down process, but must engage and consult with the people it is designed to serve.

Making a valid contribution to society is noble, but it must also be achievable. This is a political imperative and is often a mix of risk (negative consequences) and reward (positive consequences). A risk management approach is well suited to dealing with the uncertainty of future actions, and is typically a function of probability of occurrence and the impact of any consequences should they eventuate. The risk attitude of the key stakeholders will always be a consideration.

Once the project’s risk and reward profile has been accepted, it then needs to be determined if the impact of the project on its surroundings is sustainable. Few projects are truly sustainable within a broad system boundary. However, once again a trade-off is needed, in this case between progress and conservation. If the ecological footprint of the project is within acceptable limits, then the design process is complete and detailed documentation of the project can be finalized.

Figure 2 highlights there is a sequence during the design process to ensure overall success can be achieved without exploring solutions that ultimately do not meet stakeholders expectations. Each success factor is treated like a compliance ‘gate’ before success can be achieved without exploring solutions that ultimately do not meet requirements.

The key stakeholders in this phase are project team and regulatory authorities. They form an important communication bridge between ‘owners’ and ‘users’. Their focus concerns the best method to deliver the project. Success factors can be viewed as an assessment of being within budget, on schedule, as specified and with no surprises using six KPIs as defined by Langston (2013). The objective is to do the project right. A comparison of planned versus actual performance can evaluate success on a fixed scale (-100 to +100).

The six KPIs embedded in Langston’s 3D Integration Model, applicable to the assessment of any project regardless of type, size or location, comprise:

1. Value. This is defined as the ratio of scope over cost, assessed in the context of stakeholder management. It should be maximized.
2. Efficiency. This is defined as the ratio of cost over time, assessed in the context of resource management. It should be maximized.
3. Speed. This is defined as the ratio of scope over time, assessed in the context of procurement management. It should be maximized.
4. Innovation. This is defined as the ratio of risk over cost, assessed in the context of communications management. It should be maximized.
5. Complication. This is defined as the ratio of risk over time, assessed in the context of quality management. It should be minimized.
6. Impact. This is defined as the ratio of risk over scope, assessed in the context of environmental management. It should be minimized.

It is not possible to optimize all KPIs. The equation for determining the best mix of success factor performance is given by Equation 1 (Langston, 2013). Project delivery success (PDS) is calculated for both planned and actual performance, and the percentage change between them is computed after delivery has been completed. High positive changes between planned and actual PDS are preferred.

\[
PDS = \frac{\text{scope}}{\text{cost} \times \text{time} \times \text{risk}} \quad \text{(Equation 1)}
\]

where:
- scope = a measure of the size or extent of the project
- cost = the cost of implementing the project
- time = the duration (e.g. working days) for implementing the project
- risk = the mean risk level (probability x impact) of all risk events

From a delivery perspective, basically projects that deliver more scope for less cost, time and risk are considered successful. This may occur regardless of the merits of the design itself. The measurement of PDS is based on the PMBOK® Guide (PMI, 2017).

The link between project management knowledge areas and generic KPIs is illustrated in Figure 3. The model underpinning PDS takes the form of a tetrahedron, where the vertices, edges and faces all have meaning (Ghanbaripour et al., 2017).
3.3 Project Influence

The key stakeholders in this phase are client/end-user and local community. Their focus concerns ensuring that the project fully realizes the designed objectives and leads to satisfaction (or delight). Success factors can be viewed as whether the outcome is desirable, adaptable, practicable and serviceable. These qualities are considered to be generic across project types. The objective here is to do the right project right. An opinion-based 5-point Likert survey of stakeholder satisfaction can be used to evaluate success on a fixed scale (-100 to +100).

For each of the four generic success factors, ten customized (context-specific) questions are required to collect satisfaction feedback. Provided a reasonable period of time has elapsed since the beginning of the final phase, respondents should be able to provide meaningful insight into the performance of the project from either a client/end-user or community perspective. Table 1 describes the opinion scale for each question (-2 to +2). Table 2 describes the relevance scale for each question (1 to 5). Opinion and relevance are multiplied together to obtain a weighted satisfaction score between -10 and +10. Across all questions pertaining to each success factor, and across all respondents to the questionnaire, a positive mean score is good. A high score suggests a strong level of satisfaction with the project in its operate/utilize phase.

Table 1. Respondent opinion scale (-2 to +2)

<table>
<thead>
<tr>
<th>PERSONAL OPINION</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
<td>+2</td>
</tr>
<tr>
<td>Agree</td>
<td>+1</td>
</tr>
<tr>
<td>No opinion</td>
<td>0</td>
</tr>
<tr>
<td>Disagree</td>
<td>-1</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>-2</td>
</tr>
</tbody>
</table>

Table 2. Respondent relevance scale

<table>
<thead>
<tr>
<th>PERSONAL RELEVANCE</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very important</td>
<td>5</td>
</tr>
<tr>
<td>Slightly important</td>
<td>4</td>
</tr>
<tr>
<td>Neutral</td>
<td>3</td>
</tr>
<tr>
<td>Slightly unimportant</td>
<td>2</td>
</tr>
<tr>
<td>Not important</td>
<td>1</td>
</tr>
</tbody>
</table>

Desirable relates to the attractiveness of the project and speaks of intrinsic value to the client/end-user or local community. It may include beauty, elegance, quality, empowerment and other intangible attributes that bring delight and happiness, or enable transformation. Adaptable relates to the flexibility of the project and its ability to accept change without causing too much unnecessary disruption or churn. It may include future modifications or change of purpose, process re-engineering and avoidance of becoming prematurely obsolete. Practicable relates to the project being fit for purpose and fulfilling the needs and expectations of the client/end-user or local community in terms of functionality and utility. Does it work well? Does it deliver on what was specified or needed? Finally, serviceable relates to the enduring nature of the project. Is it a project that will be treasured in future years and capable of upgrade as and when required? It may aid sustainability, operational energy profile, future-proofing and contributions to those it aims to serve. Is it in harmony with its natural surroundings?

While the four identified success factors are generic and share the same method of assessment and arrival of an overall satisfaction score, the contextual questions to assess them will need to be customized to the peculiarities of the project itself. For example, an office fit-out project might consider contextual questions for desirable, adaptable, practicable and serviceable criteria concerning issues such as décor, workstation configuration, secure storage space and energy star rating respectively, while a live concert project might consider the popularity of the headline act, provisions in case of inclement weather, sound and lighting innovation and safety of the crowd on the day of the event. Contextual questions cannot be generic, and may even need to be tailored to different groups of stakeholders (such as employees, local community, visitors, etc.).

3.4 Benefit Realization

There is horizontal connectivity between success factors (e.g. feasible > within budget > desirable). This connectivity ties back to wider system characteristics of financial, social, political and environmental consequences. Factors within phases have equal weight and, when combined together, negative scores for any phase indicate an unsuccessful project outcome. Overall success is the mean (unweighted) score of design, deliver and delight, each judged by a different stakeholder group. High scores are preferred.

Table 3 describes the connections between success factors over time (scores provided are for illustrative purposes only).

Table 3. Phase-consequence matrix

<table>
<thead>
<tr>
<th>CONSEQUENCES</th>
<th>PROJECT INITIATE</th>
<th>PROJECT IMPLEMENT</th>
<th>PROJECT INFLUENCE</th>
<th>SCORE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>feasible</td>
<td>within budget</td>
<td>desirable</td>
<td>78</td>
</tr>
<tr>
<td>Social</td>
<td>useable</td>
<td>on schedule</td>
<td>adaptable</td>
<td>69</td>
</tr>
<tr>
<td>Political</td>
<td>achievable</td>
<td>as specified</td>
<td>practicable</td>
<td>71</td>
</tr>
<tr>
<td>Environmental</td>
<td>sustainable</td>
<td>no surprises</td>
<td>serviceable</td>
<td>62</td>
</tr>
<tr>
<td>SCORE (%)</td>
<td>80</td>
<td>58</td>
<td>72</td>
<td>70</td>
</tr>
</tbody>
</table>

There is an implication in i3d3 that higher levels of project success lead to greater benefit realization and collective utility. But this is far from guaranteed. Social cost-benefit analysis, which is outside the scope of this paper, is likely to still be the best method to measure these things (Langston, 2005). It too would consider financial, social, political and environmental consequences, but would express outcomes in the form of a discounted cash flow. While this technique is used to model expected outcomes, especially for large projects, it is rarely if ever used in hindsight to verify that benefits were actually realized. Monetary calculations also inherit problems of different currencies, equivalent purchasing power and accounting for macroeconomic changes over time.

4 Discussion

A key measure of overall success is benefit realization (Serra and Kunc, 2015). Benefits include both tangible and intangible criteria and hence they resist conversion into monetary terms. Successful projects should aim to bring a positive collective utility to our society, even though there will always be winners and losers. For a project to be successful, it must show this consistently over time (i.e. reflect good design, effective delivery and make a lasting contribution). Benefit realization requires a long-term view of a project, and cannot be confined to what has traditionally been described as implementation.

Projects have some common characteristics. First, they can be divided into a sequence of initiate (design), implement (deliver) and influence (delight) phases that reflect the life cycle for the intervention. Second, each phase potentially has financial, social, political and environmental consequences for stakeholders, and these stakeholders vary
over time. Third, phases and consequences create a matrix of success criteria that are capable of individual and collective measurement using a common scale (-100 to +100).

The previous discussion of $I^3d^3$ has identified twelve generic criteria for measuring success. During the project initiate phase, successful projects must demonstrate that they are feasible, useable, achievable, and sustainable. There is a sequence for these criteria, in that before being concerned with a project’s sustainability it first needs to be achievable, before worrying about its useability it first needs to be useful, and before deciding if it has useability it first needs to be feasible. During the project implement phase, successful projects must be delivered within budget, on schedule, as specified and with no surprises. Here there are clear trade-offs, and an equation can be employed to determine the essential change between what was planned and what actually happened. This change can be positive or negative. During the project influence phase, successful projects must be relevant to the end-users in terms of whether they are desirable, adaptable, practicable and serviceable. Each phase needs to produce a positive outcome that reflects success on a fixed scale, and over time acceptable benchmarks can be determined to add further insight to the interpretation of performance.

The objective of this research is to ultimately eliminate the controversy over what is judged as successful and what is not. Further, the model proposes that different techniques are used during each phase to best capture the evaluation of identified criteria. Clearly success is judged in ‘the eyes of the beholder’ and hence multiple stakeholder groups must be involved. Looking at financial consequences, a successful project must be feasible to do, delivered within budget, and desirable to those for which it is intended to serve (Kerzner, 2017). Feasibility is often measured as a ratio of benefits to costs (BCR), where the result BCR>1 might be considered as a sign of success as it is likely to return a profit (Bersaneti and Carvalho, 2015). The higher the ratio, of course, the happier those with a financial interest in the project will feel (Zavadskas et al., 2014). Once a budget has been set, staying within it is important to those charged with its delivery. But regardless of whether both of these criteria are achieved, if the end-users have little interest in it, its success up until that point might be somewhat meaningless.

Looking at social consequences, a successful project must be useable and help people, be delivered in a timely fashion, and be adaptable to changes in people’s needs into the future (Sy, 2007). Useability can be measured via an opinion survey of a representative sample of people affected, and would need to show positive local support. Once its purpose is proven, the project would need to be competed as soon as possible. To avoid premature obsolescence, the project would also need to be sufficiently adaptable to meet changing requirements without significant new investment.

Looking at political consequences, a successful project must be achievable in terms of the rewards and risks (pros and cons) of the intervention, delivered to specified standards, and address the needs of end-users in practice (Serrador and Pinto, 2015). Achievability is a function of the probability of positive and negative risks and their impact on stakeholders. It demands that design is reconciled against actual performance to ensure that initial expectations are fully realized.

Looking at environmental consequences, a successful project must be sustainable over its designed life, involve no nasty surprises or undesirable consequences, and be serviceable in the context of providing an enduring legacy into the future (Sanz-Caleco et al., 2015). In terms of environmental impact, one may consider current regulatory requirements and the project’s footprint (Sánchez, 2015). Life cycle analysis is an appropriate technique for assessing the level of sustainability in an objective fashion.

This approach used in $I^3d^3$ is expected to apply to projects of any type, size or location. Scores are based on currency, timing or other date stamp. Criteria are generic. Size may affect the quantum of benefits realized but not the requirement for benefits and positive collective utility. The approach is also applicable to any country, rich or poor, and hence can support global comparisons.

There is a disconnect, however, between the three phases as a result of changes in stakeholder power and interest (Griffith et al., 1999). This can be mitigated by effective communication and the use of technologies to share knowledge and ensure that objectives are consistently pursued over time. Project success planning ought to involve strategic thinking and management (Shenhar et al., 2001). Phases should not be compartmentalized but rather provide opportunities for feedback and learning. Torbic and Stroh (2001) assert that if end-users are satisfied, the project can be considered successfully completed in the long run. However, a communication bridge from project initiate through to project influence is essential to ensure that benefits are indeed realized. In other words, what is important is that right projects are done right. This is the essence of project success.

Success is a function of stakeholder satisfaction and is reflected in the relationships that are formed and maintained between key people over time. With that comes the realization that there is more than one stakeholder to please, that project objectives will vary between them, and that the passage of time is an important ingredient in understanding and quantifying satisfaction. Judging criteria should be transparent. But none of this precludes generic criteria independent of project type, size and location. Obviously, not all projects will be successful – for example, some may just be motivated by self-serving political imperatives or be poorly planned responses to an emergency situation – and fail to deliver the benefits or collective utility demanded of them. Being able to rank projects in hindsight according to their level of success, however, is still valuable. It enables both reflection and continuous improvement to occur, ensuring we have an opportunity to learn from things that worked and from things that didn’t.

In applying the proposed $I^3d^3$ framework, it might be concluded that ‘the devil is in the detail’. Can we reasonably place a number on each criterion so that we can determine mean scores horizontally and vertically within the phase-consequence matrix? Can a doghouse actually be more successful than an opera house, and can such a conclusion be defended? Is it even useful to make such diverse comparisons? These questions require further investigation and empirical testing. This paper is merely the beginning of a quest to find a way forward to quantify success or at the very least to establish clear criteria for how, when and by whom success is ultimately to be judged.

5 Conclusion

Project success is a topic fraught with difficulty due to a lack of agreement about its measurement within the existing literature. Adding to the confusion, projects (or even programs, as aligned groups of projects) are seen as having a defined beginning and end, after which they commonly enter a period of application that is considered outside the project’s boundary. We need to talk about ‘product success’ instead of project
success. But whatever the terminology, it is clear that success cannot be determined at a solitary point in time, nor can it be assessed from a singular perspective.

The next steps must be to develop detailed models, test and validate them on real projects across a wide range of type, size and location, and promote the importance of measuring success consistently into the future as an extension of the ‘lessons learned’ protocol. It is the responsibility of the project manager, in our opinion, to take the lead on this.

6 Acknowledgement

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7 References


Will off site manufacture destroy employment in the construction industry?

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Abstract:
Recent years have seen a rapid rise in the percentage of offsite manufacturing of elements and components for building construction projects. The potential benefits of offsite construction are well known and have been demonstrated in a wide variety of project types. There has been some speculation that the result of this change might be a loss of onsite jobs and a net transfer of construction work to lower wage economies overseas. As is often the case, a realistic picture of the results of structural change is more nuanced. There may be winners and losers in this story. Several Australian construction enterprises are already embracing the possibility of new modes of operation which can carve out a viable slice of the project delivery market in the face of new global competitors. The aim of this paper is to report on two case studies of companies who are achieving growth while delivering quality outcomes in an increasingly disruptive industry context. It would seem that there is potential for future competitive locally based companies who can compete successfully in the global construction context.

Keywords:
Offsite construction, globalisation, competitive advantage, disruption.

1 Introduction

Many industries have experienced the turbulence of disruptive change and unanticipated competition (Christensen et al. 2002). The construction industry has tended to feel itself to be largely immune to disruptive globalisation because national jurisdictions control their own building regulations and because the cost of shipping heavy construction materials around the world was thought to be prohibitive. There is evidence that this may be changing and the construction industry may feel the pressures of globalisation already experienced in other industry sectors.

Press barons once felt that classified advertisements in newspapers were “rivers of gold” that would permanently subsidise high quality journalism. However, they did not foresee that online competitors would very quickly replace newspapers as the main source of employment, real estate, tender notices and personal advertisements. At the same time, social media has usurped the traditional role of the press as the primary information source on current events. The result is that long established journals have struggled to find a role in a new more competitive environment and permanent employment of journalists has plummeted (Plunkett 2005).

Other industries have been disrupted by specific technological innovations. Digital cameras have virtually obliterated the film camera and its associated delivery services.
Devotees may hold on to the old technology, but it has ceased to occupy a mass market. As a result of these developments, businesses and employment in photography have either disappeared or changed radically (Lucas and Goh 2009; Čtutién and Thattakath 2014). The recorded music industry has experienced a similar pattern of change with the advent of online streaming services which have displaced CDs (Moreau 2013). Of course, CDs, themselves, were disruptors for the previous cassette tape technology.

Christensen and Tedlow (2000) began formulating an economic theory of disruption by first looking at the retail sector and then generalising to other industries (Christensen et al. 2000; Christensen et al. 2000; Christensen & Tedlow 2000). They have widely documented the impact of disruption while strategizing about managing the risk and controlling the outcomes of disruption.

Disruption can also come in the form of service innovation without any specific technological change. The behaviour revolution created by Uber and similar ride-sharing services has induced value loss for taxi licences, as well as employment consequences (Cramer and Krueger 2016). The sharing economy more generally, has fostered change in service delivery but the consequences of these changes have yet to be fully played out. Some researchers see the sharing economy as a positive and self-empowering development (Juho et al. 2016) while others point to the impact on security of employment as a negative outcome (Zervas et al 2013).

1.1 Employment

In a large study of the outcomes of employment changes in the global manufacturing sector, Felipe and Mehta (2016) found that while the manufacturing sector’s share of global employment and productivity did not fall between 1970 and 2010, productivity growth of within-country manufacturing was counterbalanced by a shift of manufacturing jobs to lower productivity economies. In other words, factory jobs are moving from advanced economies to less developed countries where labour is cheaper but productivity is also lower. This finding sends a critical message for the construction industry which is less advanced on the path to globalisation than the manufacturing sector.

The important question for construction companies in advanced economies, is how to compete in a globalised world by prioritising smart solutions over the temptation to exploit cheap labour. The possible deficits in quality and safety of building components that may otherwise result are a serious problem. The research agenda for this paper is to find exemplars of Australian construction businesses who are already addressing these twin challenges of globalisation and industrialisation. Can the storylines of such ‘clever’ construction companies provide advice and inspiration for others who struggle with the challenge of change? The research will concentrate on the growing trend towards Off Site Manufacture (OSM) as a disruptor of traditional construction business models. Alongside this, the paper will examine whether OSM based firms can utilise strategies for maintaining employment and quality standards in their home market.

In the context of global change and disruption, case studies can provide qualitative insights into how individuals are responding to the challenges of changing markets and procurement methods. This is an exploratory study and is speculative in nature. It makes no assertion that the problems discussed have easy solutions. A case study approach can yield useful information but it is of necessity limited in the amount of recommendations it can make. Only companies active in the Sydney region have been studied and it is hoped that connections with other researchers may be made to expand on the theme of this research.

2 Literature Review – The context of Off Site Manufacture

Off Site Manufacture (OSM) in the construction industry context can be defined as the completion of substantial parts of construction works prior to their installation on-site. OSM can range from pre-assembled sub-elements to modular elements to whole buildings (Gibb and Haack 2003). Perhaps the major driver of the move towards OSM has been the long term fall in the productivity of the construction industry compared to the manufacturing industry (Changali et al., 2015).

2.1 Falling construction productivity

This falling productivity is represented in Fig 1 below. It can be ascribed to many shortcomings that the industry is known for. These include poor planning, inadequate communication and insufficient risk management. Some of the proposed solutions are modular design and standardisation along with prefabrication and preassembly methods (Peltokorpi et al. 2018).

Productivity in manufacturing has nearly doubled, whereas in construction it has remained flat.

Overview of productivity improvement over time

![Graph showing productivity improvement over time](Source: Changali et al., 2015)

2.2 Impact of OSM

Several researchers have investigated the potential changes that the trend to OSM is likely to have on the traditional construction industry. Bismas et al. (2006) persuasively argued that value-based assessment rather than simple cost-based assessment needs to be in place before really effective choices between off-site and on-site production can be made. The time, cost, quality, labour and safety implications of OSM need to be measured holistically if the mooted productivity benefits are to be achieved.

Similarly, Arashpour et al. (2016) tackled the issue of the integration of uncertainties in on-site and off-site project activities. The authors also recommend a holistic approach where the risks in both situations are treated in an integrated manner. Any kind of
construction operation is likely to be characterised by higher risk than most other industry sectors because of the number of unknowns. Hybrid construction projects incorporating both on and off-site operations can magnify the risk of interacting uncertainty on completion times (Arashpour et al. 2016). The study looked at man hours but not specifically at employment.

2.3 Drivers towards greater prefabrication use

Wong et al. (2017) examined the organisational changes that are needed to fully capitalise on the benefits of OSM or prefabrication in construction. The study noted the drivers for change include:

- Shortened construction period
- Savings on construction costs
- Improved quality of the end product
- Reduced labour inputs
- Safer work environment
- Reduced waste and pollution

The ‘reduced labour inputs’ factor implies that there may be significant net job losses associated with the greater reliance on OSM. Despite this the study did focus on enabling strategies which include training and rewards which may mediate this effect.

Alazzaz and Whyte (2015) found that employee empowerment can be linked with productivity improvements via the move to off-site construction. They report that the reliance on labour-intensive activities in the off-site context means optimal labour productivity is valued beyond that in the more chaotic world of on-site delivery. They concluded that companies need to continually adapt their training, resource development, teamwork and employee recognition policies if they are to harness the benefits of OSM. In two case studies changes in employment patterns were described but there was no specific focus on net employment (Alazzaz and Whyte 2015).

A study by Jianing et al. (2017) look at the role of architects in off-site construction and concluded that there will be significant transformation required in the thinking patterns and design methodologies of architects if they are to find places in the new economy. Employment and status are closely connected.

3 Research Methodology

Research methodologies should be chosen with regard to the research questions and/or the research objectives being studied. There is a place for fully quantitative research and for fully qualitative research as well as for a mixed methods approach. There are three research objectives for this study identified from the literature review:

1. Identify some of the processes that contribute to the accelerating trend towards OSM in construction
2. Examine the motivation and practice of construction leaders who are already addressing the challenges of change
3. Draw out the strategies that enable local companies to compete in a globalised market and maintain employment opportunities within Australia

As these research objectives are primarily qualitative in their intent, the appropriate methodology is one that draws out the storylines of the lived experience of the businesses involved in change processes. The literature sets the context for a structured case study method which will tease out the learnings from successful industry leading businesses.

As Yin (2009) notes, case studies can be used to explore ‘how’ and ‘why’ questions in a nascent research area that is not yet widely studied in a quantitative way. Case studies can provide storylines which assist in developing theory for later quantitative testing. For this reason, case studies rather than surveys or structured interviews were chosen as the methodology for this preliminary study.

3.1 Case study method

The two case studies selected are construction businesses which specialise in different forms of off-site construction processes. They have been recognised by their peers as leaders in OSM. In each case, information was gathered from internet sources, company websites, promotional material and site visits to projects underway. Case study methodology is particularly useful for gathering broad scale information on a change process which will ultimately be used to develop theory in the manner described by Glaser and Strauss (1967) in their seminal work on Grounded Theory. This paper presents the first stage of such an endeavour. With the caveat that research that is some sense aims at predicting future trends will always be subject to the vagaries of the unforeseen, the study attempts to identify trends for further evaluation in future studies.

4 Findings and Discussion

The case study information for two medium-sized construction companies who are heavily involved in OSM is the subject of this study. The material was gathered over the course of 2017 to 2018. It consisted of company website and promotional material alongside site visits to two current projects under construction.

4.1 Case Study 1 – Steel fabricator who builds residential tower upgrades

Established in 2003, CS1 has developed its business in steel frames and trusses by learning how to take a manufacturing approach to building. They are now using the controlled environment of their extensive manufacturing facility to apply a modular approach to construction which is all produced within Australia.

The company is currently involved in rapid construction of multi-storey affordable student housing in inner city sites. As shown in Fig.2 they are sites with restricted access and other constraints such as building over existing occupancies which continue to be utilised during the construction period. Cost of land and the complexity of access routes have led the builder/developer to look for innovative solutions to housing shortages. The steel framed building illustrated is built on top of existing under-used commercial space. Consequently, footings costs are eliminated as long as the new structure is sufficiently light in weight to be carried on the existing base.

Steel framing for residential medium rise building is unusual in Sydney. The builder is also the fabricator so he is able to bring his particular expertise in off-site detailing and on-site erection to the project. The result can set a precedent for the improved utilisation of currently less than optimal sites in difficult locations.

The builder/fabricator has formed a connection with a developer who looks for potential sites such as under-utilised clubs, factories and warehouses. The lightweight prefabricated steel structures are then designed to enable increased use of the site.
footprint to provide much needed affordable small apartments which are utilised partly for student housing.

Figure 2. Affordable student housing in inner Sydney
(Images: Chandler)

4.2 Case Study 2 – Cross Laminated Timber (CLT) panelised construction specialist

CS2 focuses on a business which specialises in the construction of large scale multi-residential projects including communities of houses, townhouses, retirement villages, as well as, associated facilities such as schools. They have a specific focus on new building products and modern technology as a way of ‘maintaining bespoke quality at an affordable price’ (Strongbuild 2018). They have a streamlined Off Site Manufacturing facility in Western Sydney. Their commitment to customers centres on ‘more control’, ‘less risk’ and ‘more certainty’.

The company uses detailed 3D design in house to produce optimised workshop drawings, which then translates to their automated manufacturing facility. Using sustainably sourced timber they produce panelised floors, walls and roofs, as well as joinery modular components which are transported to site for streamlined construction. The integrated system is capital intensive but it delivers quality outcomes in fast time and at affordable rates.

The warm quality of the CLT interiors can be seen even in the incomplete buildings. The expertise gathered while delivering innovative structural and panelised systems is likely to yield dividends on future projects. The builder has invested time and money into delivering a new kind of construction project within the local industry context. Employees are valued and training and advancement is strongly encouraged.

4.4 Case study evaluation

The two businesses in the case studies demonstrate commitment to competing in a rapidly changing environment where local companies may need to contend with competitors who have much larger economies of scale in their own home markets. Table 1 shows how they compare with the project features identified by Wong et al. (2017). Of course, as the companies were identified because of their known reputations for innovation and integration of OSM, it is unsurprising that they meet the checklist criteria. It is not suggested that many Australian building companies have reached this stage yet.

The case studies demonstrate that it is possible for medium sized Australian companies to deliver new kinds of building projects by using OSM. They have done this not only by adopting new technologies but by recreating themselves as new kinds of building enterprises. As industry veteran David Chandler has stated it is important to ‘build a...
business before you build a factory' (Chandler 2016). Both case study companies have developed business strategies to manage their growth trajectories while continuing to employ local people. At the same time they are upskilling their workers both on-site and off-site.

As previously stated this research is part of an ongoing research effort to look at the impact of OSM on overall employment in the Australian construction industry. It is not yet possible to give a definitive answer to the research question. The best that can be said at the moment is that we have seen cases of Australian construction companies who are attempting to make the shift to OSM using their existing expertise and innovative project selection.

5 Conclusion and Further Research

Off Site Manufacture (OSM) is a growing section of the Australian construction industry. It represents one of the ways that the industry can respond to the threat of globalisation and disruption which has caused difficulties for so many other industries. There is no reason to see this process as entirely negative for Australia. By taking an innovative approach based on practical experience in the delivery of building projects, agile companies can find themselves a place in the new economy.

This paper has described the impact of disruptive change and the potential for such change to affect the construction industry. In terms of the three research objectives identified from the literature review, a start has been made for a much longer study. Some of the processes that contribute to the accelerating trend to OSM have been identified as falling construction industry productivity and the rise of globally competitive OSM businesses (objective 1). Two current leading businesses in the area of OSM in the Sydney region were identified and their operations studied (objective 2). By means of descriptive material gathered, the enabling strategies for these companies have been identified (objective 3). They were found to be largely in line with the findings of Wong et al. (2017) whose study was based in Victoria.

The question of whether net employment will be negatively impacted by OSM remains unanswered. The most that can be said is that there are examples of companies actively trying to maintain their own workforce while competing with international supply chains. This is a small study that can potentially be expanded to a larger geographical location.

The study has embarked upon a debate about the desirable and undesirable outcomes of technological change in the construction industry. It is hoped that many voices will carry on with contributions on the issues raised.

6 Acknowledgement

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7 References


Why transform the building industry? A case for drivers and barriers to innovation acceleration

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Abstract:
Challenges with performance and productivity, quality achievement, and uptake of innovation (albeit technology, skills or processes) are rife in the building industry. The industry needs disruptive changes currently being hampered by its inability to innovate effectively and a lack of investment in research and development. A key task is how technological innovations can be accelerated to shape the future of construction to make a better industry. This study is undertaken with a view to providing information on the drivers and barriers to innovation creation/ adoption. It further identifies how government and industry can drive more innovations to achieve significant productivity performance. Data for the study was obtained through focus group of practitioners within the building industry in New Zealand (NZ). The responses were analysed using content analysis, facilitated by nVivo computer software. Notable innovation drivers include case studies and enormous data from successful innovations that can foster reasonable confidence in future innovators. Government and industry can drive more innovations through collaborative contracts, shared best practice, case studies, government policy and a need to examine NZ environment and capability. From a practical perspective, clients and contractors may be convinced to invest in technological innovations, increasing or accelerating its uptake and more fully realising the benefits it could add to productivity performance, growth and long-term success. With qualitative evidence available, this paper may provide useful information for researchers regarding the development of case studies by analysing organisations/companies that implement innovation, their successful actions/processes, barriers overcoming actions, and sources of new ideas. This could create an avenue for innovation acceleration in the industry.

Keywords:
Drivers, barriers, innovation acceleration, New Zealand, transform the building industry

1 Introduction

It is globally identified that the building industry needs to transform from its conservative approaches to practice (Holt, 2013), as it is increasingly at risk to challenges with performance and productivity, quality achievement, and slow uptake of innovation solutions such as new technologies (Schoenborn, 2012; Xue et al., 2014). Innovation is recognised to be of the utmost importance for the success of all industries (Holt, 2013; Owusu-Manu et al., 2015). Researchers and practitioners have found that innovation is a requirement for organisations to survive in any dynamic economy (Blyaye and Manley, 2004; Gambatese and Hallowell, 2011; Smith and Estibals, 2011). In fact, these studies established evidence that innovation is the catalyst for continuous improvement, relational performance and the progress of the industry. In general terms, it is an avenue to improve productivity and efficiency (Maghsoudi et al., 2016); hence the subject appears to be a crucial topic for research. However, the building industry in particular has been reported as a rather slow innovator (Reichstein et al., 2005; Gambatese and Hallowell, 2011) as it seems very challenging to practice innovation in the sector (Dansieh et al., 2017). Possible reasons for this could be attributed to uncertainties and hence risks associated with construction project developments (Shibeika and Harty, 2015). For this study, innovation is defined as the process by which organisations successfully transform new ideas into improved products, services or processes, to advance, compete and differentiate themselves (Loosnomre, 2014) as well as improve the values of productivity and project performance (Maghsoudi et al., 2016). Following Gledson and Phoenix’s (2017) classification, technological innovations (products, processes and services) were considered for this investigation, justifying the overall aim of this study.

In the construction domain, New Zealand (NZ) has not been immune to the global lack of innovation. Although, innovation has been in its long-term national agenda. Evidence suggested that the sector is a low innovation/technology performer with sub-optimal contribution (5% of total expenditure) to Research and Development (R&D) expenditure when compared to all-industry utility averages; and it contributes relatively less to overall innovation effort (Statistics NZ, 2012). For example, in 2010, the Building and Construction Sector Productivity Partnership was established to actively address the challenges of low productivity within the sector. The partnership identified innovation as critical to achieving significant productivity improvements. To help motivate the global industry, the World Economic Forum (WEF) (2016) produced/developed an industry transformation framework listing 30 measures that could cause a leap forward in industry productivity and innovation (see WEF, 2016 Figure 1: Construction Industry Transformation Framework). These measures are supported by best practices and case studies of innovative approaches. In 2017 BRANZ Industry Transformation Initiative produced an industry transformation framework to achieve a step change in productivity, quality and reputation. This nationwide initiative seeks to nurture a ‘culture of innovation’ within the New Zealand industry. However, there is also a need to provide evidence-based research to help underpin, such leadership initiative. New technologies such as BIM, 3D printing, robots, drones, improved Prefab and augmented reality are transformative (WEF, 2016) and could incentivize locally based solutions for innovation adoption/implementation.

Much literature has suggested various drivers and barriers to innovation development and how innovation could be implemented in construction projects (Aouad et al., 2010). In response to the accumulating evidence that the sector is plagued by challenges with performance and production processes, Winch (2008) critically questioned the empirical observations of such claims. While it is impossible in this current assessment to cover this entire literature, this study explored some of the key drivers and barriers (see Tables 1 and 2). It is noteworthy that financial concerns can act as both a driver and barrier. The current study posits that aforementioned issues could offer fundamental evidence towards motivating innovation in construction projects to transform the industry.
Most research on construction innovation obtained data from firms or organisations based in the Asia, Australia, Europe, Middle East, and United States (Gambatsetse and Hallowell, 2011). A key task is how technological innovations can be accelerated to shape the future of construction to make a better industry. This study is undertaken with a view to providing information on drivers and barriers to innovation creation/adoption and its acceleration, and their relationship to the NZ experience. This is an under-researched area in NZ, and such information would help decision makers improve the current state of innovative practice. The current study aimed to fill this gap, and further identify how government and industry can drive more innovations to achieve significant productivity performance. To help achieve this, the current assessment obtained data through focus group of practitioners within the building industry in New Zealand (NZ). Participants from two industry sectors (residential and commercial) were involved to investigate innovation acceleration in the context of construction.

2 Research Methodology

Within the limitations of data collected, a focus group approach that uses qualitative data was undertaken to engage with different stakeholders in the industry and obtain a deeper understanding of the major issues facing the industry (Creswell, 2013). Focus groups are appropriate where an in-depth knowledge of an opinion-seeking panel is required, and where participants are requested to share their thoughts on new ideas, products and services (Gill et al., 2008). This method has been receiving considerable attention among researchers in different research disciplines. With the focus group method, the interaction between participants can reveal information that would be impossible to capture in an individual interview (Morgan, 2000). This methodology has the potential to provide deeper insights into the topic through a direct and intense encounter with key individuals. The success of this method strongly depends on the quality rather than quantity of the participants.

A series of focus groups was conducted in June 2017. The focus groups took place in Auckland, Wellington and Christchurch to reduce where possible potential geographical impacts and biases associated with specific regional issues. In addition, it was intended to ensure a maximized participation rate from the various facets of the industry, as well as focus the participants on the national need rather than the local symptoms.

Furthermore, to enhance the degree of stakeholder engagement and obtain robust findings, a wide range of expertise (including construction project managers, engineers, architects, quantity surveyors, facility managers, developers, local authorities, construction suppliers and manufacturers and health and safety managers) was invited to participate. 50 construction professionals participated in three focus groups. A stratified sampling procedure, suggested by Fellows and Liu (2008), was adopted to obtain a representative sample from the target population. Each session lasted for about three hours and was then transcribed verbatim. Questions that were asked focused on technological innovations and how they impact on productivity performance, with participants who are reasonably experienced in project developments and therefore have some knowledge of issues relating to project innovations. A summary of participants is presented in Table 3. This methodology allows the researchers to obtain reliable findings by engaging and capturing the opinions of all participants in the research.

### Table 1: Comparison of studies on innovation drivers in other contexts

| Author | Purpose | Study area | Area | Area
|--------|---------|------------|------|------
| Ozothon et al. (2010) | Measuring innovation in construction | UK | UK | UK
| Extensive inter | Performance (cost reduction, productivity, effectiveness) | Sweden | Sweden | Sweden
| Suprun and Stewart (2015) | Exploring drivers and barriers affecting innovation implementation in Russia | Russia | Russia | Russia
| Note: R = Rank | |

### Table 2: Comparison of studies on innovation barriers in other contexts

| Author | Purpose | Study area | Area | Area
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| Ozothon et al. (2010) | Measuring innovation in construction | UK | UK | UK
| Hemstrom et al. (2017) | Investigating the propensity to adopt innovations in Swedish construction | Sweden | Sweden | Sweden
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Content analysis was used to analyse the focus group responses. This is a research method for the interpretative analyses of text data through the systematic classification process of coding and identifying themes or patterns (Gibson and Brown, 2009). Essentially, content analysis is used to search for certain words or concepts within the texts being analysed, and to automatically count how often such words occur within the texts. This task can be facilitated manually or by using computer software such as NVivo. This analysis was done manually as the researchers considered engaging themselves within the robust content would allow them to capture or familiarise with the discussion that had occurred.

Table 3: Focus group participants

<table>
<thead>
<tr>
<th>Position</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>12</td>
</tr>
<tr>
<td>Architect</td>
<td>6</td>
</tr>
<tr>
<td>Quantity Surveyor</td>
<td>4</td>
</tr>
<tr>
<td>Consultant Engineer</td>
<td>4</td>
</tr>
<tr>
<td>Facility Manager</td>
<td>6</td>
</tr>
<tr>
<td>Developer</td>
<td>6</td>
</tr>
<tr>
<td>Health &amp; Safety Manager</td>
<td>2</td>
</tr>
<tr>
<td>Construction Supplier/Manufacturer</td>
<td>4</td>
</tr>
<tr>
<td>Project Director (Public Sector/Local Authority)</td>
<td>2</td>
</tr>
<tr>
<td>Construction Manager (Contractor)</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
</tr>
</tbody>
</table>

3 Findings and Discussion

The questions for the focus groups explored what innovation means; drivers and barriers; and possible ways by which the industry/government can drive more innovations. The focus group participants are senior professional staff in their individual firms or organisations. This information indicates that the participants are reasonably experienced and capable of exercising sound judgement in responding to the questions. This enhances the validity of the focus group (Rosenthal, 2016). Therefore, based on each of the research questions, responses provided below by them could be relied upon for this study.

• What does innovation mean in the building industry?

As explained by a project manager, a focus group participant:

“The subject is around improving upon what we currently do. How we improve our processes, the design and quality of products. The whole concept is sharing information in a shared learning environment that is problem-solving, risk-involving, solutions are robust, and value added to business”.

Understanding the meaning of innovation is insufficient as has been cited in the literature on various occasions (Blayse and Manley, 2004). Some participants suggested that knowing why we should innovate, ability to innovate and implement innovations are also important, as innovation involves people doing something new to experience material changes and social and/or economic impacts. This is in line with a view that innovation appears to be a crucial subject for research (Maghoudi et al., 2016), and has acquired recognition in recent years owing to its impact on economic development and productivity improvement (Smith and Estibals, 2011). In addition, it was stressed that it takes a team/collaborative effort to innovate and this principally involves the client, designer and contractor depending on the project delivery system. These actors/innovators must be prepared to bear the risks involved in the problem-solving process; this is challenging, and hence client value must be clearly defined.

• What are the drivers and barriers for innovation creation in New Zealand?

During the focus group sessions, a number of issues were identified as drivers or factors that create the need for organisations to innovate (drivers), and the reasons why the building industry is slow to innovate (barriers) respectively.

As noted by one of the participants that innovation involves people doing something new. It was further stressed that the ability to create new ideas and implement them should be the major attribute of an innovator and our creative ability lies in the development of our mind. Understanding what we are trying to change is very important and developing “why not approach” is a force behind the willingness to implement innovations. As potential innovators adopt this approach, barriers are turned to drivers, and threats to opportunities; however, they take the risks to succeed. Also, an innovator should have a bold vision towards building issues and other challenges (e.g. energy, infrastructure, transportation) as well as building industry technologies (e.g. ICT, logistics, BIM, tools, new designs and products, techniques). Environmental issues (e.g. emission of materials, air pollution) should not be left behind, as the strength to innovate effectively lies in this quality of having a bold and aspirational vision.

Innovation capture denotes having respect or recognition for the value of innovation as a driver for organisations or employees to create new ideas for their own immediate and future benefits. Getting professionals from various disciplines (e.g. architects, quantity surveyors, builders, planners, project managers, developers, etc) to work together in innovative fields will go a long way to ensure effective innovation and robust solutions. Similarly, collaborative contracts (e.g. alliance, public-private partnership, joint venture, partnering) is a driver, as one is conscious of the fact that internal or external collaboration/ teamwork among professionals, organisations/firms, government and industry will ensure efficiency during innovation process. In addition, innovation brings success and higher profit to companies that engage in it. Therefore, such companies need to define their profit margin, and this is a determinant for innovation creation. Although, innovation is capital intensive and some people think they cannot innovate because it costs money, whereas the end result is higher profit. They lack understanding of the loop – is a lack of profit inhibiting innovation growth or is a lack of innovation inhibiting profit growth?

Having to show to people that innovation ensures positive results, case studies and big data from case studies are needed. Examples of successful innovations from other countries and organisations, and their best practice and performance is case studies providing some degree of confidence for future innovators by seeing the success that has been achieved by innovators elsewhere.

However, barriers to innovation creation are the reasons why the construction industry is slow to innovate. Innovations are risk-based. Innovation can be a company’s most powerful tool and a key driver of value. For example, many executives that are fearful of the risks inherent in pursuing new ideas, may hesitate to unleash its full potential. They prefer, indeed, to renovate rather than to innovate. An example was raised about 64 percent of the 519 companies in Accenture’s 2012 innovation survey. A cross-industry sample of US, UK and French players did not focus largely on line-extensions. Only 20 percent viewed their innovation efforts as potential changers and 16 percent said they were using innovation to drive competitive advantage. An innovator needs to be bold to innovate and not being conservative.

Having uneducated clients/actors that are conservative and they lack understanding of their requirements as well as value of innovation, training, fresh thinking/creativity, technical confidence/competence and knowledge development could be responsible for such lukewarm or nonchalant attitude towards innovation.
Condition of contract (NZS 3910) does not have innovation content and this document should encourage innovation. Its review was suggested to reflect a clause that bears innovativeness for practice. Another barrier mentioned is bidding system (tendering). If bidding is based on pricing and price is the main determinant for bidding success, the contractor with low price wins. Such a contractor may not be keen to include a transformational, innovative aspect to the tender.

Affordability to innovators is another barrier suggested, because thinking and implementing innovation cost money but this results in higher profit in the long run. In addition, lack of data management is a crucial issue that needs attention. Lessons learnt from projects completed are data that need to be compiled and kept. As projects are completed, they are discarded, and their data are not used to improve proposed projects in the face of problem-solving exercise. In addition, it would seem apparent that the government needs to change its attitude towards innovation – especially in the domain of crown properties owned by ministries, councils, and other entities such as universities, colleges and schools as they are seen not having a long-term plan, support and goals for innovators. If anything, government tends to discourage innovation in this space. Given the context of New Zealand and the recent history of leaky buildings as the result of construction materials/planning/design innovations like monolithic cladding and internal guttering it is not hard to understand the reticence of governmental bodies given their liabilities and the consequences of innovation failure.

However, an insight into UK innovativeness by Gledson and Phoenix (2017) revealed cost efficiency as the predominant driver for innovation. To gain a deeper insight into the drivers, and barriers of innovation, learning from Russia, Sweden and UK is worthwhile. Results from literature (see Tables 1 and 2) show that performance improvement in terms of cost (Ozorhon et al., 2010), public support through subsidies and grants (Suprun and Stewart, 2015), and financial incentives or intervention (Hemstrom et al., 2017) are the main drivers. Whereas, economic conditions (Ozorhon et al., 2010), high construction cost (Suprun and Stewart, 2015), and initial/project costs rather than life cycle costs (Hemstrom et al., 2017) are the top barriers. It is thus interesting to note that financial concerns can act as both a driver and a barrier to innovation uptake. This suggests that companies tend to innovate to increase their profitability, but they cannot innovate unless their economic condition allows.

- How can industry/government drive more innovations?

The study participants pointed to the need for collective responsibility between the government and industry to be able to drive more innovations in the following ways:

i. Collaborative contracts (e.g. alliance, public-private partnership, joint venture, partnering) can be used to drive more innovations, as one is conscious of the fact that internal or external collaboration/team work among professionals, organisations/firms, government and industry will ensure efficiency during innovation process.

ii. Shared best practice/Shared future vision – Holding periodical meetings/discussion is essential between industry leaders and government decision makers to share mutual understanding towards the future of innovation.

iii. Case studies to be made generally available – As mentioned by the participants, case studies are needed to show people that innovation ensures positive results i.e. examples of successful innovations from other countries and organisations. At present another inhibitor for the industry is a lack of interest in or access to literature and findings from active research.

iv. Comparing projects – Failed practices that innovation could have saved can serve as a lesson to drive more innovations.

v. Better understanding of business improvements – Goals should be set, and methods should be defined to achieve the goals. Understanding that business improves through innovation is a way to drive more.

vi. One area flagged by multiple participants was the need to substantially rethink the standard methods of construction using timber as a means to increase timber use and the affordability of housing in NZ. With this in mind, NZS 3604 for timber framed buildings was cited as being in substantial need of a rethink and expansion in order to take timber framed structures beyond their current limit of 10m. The specification, as well as access and adherence to it, can be used as a tool to drive more innovations and this is useful to practitioners.

vii. Government policy/regulation with innovation clause will go a long way to add value to projects and products. This can be used to drive more innovations.

viii. Challenge and change what is currently understood by innovation in the NZ construction industry - Investigations have revealed a substantial perceived inability of the industry to innovate effectively. This current state of the industry must be challenged to drive more innovations.

ix. Understanding what we are trying to change is very important and developing “why not approach” by the industry leaders and government is a force behind the willingness to implement more new ideas.

x. A need to look at New Zealand environment/NZ competence and capability – A solution for transforming the industry through innovation should be tailored specifically to New Zealand environment bearing in mind the NZ competence and capability to drive more ideas.

The NZ industry can learn more from Australia in respect of driving more innovations to improve productivity performance by increasing predictability of delivery, driving greater integration and collaboration, increasing industry engagement with new technologies, deeper supply chain collaboration, better use of data and analytics, increasing R&D sponsorship, early contractor involvement, ensuring realistic project planning and feasibility, review of contract and procurement models, and incentivizing innovation among others (see Loosemore [2015], and National Science Challenge [2017] for comprehensive reviews).

4 Conclusion and Further Research

Within the limitations of the focus group data collected, prominent innovation drivers include case studies/successful innovations and big data from other countries and organisations. The best practice and performance from overseas and foreign organisations could be case studies that can instil high degree of confidence in future innovators. Meanwhile, the largest innovation adoption barrier has been related to lack of government interest. However, international literature held the view that financial concerns can act as both a driver and barrier to innovation creation (Ozorhon et al., 2010). Ways in which the government and industry can drive more innovations include collaborative contracts, shared best practice, case studies, comparing projects, better understanding of business improvements, government policy/regulation and a need to look at NZ environment/NZ competence and capability, as perceived by the participants.
The focus group and content analysis facilitated by NVivo, provided deeper insights into the subject/questions through an intense interaction with key participants. This revealed information that would rather be impossible to grasp in an individual interview, as suggested by Morgan (2000). These findings corroborate Aoud et al.,’s (2010) assertion that the benefits of innovation can only be achieved by fully understanding the components of the whole innovation process that is based on knowledge acquisition, transformation and diffusion. Similarly, organised effort is needed to invest in new ideas and convert them into practice in a systematic way.

With qualitative evidence available, this paper may provide useful information for researchers regarding the development of case studies by analysing organisations/companies that implement innovation, their successful actions/processes, barriers overcoming actions, and sources of new ideas. This could create an avenue for innovation acceleration in the industry.

From a practical perspective, clients and contractors may be convinced to invest in technological innovations, increasing or accelerating its uptake and more fully realising the benefits it could add to productivity performance, growth and long-term success.

Further development of the work reported in this study, when data are further collected and analysed, will provide information for the development of an innovation tool. This tool could assist construction industry practitioners in NZ to have a better and reliable pathways for innovation uptake towards productivity performance.

5 Acknowledgement

The authors gratefully acknowledge the research fund provided by the New Zealand Government and the Ministry of Business, Innovation and Employment’s (MBIE) National Science Challenge Initiative, to facilitate data collection for this study. The authors would also like to express their profound gratitude to the University of Auckland, New Zealand for the award of a post-doctoral research fellowship to the corresponding author for his post-PhD research.

6 References


Risk Allocation for Indonesia’s Performance Based Contract (PBC) for Road Rehabilitation and Maintenance Project

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Abstract:
Performance Based Contract for road maintenance is an effort to improve the traditional method. In Indonesia, PBC has been applied on several road rehabilitation and maintenance project. Unfortunately, the implementation of PBC in Indonesia has many problem and needs to develop in several aspects. Experience in some PBC pilot projects (especially in Pantura Lane Road), contractors must bear vehicle load which exceeds the capacity (overloading vehicle) risks and natural disasters that are beyond the control of the contractor. The allocation of risk between project owner and contractor in a PBC contract plays an important role for the success of the project. It should be based on a proper assessment of the involved risks and choosing the party best able to manage them. The purpose of this research is to develop Indonesia’s PBC for road rehabilitation and maintenance project based on fair risk allocation. The study took samples in several national roads in Pantura Lane Road. Risk allocation algorithm proposed by Martin Barnes (1983) is applied to determine the best able party to manage the risk by considering magnitude and cost of each risk factor. The results show that the risk of natural disasters and overloading vehicle risk should not be bear by the contractors. Force Majeure risk should be allocated to the owner by creating an addendum contract for all other risks. The study shows that the contractor still bear overloading risk, then the owner must facilitate actual traffic volume data and actual total weight data for engineering designing process.

Keywords:
Risk, performance, contract, roads, maintenance

1 Introduction
Indonesia’s Government agencies Directorate General of Highway (DGH) are starting to see the benefits of using contracts in which a contractor is responsible for both the construction and maintenance of roadways. In handling the road condition, DGH conducts road management activities such as: periodic maintenance activities and increased structure (betterment). Basically, road maintenance activities are to maintain the condition and level of service of the road, so that they obtain the minimum total costs of transport and has a longer service life. Maintenance of roads according to the World Bank (1998) is a process for optimizing the performance of the road network throughout the year, aiming to keep these roads still function to serve the economic needs of society throughout the year and reduce vehicle operating costs. Generally, national road maintenance work uses a traditional contract with the method of delivery Design-Bid-Build (DBB).

The characteristics of DBB delivery method are the contract for design work and construction work separately conducted, while routine maintenance work is usually done by inhouse management. Other characteristics, are traditional contract using unit price, and requires technical specifications that have been set by the owner. PBC is an approach that holds contracts with delivery methods Design-Build-Operate-Maintain (DBOM). At the PBC, design work, construction, maintenance contracts are integrated into a single package and only to one contractor. This new contracting scheme allocates higher risk to the contractor, but at the same time opens up opportunities to reduce the cost of achieving the specified standards as a result of implementing new technologies, materials, processes and innovative management strategies (Zielow 2001). PBC uses lump sum fixed price and applies incentives and disincentives in the payment mechanism. With the mechanism as mentioned above, PCB diverts a significant risk to the contractor. In Indonesia, The World Bank recommendations, the Ministry of Public Works have implemented two PBC pilot projects in 2011, the Pantura Section Demak-Trengguli (7.68 kilometers) in Central Java Province and Section Ciasem-Pampanakan (18.5 kilometers) in West Java Province. Both sections are categorized as national roads. The contract duration for both projects is four years. In 2012, Ministry of Finance to agree on allocating four more PBC projects with 7 (seven) year contract duration. These are: section Semarang-Bawen, West Java (22 kilometers), contract period: 2012-2018, section Bojonegoro-Padangan, East Java (11 kilometers), contract period: 2012-2018, section Padangan-Ngawi, East Java (10.70 kilometers), contract period: 2012-2018, and section Sei Hanyu-Tb. Lahung, Central Kalimantan (50.60 kilometers), contract period: 2013-2020.

PBC for road maintenance project is becoming popular and many road authorities are trying to introduce PBC in their countries. Pilot project of PBC is needed before it is fully introduced to measure the feasibility, capability, cost and quality of work and establish a relationship between the contractor and the road authority (World Bank, 2012). The road authority should try to address these needs during the pilot project. Moreover, the literature review and analysis of this research has identified issues that related to the risks. In this study, the risk of road maintenance work projects under PBC scheme is defined as uncertain events or conditions which have a negative impact on project objectives, that is increased cost of the project. List of the risks obtained through literature study of various references. The purpose of this research is to develop Indonesia’s PBC for road rehabilitation and maintenance project based on fair risk allocation. The study took samples in several national roads in Pantura Lane Road. Risk allocation algorithm proposed by Martin Barnes (1983) is applied to determine the best able party to manage the risk by considering magnitude and cost of each risk factor.

2 Literature Review
All construction projects are unique and have their own risks. Such projects involve a number of parties concerned, starting with the owner, contractor, designer, suppliers, and others. All parties involved in a project inevitably carry certain risks. Risk can be defined as a hazard, a probability of it to occur and the potential of losses and resulting gains (Turskis et al, 2012). Risk can be defined as a difference of actual and expected results. Risks can be managed, reduced, transferred or accepted, but it cannot be ignored (Lam et al, 2007). Risk in the construction and maintenance industry has increased with project size and cost. One might even say that today construction is mainly risk management. Risks are found throughout all phases of a project and vary greatly according to the type of construction, the contracts involved, and the type of delivery system. To be successful, the organization should be committed to addressing the management of risk proactively.
and consistently throughout the project (PMI, 2004). Risk management process usually consists of four stages: risk identification, risk analysis, selection and monitoring of risk management techniques to the consequences of risk. The implementation phase of construction started after the owner and the contractor sign a construction contract. The purpose of construction contract agreement is to allocate the rights, responsibilities and risks between the parties. Construction business is a business with high risks, such as financial risks, political risk, security risk and risk at the time of execution which to be managed and handled by contractors. From the moment that the decision to begin design is taken until the new facility is in use, the owner is uncertain about the outcome of the project. Performance Based Contracts (PBC) is defined as the type of contract in which payment is made if the contractor meets the performance indicators that have been agreed in the contract. Performance Based Contracts focused on outcome (what), compared to how the work is done (how). Therefore, in terms of risk allocation, PBC is a contract that allocates a greater risk to the contractor (Ziethlow, 2004), (Stankevich, 2014). The provisions contained in the contract should clearly define "new role" of the project owners and contractors. The parties involved would have to clearly identify all potential risks and allocate it to the party best able to manage it, for example: how to allocate risk in predicting traffic growth and how to allocate the risk of unexpected costs that are beyond the control of the contractor.

2.1 Risk Identification
In spite of the many types of possible risks in Indonesia’s PBC, there are mainly three types of risks that are presented on any infrastructure project.

1. Design risks: these risks relate to the problems during the design phase that are associated with cost overruns.
2. Construction risks: these risks relate to the problems during the construction phase that are associated with cost overruns.
3. Maintenance risks: these risks relate to the problems during the maintenance phase that are associated with cost overruns.

2.2 Risk analysis
In order to carry out effective risk assessment, it is important to do a qualitative evaluation in order to determine the probability of occurrence and the level of impact of each risk. In 2014, Susanti et al identified the risks present in road maintenance PBC projects in Indonesia. They surveyed PBS piloting project in Indonesia, asking for the probability of occurrence, level of impact and some missed risks. This study uses qualitative assessments to determine priorities or levels of risk significance. Qualitative assessment includes an assessment of the probability of the occurrence of risk and the impact of risk on increasing project costs.

2.3 Risk Allocation
Regarding the risk allocation, Martin Barnes proposed a methodology. In the specific case of the PBC, the parties (public sector and private sector) should determine the amount of risk willing to take according to their expected return. This risk allocation was shown as a Risk-allocation algorithm based on probability distribution. A probability distribution is the best set of data by which to measure risks. For many risks, the distribution is approximately normal and can be defined by its mean value and standard deviation. The standard deviation is a measure of the width of the distribution. The principle suggested is that externally arising risks should not be allocated to the contractor as he would charge too much for carrying them. Risk-allocation algorithm proposed by Martin Barnes has six steps:

1. Prepare a list of the unrelated risks that have to be carried by one or other of the parties.
2. Identify the risks that are predominantly outside the contractor’s control. Allocate these to the client and remove them from the list.
3. Rank the list in order of magnitude (measured as the standard deviation of cost uncertainty).
4. Add the risks (taking the square root of the sum of the squares), working from the largest first and noting the cumulative total. Stop when the cumulative total levels out.
5. If the cumulative total exceeds a tolerable threshold (Perhaps 10% of the estimated cost), consider what steps could be taken either to reduce each risk or to share it between the two parties (e.g. by using ground reference conditions). Go back to step 3 and continue.
6. If the cumulative total is less than the threshold, allocate the remaining large risks and all the small risks to the contractor.

3 Research Methodology
Research methodology adopted in this paper is a mixed "quantitative and qualitative" method. Quantitative approach to get risks dominant. However, this paper's research design is solely a quantitative approach that includes: (1) the quantification of the risk costs through a cost breakdown structure (CBS); (2) Monte Carlo Simulation to get risk cost standard deviation, and (3) Risk-allocation that adopted Martin Barnes’s algorithm; The first step was to identify risks in PBC projects. This was done primarily through literature review. A comprehensive list of 32 risks was developed based on previous studies (shown at Table 2). Questionnaire was developed to get the risk factors from contractors perceptions. The respondents were asked to choose between very low, low, moderate, high and very high. The second question refers to the impact on project cost once the risk event occurs. The qualitative research includes expert interviews to validate risk identification and assist with the selection of the most significant/dominant risks. Risk probability scale and risk impact scale shown at Table 1. For risk allocation model, PBC pilot project at Ciasem-Pamanukan was selected as case study. The contract cost IDR 97,406,765,972.24. The cumulative total exceeds a tolerable threshold in 10% of the contract cost: IDR 9,740,676,597,224.

<table>
<thead>
<tr>
<th>Risk Probability Assessment</th>
<th>Risk Impact Assessment</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Occur once in 10-15 years</td>
<td>1 The loss is less than 5% of the contract price</td>
<td></td>
</tr>
<tr>
<td>2 Occur once in 5-10 years</td>
<td>2 Losses between 5.1-10% of the contract price</td>
<td></td>
</tr>
<tr>
<td>3 Occur once in 2-5 years</td>
<td>3 Losses between 10.1-15% of the contract price</td>
<td></td>
</tr>
<tr>
<td>4 Occur once in 1-2 years</td>
<td>4 Losses between 15.1-20% of the contract price</td>
<td></td>
</tr>
<tr>
<td>5 Occurs throughout the contract</td>
<td>5 The loss is more than 20.1% of the contract price</td>
<td></td>
</tr>
</tbody>
</table>

After receiving the P and I scores for every risk on the shortlist, the risk severity scores on which a risk can be assessed were calculated. Severity (S) is calculated as a product of both probability and impact as in the following equation:
A Pareto analysis was made for the identification of the definitive risks for being evaluated through the PBC’s contractors interview. All phase of research methodology shown at Figure 1.

Figure 1 Research Methodology

4 Findings and Discussion

4.1 Risk Selection
Risk Breakdown Structure (RBS) was utilized to identify the risks at different stages of design, construction and maintenance phases. Some previous researchers have conducted a study on risk identification on Performance Based Contracts (Haas, et al, 2001; Pülscherwesky, B.D., 2004; Hyman., 2009; Mousavi et al, 2011; Zhu et al, 2011; Zietlow, G., 2013, Andhika et al, 2014, Susanti et al, 2014)). Table 2 shows a list of the various risks that could potentially occur at PBC road work projects.

Table 2 Risk Breakdown Structure

<table>
<thead>
<tr>
<th>No</th>
<th>Risk Event</th>
<th>Risk Code</th>
<th>Risk Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Increased costs due to design change</td>
<td>A1</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Increased costs due to design errors</td>
<td>A2</td>
<td>29</td>
</tr>
<tr>
<td>B</td>
<td>The project stalled due to changes in policy</td>
<td>B1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Cost changes due to rework to meet road performance standards</td>
<td>B2</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Increased costs due to the scope and amount of work that cannot be predicted</td>
<td>B3</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Losses due to price estimation error</td>
<td>B4</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Disputes with contractors that have an impact on the delay in the construction process</td>
<td>B5</td>
<td>12</td>
</tr>
</tbody>
</table>

4.2 Risk dominant selected
The Pareto chart was made through a weight assignment to get risk dominant short list as shown in Figure 2.
4.3. Risk Allocation

4.3.1 Risk Cost Calculation

Monte Carlo Simulation process is done with the help of @Risk software. As described, the distribution used is a triangular distribution. The minimum value, most likely value and the maximum value obtained from the respondents are then simulated to obtain the standard deviation value of each risk cost. The simulation result of standard deviation value from the three case studies can be seen in Table 3.

<table>
<thead>
<tr>
<th>No</th>
<th>Risk Event</th>
<th>Cost Standard Deviation (Rp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increased costs due to the scope and amount of work can not be predicted</td>
<td>2,062,387,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Increased costs due to the scope and amount of work can not be predicted</td>
<td>676,733,600.00</td>
</tr>
<tr>
<td>3</td>
<td>Increased costs due to fluctuations in currency exchange rates</td>
<td>138,002,800.00</td>
</tr>
<tr>
<td>4</td>
<td>Cost changes due to rework to meet road performance standards</td>
<td>891,826,900.00</td>
</tr>
<tr>
<td>5</td>
<td>Late payments to contractors</td>
<td>273,830,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Late payments to contractors</td>
<td>157,050,400.00</td>
</tr>
<tr>
<td>7</td>
<td>Cost change due to work implementation errors</td>
<td>678,733,600.00</td>
</tr>
<tr>
<td>8</td>
<td>Changes in working methods caused by the lack of environmental documents</td>
<td>363,162,600.00</td>
</tr>
<tr>
<td>9</td>
<td>Late payments due to the budget that are not available or is available but less</td>
<td>136,603,500.00</td>
</tr>
<tr>
<td>10</td>
<td>Increased costs due to design change</td>
<td>10,241,560.00</td>
</tr>
<tr>
<td>11</td>
<td>Increased costs due to design change</td>
<td>10,382,690.00</td>
</tr>
<tr>
<td>12</td>
<td>Increased costs due to design errors</td>
<td>136,987,700.00</td>
</tr>
<tr>
<td>13</td>
<td>Late payments due to work packages that are not included in the priority handling</td>
<td>137,050,400.00</td>
</tr>
<tr>
<td>14</td>
<td>Late payments due to the budget that are not available or is available but less</td>
<td>137,050,400.00</td>
</tr>
<tr>
<td>15</td>
<td>Late payments due to the budget that are not available or is available but less</td>
<td>137,050,400.00</td>
</tr>
</tbody>
</table>

Figure 2 Risk Dominant

4.3.2 Risk Allocation Algorithm

The default risk values are then sorted from the largest to the smallest. The greater the standard deviation value then indicates a large uncertainty value. The standard deviation value of each of these risks is then cumulative and the maximum limit value is assumed to bear the risk. For that, then in this study developed the amount of maximum limit value borne by the contractor. The risk allocation based on Martin Barnes Algorithm show in Table 4.
The modeling results indicate that there are two risk factors that have an adverse impact and are beyond the contractor's ability to manage them. They are: risk of vehicle overloading and risk of natural disasters, both of them must allocate to the Owner party (Road authorities).

### 5 Conclusion

Contractor party based on experience managing risk of course if burdened risk that is outside his control will raise the price as compensation to accept those risks. The benefits of risk allocation certainly allocate risks to those who have better capability in handling such risks at a lower cost. There are two risk factors that, if not allocated to those with more ability to manage, are the risk of overloading vehicles and natural disasters. Based on calculation of Barnes risk allocation algorithm: if contractors must bear all of risk then the cumulative risk cost more than 10% of the estimated cost (beyond contractors capability). By allocate the risk of overloading vehicles and natural disasters to the owner party the result show that the cumulative under 10% of the estimated cost. In fact, the owner party has capability to control the risk of overloading by regulation force, if the contractor still bear overloading risk, then the owner must facilitate actual traffic volume data and actual total weight data for engineering designing process. These risks depend on the government regulations and stability, but these risks have to be assumed by the private sector. Therefore, the government responsibility is to provide the most stable conditions such as traffic condition and limitation of overloading for the project development. The literature review showed that there are many types of risk that can be present in a PBC project. It was remarkable the comparison done between the literature review about risks and the Indonesia PBC’s projects risk, because it show the differences between the international context and the Indonesia context.

Future research must be focused on each type of risk needs to be deepened (to see more direct potential consequences), sharpened (to ensure the accuracy of risk financing on financial variables) and comprehensively verified (to increase validity). Limitations in the amount of data and respondents will certainly have an impact on determining distribution. This study uses triangular distribution as an approach. While the proposed Martin Barnes algorithm sets the normal distribution as a reference. For this reason, a comprehensive study is needed on determining the probability distribution for the Monte Carlo simulation process.

### 6 References


Organizational attributes enabling innovative culture of the building industry

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Abstract:
Improving innovation can lead to significant productivity improvements. Many organisations are aware that they should be innovating, but they lack the attributes to foster a culture of innovation in their firms and beyond. To be globally competitive, the New Zealand building industry requires a shift in the ways in which it innovates. Whilst this is recognized, this study seeks to answer the question: What are the attributes that are considered significant in enabling innovative culture within an organization? Addressing this, an overview of organizational attributes that can help promote a culture of innovation was undertaken. This paper is literature-based, and thus explored the theoretical concepts. Notable attributes include leadership, collaborative partnering/project team collaboration, knowledge management, communication, research and development, funding, education and training, supportive work environment, commitment, and organization culture/climate/structure. From a practical perspective, this study creates awareness of the attributes that should be given considerable attention by the clients and contractors’ firms towards their innovation efforts. This could enhance the culture of innovation and they (clients and contractors) may be able to invest in technological innovations, thus increasing its uptake and productivity performance. With qualitative evidence available, this paper may provide useful information for researchers regarding the development of scholarly case studies by analysing firms that engage in innovation, their successful attempts, enablers and drivers, barriers overcoming actions, and sources of innovations. This could create an enabling environment for promoting innovative culture in the industry.

Keywords:
Attributes, innovative culture, New Zealand building industry, organization, productivity

1 Introduction

Internationally, the performance of the building industry in terms of productivity, efficiency and quality achievement is considered low when compared with other industries (Schoenborn, 2012). A slow uptake of innovation solutions such as new technologies could be associated with these challenges (Xue et al., 2014). Similarly, the industry has been globally recognized as a relatively slow innovator and low-technology sector (Dansoh et al., 2017), and New Zealand (NZ) is not an exception. Evidence suggested that the New Zealand construction sector is a low innovation achiever with insignificant contribution (5% of total expenditure) to Research and Development (R&D) expenditure; and it contributes trivially to the national innovation effort (Statistics NZ, 2012). Arguably, researchers and practitioners have found innovation as a key value driver and powerful business strategy in many organizations (Suprun and Stewart, 2015; Maghsoudi et al., 2016). In general terms, it is an avenue to improve productivity and efficiency (Maghsoudi et al., 2016).

Substantive research has shown that organizational attributes affect innovative culture (Song and Chen, 2014). Evidence and arguments in construction management researches (Hodgson, 2004; Cohen, 2010; Song and Chen, 2014) indicated that organizational attributes can be either control oriented or flexibility oriented. Control-oriented organizational attributes seek to realize organizational activities as intended, while flexibility-oriented attributes attempt to allow organizational activities to emerge in a directed way. Organizational attributes (control-oriented or flexibility oriented) serve two main functions (Song and Chen, 2014): a constraining function and an enabling function. These suggest that organizational attributes affect organizational actions by functioning as barriers and enablers of organizational behaviours (Hodgson, 2004). Innovation has been found to be related to many organizational attributes, such as leadership (Ozorhon et al., 2010), collaborative partnering (Gambatese and Hallowell, 2011), Knowledge management and communication (Ozorhon, 2013), R&D (Loosemore, 2002), supportive work environment (Ozorhon et al., 2010), and etc (see Suprun and Stewart [2015], and National Science Challenge [2017] for comprehensive reviews). This study focuses on organizational attributes considered as enablers of innovative culture within construction organizations.

Much literature has focused on how construction companies manage innovation process at firm’s level (Tatum, 1987; Slaughter, 2000; Dikmen et al., 2005; Rutten et al., 2009). These studies described the technological innovation process, innovation management, drivers/barriers, and organizational attributes from the point of view of individual firms. The current study therefore proposes that aforementioned issues could offer fundamental evidence towards enabling innovative culture within an organization to transform the industry.

Most studies on construction innovation obtained data from firms located in the Asia, Australia, Europe, Middle East, and United States (Gambatese and Hallowell, 2011). A key task is how some factors can help to promote innovative culture and shape the future of construction to make a better industry. The findings may inform construction firms and industry professionals of how to enable a culture of innovation to maximize productivity performance. This study has been undertaken with a view to providing information on factors/attributes considered significant in enabling a culture of innovation within an organization; and determining their practical relevance to NZ construction environment in further research. This is an under-researched area in NZ, and such information would help decision makers improve the current state of innovative practice. The current study aimed to fill this gap. To help achieve this, the current assessment is literature-based and thus explored the theoretical concepts to investigate the enabling factors/attributes in the context of construction.

2 Literature Review

It is widely identified that the building industry, perhaps more than most others, is prone to challenges with productivity and quality achievement (Xue et al., 2014), hence it needs a shift from its conservative methods to practice (Holt, 2013). Innovation appears to be a crucial subject for research (Maghsoudi et al., 2016), and has acquired recognition in recent years owing to its impact on economic development and productivity improvement (Smith and Estibals, 2011). However, several international studies consider the sector as being slow to change (Gambatese and Hallowell, 2011; Hemstrom et al., 2017) and it seems very challenging to practice innovation in the sector.

150.

151.
The major attributable factors could be the uncertainties and hence risks inherent in construction project developments (Shibeika and Harty, 2016). Many studies have been conducted on how innovation could be defined and the importance of innovation in the construction industry (Sayfullina, 2016; Davidson, 2013; Supran and Stewart, 2015). In general terms, Aouad et al. (2010) defined innovation as the creation and adoption of new knowledge to improve the value of products, processes and services; whereas Taylor and Levitt (2007) viewed this as marketing a new concept. Similarly, the myriad of meanings identified by Gledson and Phoenix (2017) includes ingenuity, entrepreneurship, process improvement, and development and growth. For this study, innovation is defined as the process by which organizations successfully transform new ideas into improved products, services or processes, to distinguish themselves (Loosemore, 2014) as well as improve the values of productivity and efficiency (Maghoudi et al., 2016). Following Gledson and Phoenix’s (2017) categorization, technological innovations (products, services and processes) were considered for investigation, justifying the main objective of this study.

Similar to most countries, the New Zealand building industry is a major contributor to its economic growth and employment (PricewaterhouseCoopers [PWC], 2001) as the sector plays a vital role and dominates national investment in the NZ economy. While Ministry of Business, Innovation and Employment [MBIE] (2014) claimed that the sector contributes about 6.3% to the gross domestic product (GDP) and represents over 40% of the national budget revenue; PWC (2011) affirmed that construction accounts for more than 8% of employment creation and an average of 50% of the gross fixed capital formation (GCFC). However, excessive conservatism in regards to innovative culture has been identified as one of the most common characteristics of not only the NZ but also the global construction community (Ozorhon et al., 2010; Mcmeel and Sweet, 2016).

In the UK, the government is enabling a culture of innovation in construction with the aim to have an industry that is efficient and technologically advanced by 2025 (Shibeika and Harty, 2016). However, in doing so they are faced with challenges concerning the evolving nature of technologies and issues posing hindrance to investment and diffusion of innovations (Shibeika and Harty, 2016). For example, a recent survey of firms in the UK showed that construction manufacturers invest nearly three times as much in Research and Development (R&D) than contractors and twice as much as designers, indicating that innovation occurs around the industry rather than within it (Loosemore, 2014). Thus, investing in innovation leads to higher international competitiveness and faster national economic growth (Smith and Estibals, 2011).

As evidenced in Supran and Stewart (2015), Russian construction sector has been one of its economic driving forces. Despite this, it has frequently been criticised for its reluctance to innovate. Recent research by the Russian Federal State Statistics Service [FSSS] (2014) revealed that only the high-tech sectors such as information and communication technologies, biotechnology and nanotechnology have improved in terms of innovation compared to other sectors (e.g. construction, manufacturing, etc). Meanwhile, a comprehensive survey of Australia claimed that its construction sector has historically had low levels of innovation with only 30.8% of businesses innovating (Loosemore, 2014). In the same vein, the NZ building industry has not been immune to the global lack of innovation, although innovation has been in its long-term national agenda (Mcmeel and Sweet, 2016). For example, in 2010, the Productivity Partnership in NZ identified innovation as critical to achieving significant productivity improvement (Statistics NZ, 2012). Practice changes suggested for the industry include (Hemstrom et al., 2017): industrialised building, building information modelling and lean construction. However, change has proven difficult to achieve. To inspire the global industry, the World Economic Forum [WEF] (2016) developed an industry transformation framework listing 30 measures that could cause a leap forward in industry productivity and innovation (see WEF, 2016 Figure 1: Construction Industry Transformation Framework) These measures are supported by best practices and case studies of innovative approaches.

Much literature has suggested various organizational attributes and how innovation could be implemented in construction projects (Tatum, 1987; Aouad et al., 2010). In response to the accruing evidence that the sector is increasingly at risk to challenges with productivity and performance, Winch (2008) critically questioned the empirical observations of such claims. While it is impossible in this current study to cover this entire literature, this paper explored some of the enabling factors/attributes that are considered significant to innovative culture A selection of studies in developed economies on organizational attributes (enabling factors) is summarised in Table 1. The objective is to provide theoretical confirmation of the attributes/enabling factors, generated in studies from around the world. This, therefore, adds to and consolidates existing knowledge. Some of the explored attributes include:

2.1 Leadership

The principles of innovative leadership should define and allow workers to generate, interpret and implement new ideas in a way that guarantees compatibility with the mission of an organization (Berson et al., 2006). To be innovative, leadership is decisive by applying organizational strategy for supporting team expectations towards innovative culture, thus this attribute is widely regarded as a key enabler of innovation within the construction industry (Ozorhon et al., 2010). In their study, Loosemore and Holliday (2012) identified government and private sector as major clients that must lead by demanding more innovation and creating a competitive environment where innovation can thrive. They further stressed that major firms in the construction sector should also have a responsibility to lead by driving innovation through investment in R&D, educating clients and workers about the benefits of innovation, the will to support new ideas, helping smaller firms to support new ideas, sharing risk and reward, and continuously striving to improve performance on their projects. In Ivory’s (2005) opinion, many clients are unwilling and unable to effectively encourage innovation; they view buildings as short-term asset and do not understand the relationship between their buildings and their real business performance. This is the economic predicament of innovation in the building industry.

2.2 Collaborative partnering (project team collaboration)

Research has demonstrated that construction is fundamentally an industry based on relationships and people working together closely in a highly problem-solving environment (Loosemore, 2015). Previous studies claimed that encouraging people to team together and assist with idea development and implementation fosters innovation performance (Eisenbeiss et al., 2008). For example, collaborative contracts (e.g. alliance, public-private partnership, joint venture, partnering) can be used to enable or promote innovation, as one is conscious of the fact that internal or external collaboration/team work among professionals, organizations/companies, government and industry will ensure efficiency during innovation process.

2.3 Knowledge management and communication
Innovations are performed through strategies focused on collaboration respecting multiple methods of communication and knowledge transfer (Gambatese and Hallowell, 2011). While lack of communication could be considered a barrier to innovation implementation (Swan et al., 2003), the practice of communication within an organization would be an innovation enabler (Gambatese and Hallowell, 2011). Similarly, exchange of knowledge and expertise in all areas of construction is perceived amongst the main enablers of innovation (BRANZ Report, 2016). Hence, it is noteworthy that cultivating strong lines of communication within companies and encouraging knowledge sharing externally may ensure greater collaboration and innovation. In essence, knowledge sharing may lead to better quality information enabling the industry to effectively harness ideas and promote innovations at all levels.

2.4 Research and development (R&D)

Loosmore et al. (2002) affirmed that the benefits of R&D investment are restricted, as firms are not well equipped physically or mentally to undertake R&D, and this is considered to be a problematic process offering little value and a restrictively long payback period. Wilkinson et al. (2017) however claimed that R&D can provide an opportunity for ideas to be tested to ensure suitability for universal application. The opportunity that can be provided by R&D to carry out a project makes it an integral part of the innovation process. Wilkinson et al. (2017) further claimed that R&D investment by the construction industry has been low. Modern infrastructure and construction may benefit enormously by increasing R&D investment to exploit the use of new technologies to provide innovative new solutions, thereby making radical changes to the construction and management of infrastructure.

2.5 Supportive work environment

When people work in a supportive environment, they tend to produce results; such an environment is called a positive work climate. Work climate is known as the weather of a workplace, and this influences people’s behaviour at work. Most importantly, a positive work climate can lead to and sustain staff motivation and high performance (Stringer, 2002). A critical component for enabling innovation both intra- and inter-organizationally is fostering a culture in which people are not subjected to punitive sanctions for making mistakes, or if they pursue initiatives that are not successful (Report of the Construction Task Force, 1998). While a supportive climate is essential to fostering creativity, creativity of individual employees seems to be the cornerstone of organizational innovation (Oldham and Cummings, 1996). It is noteworthy that where schemes are put in place without the surrounding cultural factors of leadership and supportive environment, they (such schemes) are not likely to flourish (Ozorhon et al., 2010).

3 Research Methodology

This study is a theoretical research based on literature review and thus explored concepts on firms’ attributes considered significant in enabling a culture of innovation. The literature review provided a general overview of recent research on organizational attributes that act as enablers of innovation. The literature sources were accessed through databases which provided numerous academic journals, conference papers and national reports. In addition, some textbooks found to be useful to the research process were referenced. Thus, a comprehensive literature survey was carried out to collect information on relevant studies on this topic. The search process made use of the following search engines and paper archives: Google and Google Scholar, Emerald and...
Scopus Journal databases. This extensive search strategy enabled these researchers to capture both formally published papers and a few recent national reports. This method is capable of sharing with readers the results of other studies that are closely related to the one being undertaken, conforming to suggestions by Cooper (2010). This relates a study to the larger knowledge in extant literature, fills in gaps and expands existing knowledge (Marshall and Rossmann, 2011). Essentially, this method is used to provide a framework for establishing the importance of the study, and a benchmark for results comparison (Cresswell, 2014). Thus, this methodology has the potential to provide deeper insight into the topic through an intense encounter with theoretical concepts. The success of this method strongly depends on the quality rather than the quantity of the concepts.

Table 1: Comparison of studies on organizational attributes (enabling factors) of innovative culture in extant literature

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<tbody>
<tr>
<td>Study area</td>
<td>UK</td>
<td>USA</td>
<td>USA</td>
<td>UK</td>
<td>Russia</td>
</tr>
<tr>
<td>R1</td>
<td>Leadership</td>
<td>Owner influence</td>
<td>Effective upper management</td>
<td>Collaborative partnering</td>
<td>Public support through subsidies and grants</td>
</tr>
<tr>
<td>R2</td>
<td>Supportive work environment</td>
<td>Presence of an innovation champion</td>
<td>Owner/client support</td>
<td>Supportive work environment</td>
<td>Competitive pressure</td>
</tr>
<tr>
<td>R3</td>
<td>Collaboration with partners</td>
<td>Project team collaboration</td>
<td>Organization culture</td>
<td>Leadership</td>
<td>Information gathering</td>
</tr>
<tr>
<td>R4</td>
<td>Deep understanding of the customers</td>
<td>Project team integration</td>
<td>Presence of an innovation champion</td>
<td>Commitment</td>
<td>Coordination with universities and scientific research institutes</td>
</tr>
<tr>
<td>R5</td>
<td>Education and training policy</td>
<td>Communication</td>
<td>Level of communication within the firm</td>
<td>Knowledge management practices</td>
<td>Demanding market</td>
</tr>
<tr>
<td>R6</td>
<td>Knowledge management practices</td>
<td>Lessons learned/knowledge management</td>
<td>Amount of funds available for research and development</td>
<td>Reward schemes</td>
<td>Personnel participation</td>
</tr>
<tr>
<td>R7</td>
<td>Encouraging staff to get involved with external networks</td>
<td>Upper management support</td>
<td>-</td>
<td>Innovation policy</td>
<td>Access to modern technologies, practices and solutions</td>
</tr>
<tr>
<td>R8</td>
<td>Use of problem-solving techniques</td>
<td>Research and development</td>
<td>-</td>
<td>-</td>
<td>Cooperation between participants of the construction process</td>
</tr>
<tr>
<td>R9</td>
<td>Awards, grants, funds</td>
<td>Employee recognition</td>
<td>-</td>
<td>-</td>
<td>Strict standards and regulations</td>
</tr>
<tr>
<td>R10</td>
<td>Government schemes</td>
<td>Organizational structure</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R11</td>
<td>Reward schemes</td>
<td>-</td>
<td>-</td>
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<tr>
<td>R12</td>
<td>Emphasis on R&amp;D</td>
<td>-</td>
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Note: R = Rank

4 Findings from the review of literature

It becomes evident from the review of related literature that frequently occurring attributes (see Table 1) have been identified as enabling factors of innovative culture. This, therefore, adds to the current state of knowledge regarding issues relating to organizational attributes that can help promote a culture of innovation; and to determine their practical relevance to NZ construction environment.

As can be seen from Table 1, a thorough review of related literature revealed a number of factors identified as organizational attributes that substantially influence the innovative culture of the building industry in various contexts (Ozorhon et al., 2010; Gambatese and Hallowell, 2011; Ozorhon, 2013; Suprun and Stewart, 2015). The insight gained from the submission suggested the following attributes: (1) leadership, (2) collaborative partnering/project team collaboration, (3) knowledge management, (4) communication, (5) research and development, (6) funding, (7) education and training, (8) supportive work environment, (9) commitment, and (10) organization culture/climate/structure. Making this clear, this insight provided for positioning this study within the various observable factors prominent for application in practice. Based on the foregoing findings, these attributes should help firms enable or promote innovative culture within them, and beyond.

5 Conclusion and Further Research

Within the limitations of the theoretical exploration, prominent firms’ attributes include leadership, collaborative partnering/project team collaboration, knowledge management, communication, research and development, funding, education and training, supportive work environment, commitment, and organization culture/climate/structure. These will be validated in a pilot study to be conducted with a few construction practitioners to determine their practical relevance to NZ construction environment. However, an early study by Tatum (1987) held the view that leadership, supportive organizational structure, collaboration, and customer orientation are the main firms’ attributes that act as enabling factors of innovative culture in their order of importance.

This paper made the following contributions. First, it provides useful information for researchers regarding the development of scholarly case studies by analysing firms that engage in innovation, their successful attempts, enablers and drivers, barriers overcoming actions, and sources of innovations. This could create an enabling environment for promoting innovative culture in the industry.

Second, from a practical perspective, this study creates awareness of the attributes that should be given considerable attention by the clients and contractors’ firms. This could enhance the culture of innovation and they (clients and contractors) may be able to invest in technological innovations, thus increasing its uptake and productivity performance. Further development of the work reported here, when further data and are collected and analysed, will provide information for the development of an innovation tool for application in New Zealand. Future study could also explore a factor approach to the analysis of factors responsible for slow uptake of innovation in the NZ building industry.
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The optimal sizes of workstation area and storage area in a precast plant for manufacturing of modular prefabricated products

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Abstract:

Inspired by the Toyota production system which represents the highest levels of manufacturing efficiency in the world automobile industry, some precast factories plan to adopt a similar automated guided vehicle (AGV)-based flow production system for manufacturing of their modular prefabricated products. However, the manufacturing system of modular prefabricated products has many unique features. The deviations between successive operation times cause a large number of queues accumulated in the system. And after some operations, the interim products may need a long settling period. Due to the big product size, the queues and the settling units will consume a large area. As a result, facility layout becomes a key concern in design of such a manufacturing system. This paper aims to propose an optimal arrangement of the sizes for workstation area and storage area for a particular production project. The operations on the workstations are allowed to be changeable. A bi-objective optimization model is developed and solved using a non-dominated sorting genetic algorithm. A simulation approach is adopted to assess how good a chromosome in the genetic algorithm it is to this optimization problem. Finally, a nondominated sorting genetic algorithm. A simulation approach is adopted to assess how good a chromosome in the genetic algorithm it is to this optimization problem. Finally, an industry case is studied, showing the potential of the developed approach to guide the real-world practice.

Keyword:

Facility layout, flow manufacturing, genetic algorithm, modular prefabricated products, simulation

1. Introduction

1.1. Motivation

Since the end of last century, people began to compare the construction industry with the automotive industry, especially the Toyota production system (TPS), which displays the highest levels of manufacturing efficiency in the world automobile industry (Gann, 1996; Crowley, 1998). These cross-industry learning practices discovered that the prefabricated house production systems and the automobile production systems share many similarities. The concepts of lean production concept and integration with computer integrated manufacturing (CIM) that are implemented in the TPS have attracted considerable interests from architects and builders. In this context, moving the building process from the physical site to a controlled plant environment becomes a growing trend. With prefabricated construction, the building elements are fabricated in a manufacturing factory simultaneously with the site work using the same materials and following the same building codes and architectural specifications as traditional construction. Once assembled at site, they are virtually indistinguishable from their site-built counterparts. Compared to the traditional construction methods, prefabricated construction provides benefits including improved quality, productivity, efficiency and safety (Zhai, et al., 2014). Furthermore, prefabricated construction is recognized for its significant role in the creation of sustainable urbanization (Hong, et al., 2018). Hence, authorities are actively promoting the use of prefabricated building elements. For example, Singapore as a country having severe labor shortage is taking on a batch of rules to raise the precast level in all residential projects on government land sale (GLS) sites (www.bca.gov.sg).

Based on the level of manufacturing and the magnitude of offsite assembly, prefabricated construction can be categorized into four categories: pre-cut, panelized, modular and manufactured (Gibb, 1999). Among the spectrum of prefabricated products, prefabricated bathroom unit (PBU) and prefabricated prefinished volumetric construction (PPVC) are the most complete in factory finishes. They are 3D building components with internal finishes, fixtures and fittings and assembled on site in the manner of Lego blocks. PBUs and PPVCs are now widely used in multi-level and even high-rise buildings of various functional purposes. In the drive to push for productivity, precast factories are stepping up efforts to adopt an automated guided vehicle (AGV) flow production system for mass manufacturing of PBUs first, if successful, then PPVCs. The current practice requires the workers carrying their tools and the materials to find the assigned units in a maze of rows and columns. There are a lot of time wastes in logistics. However, the flow production method divides the process into many segregated operations and each operation is performed on a workstation. The work-in-progress are moved around the fabrication yard by AGVs whereas workers stay at the fixed workstations.

Facility layout has a significant impact on manufacturing performance of such a flow production system. A poor layout can disturb the production flow and even make the entire system being deadlocked. As the size of a PBU or a PPVC is usually very large, the queues in the system will consume a lot of storage space. And unfortunately, this is an unbalanced production line that the longer operation (e.g., tiling) can be more than 48 hours while the shorter (e.g., ponding) can be less than 1 hour. As a result, a great amount of queues are unavoidable. After workstation operations (e.g., tiling and ponding), a long settling period may be required. The settling units are also placed in the storage area. Therefore, a very large central storage area which restricts human entry is eventually needed. In order to lower down the need on storage area, a flexible system in which the workstations are changeable to perform different operations is preferred. A group of workers who are capable of different operations support this dynamic adaptation. The transition from one operation to another requests only a flexible material handling system yet the workstation setup cost is ignorable.

Shortest production time and highest workstation utilization are the two key concerns in the design of an efficient manufacturing system for the modular prefabricated products. In this regard, this paper develops an optimization approach which is able to propose an appropriate number of workstations for the manufacturing system given the plant size. When the number of workstations is decided, the storage space then can be easily derived. A rule-based scheduling system is designed to arrange operations on the workstations dynamically adaptable to the production status. A bi-objective optimization model is developed and solved using a non-dominated sorting genetic algorithm. A simulation...
approach is adopted to assess how good a chromosome in the genetic algorithm it is to this optimization problem.

As the two objectives are conflicting, there is no single solution that can improve one objective without degrading the other. A set of optimal solutions will be finally generated. In the real practice, the selection of a proper solution will be made on consideration of many practical factors. Solution of a smaller number of workstations will be more likely to be chosen when manpower resource is in short. On the other hand, solution of a bigger number of workstations will probably be chosen when project time is quite tight. Hence, the developed approach provides a useful tool for facility planning in the modular prefabricated manufacturing environment.

1.2. Literature review

There are a lot of research on Toyota production system in the past decades (Sugimori, et al., 1977; Lander & Liker, 2007; Sakai & Amasaka, 2008; Li, 2013). The TPS is the best-known example of lean. It presents two distinctive features: the first is the concept of “reduction of cost through elimination of waste” and the second is the concept of “to make full use of the workers’ capabilities”. The successful story of the TPS has led to a movement of “lean production” in many other industries. In 1980s, the advanced TPS integrated “just-in-time” with computer integrated manufacturing (CIM) (Monden, 2011). The addition of computer technologies and information systems further reduce costs, increase quality, and decrease lead-time.

Automated guided vehicles are widely used in the environment of flexible manufacturing. The automated guided vehicle – flexible manufacturing system (AGV-FMS) represents a highly sophisticated CIM implementation and has attracted a great amount of research efforts (Vosniakos & Davies, 1988; Maughan & Lewis, 2000; Reddy & Rao, 2006; Babu, et al., 2010; Umar, et al., 2015). A typical FMS is composed of a group of numerically controlled machines and an automated materials handling system (MHS). Majority of the research efforts focus on scheduling of the machines and the AGVs (Reddy & Rao, 2006; Babu, et al., 2010; Umar, et al., 2015). The developed off-line algorithms often simultaneously schedule the machines and the AGVs. They usually assume the types and number of machines are known and there is sufficient input and output buffer space for each machine. However, these assumptions are not appropriate for the investigated manufacturing system where storage space is a bottleneck to the system.

Facility layout is a key element to the AGV-based flow production system (Hammad, et al., 2008). The problem of facility layout has been actively studied for half a century (Hosseini-Nasab, et al., 2018). The research of facility layout goes two directions: block layout and machine layout (Keller & Buscher, 2015). The former specifies the relative location of each department inside the factory while the latter deals with the machine layout in the department which is also considered as detailed layout. Block layout is close to the problem investigated in this paper. A pairwise exchange technique which is called computerized relative allocation of facilities technique (CRAFT) (Armour & Buffa, 1963) can be used to solve the block layout problem. However, CRAFT is a heuristic method, and it does not guarantee optimality because not all the combinations are assessed.

Besides, the block layout problems are often converted into a quadratic assignment problem (QAP) (Koopmans & Beckmann, 1957). A typical QAP assumes all the departments are of equal area. Although some researchers (Armour & Buffa, 1994) modified it to account for unequal-area facility layout problem (UA-FLP), the developed modified QAP is found inefficient (Bozer & Meller, 1997). But recent studies on UA-FLP have achieved some encouraging progresses (Wong, 2010; Aiello, et al., 2013; Liu, et al., 2018). Various efficient meta-heuristics are developed for the problem. For example, Wong developed an ant colony optimization (ACO), Aiello et al. proposed a non-dominated sorting genetic algorithm (NSGA-II) and Liu et al. designed a particle swarm optimization (MOPSO). However, the UA-FLP model is based on slicing tree structure that the parent rectangle is divided completely either in horizontal or vertical direction from one side to the other and recursively continue with the newly generated rectangles. This model will generate a lot of child rectangles. But the investigated problem is composed of only two departments which are workstation area and storage area. Consequently, the slicing tree structure is not very proper for the investigated problem.

From the above literature review, it is found there is no existing facility layout model appropriate to this investigated problem.

1.3. Our contributions

AGV-based flow production system is novel for manufacturing of modular prefabricated products. There is no such a system in real world yet. This paper gives a framework of facility layout planning for this conceptual system. The major contribution of this work is to provide a way for the managers to decide the best arrangement of the sizes between the workstation area and the storage area in a given size of plant area. The production schedule is also simultaneously obtained from the optimization. The production time and the workstation utilization are able to be predicted.

1.4. Organization of the paper

The organization of this paper is arranged in this way: following the introduction is the optimization model. The section gives its mathematical expression. Section 3 describes the solving approach. The design of NSGA-II and the rule-based simulation are explained. Section 4 shows study on an industry case. And finally Section 5 concludes the paper and recommends the future research.

2. Optimization model

2.1. Decision variable

\[ x: \text{number of workstation slots}, \ x \in \{1, S\} \]

\[ \alpha_{i}: \text{binary variable, } 1 \text{ if workstation } i \text{ is busy at time } t, \ 0 \text{ otherwise} \]

\[ \beta_{i}: \text{binary variable, } 1 \text{ if storage space } j \text{ is occupied at time } t, \ 0 \text{ otherwise} \]

2.2. Parameters

\[ S: \text{given plant size} \]

\[ N: \text{production volume} \]

\[ T: \text{production time} \]

\[ t: \text{time}, t = 0, ..., T \]

\[ y: \text{number of storage slots}, y = S - x \]
The developed optimization model has two conflicting objectives: minimizing the production time and maximizing the workstation utilization.

**Objective (1)**

\[
\text{Minimize } T \quad (1)
\]

**Objective (2)**

\[
\text{Maximize } U = \sum_{i} \sum_{t} o_{i}(x_{i}) / (x \cdot T) \quad (2)
\]

**Constraints**

Constraint (3) indicates that the total number of PBUs currently in the manufacturing system should not exceed the capacity of the system. Constraint (4) shows that one PBU occupies only one slot in the storage area for settling or queuing.

\[
\sum_{i} o_{i}(x_{i}) + \beta_{t} \leq C, \forall t \quad (3)
\]

\[
\sum_{i} \beta_{t} = \sum_{i} \left[ t \cdot \left( 1 - ST_{o_{i}(x_{i})} \right) PT_{o_{i}(x_{i})} + ST_{o_{i}(x_{i})} \right], \forall t \quad (4)
\]

**3. Solving approach**

**3.1. Non-dominated sorting genetic algorithm**

The developed optimization model has two conflicting objectives: minimizing the production time and maximizing the workstation utilization. A multi-objective optimization problem with conflicting objectives, no single solution exists that can simultaneously optimize all the objectives. Therefore, there are multiple optimal solutions for the problem. The set of multiple optimal solutions creates the non-dominated front, also called Pareto front. Searching the Pareto front typically involves the use of a population-based search algorithm such as genetic algorithm. Deb et al. proposed a non-dominated sorting genetic algorithm (NSGA) in 1994 (Srinivas & Deb, 1994) and a revised one, namely NSGA-II in 2002 (Deb et al., 2002). NSGA-II is a fast and elitist multi-objective evolutionary algorithm (MOEA). It can sort out a complete set of Pareto fronts in a single run. Compared to its previous version, NSGA-II has the following three features:

1. \(O(MN^2)\) computation complexity (where \(M\) is the number of objectives and \(N\) is the population size);
2. (2N) evolution strategy. Successive population is produced by selecting \(N\) better solutions from a combination population of parents and children. If the number of elitists exceeds the number of population size for the next generation, there is no need to continue the sorting procedure.
3. Crowded-comparison. The density of solutions surrounding a particular solution in the population is estimated by calculating the average distance of two points on either side of the point along each of the objectives. The boundary solutions are assigned with infinite crowding distance. The solutions having the same objective values may have different crowding distances. However, if more than two solutions share the same objective values, the additional solutions will be assigned with a crowding distance of 0.

The pseudo codes of the NSGA-II and the non-dominated sorting procedure are given as below:

**NSGA-II procedure**

1. Initialize the population by randomly creating individuals
2. Non-dominated sorting of the parent population
3. While not enough individuals in the child population
   (1) Do tournament selection to select parent 1
   (2) Do tournament selection to select parent 2
   (3) Crossover parent 1 and parent 2
   (4) Mutate on the crossover children
4. Construct a combination set by combining the parent population with the child population which is obtained from the genetic operators
5. Non-dominated sorting of the combination set
6. Select the elitists from the sorted combination set to create the population for the next generation
7. Repeat from 2 to 6 until meeting stop conditions

**Non-dominated sorting procedure**

1. Calculate the values of the two objective functions for the child population
2. Order the child and its parent population according to the two objectives into a hierarchy of non-dominated Pareto fronts
3. Calculate the crowding distances between members on each front
4. Discriminate members of the population first by order of dominated precedence of the front to which the solution belongs and then distances within the front

Every individual in the population has two attributes: (1) non-domination rank, and (2) crowding distance. Between two solutions with different non-domination ranks, the solution with lower rank is preferred. Otherwise, if both solutions belong to the same front, then the solution that is located in a lesser crowded region is preferred.

The chromosome used in the NSGA-II is designed in a binary form, the size of which is equivalent to the given plant size. Each digit in the chromosome points to a location in the fabrication yard and the binary digit itself indicates this is a workstation slot or a storage slot. For example, 1 indicates a workstation slot and 0 indicates a storage slot. The binary values of the chromosomes in the initial generation are randomly generated with a given probability. A tournament selection operator based on the rank and crowded distance is introduced in the parent selection for crossover. The tournament size is 2. Single-point crossover method is introduced and it happens with a given probability. Mutation is performed by altering a digit in the chromosome and it happens with a given probability.
As iteration goes, the populations of GA will become more and more homogeneous. Loss of population diversity will lower down the search capability of the algorithm. Also, if the population size is less than the number of solutions on the Pareto front, the found solutions will be incomplete. To overcome these difficulties, the duplicated individuals in the population will be replaced by randomly generated ones. The related GA parameters are summarized as below:

- **Gen**: iteration
- **Pop**: population size
- **P_b**: binary value probability
- **P_c**: crossover probability
- **P_m**: mutation probability

The objective values of a chromosome are obtained from running simulations. And the design of the used simulation approach is explained in the following subsection. In order to save computational cost, a library is built to store the objective values of different combinations of workstation numbers and storage slot numbers. If the objectives values of a given number of workstations and storage slots have already been in the library, the values can be simply retrieved from the library without conducting another full run of simulation.

### 3.2. Simulation

A rule-based simulation is developed. It provides useful knowledge about the dynamic behavior of the production system. In this paper, first-come-first-served rule (FCFS) is applied. The purpose of this program is to calculate the workstation utilization and the production time. Figure 1 gives the flowchart of the simulation algorithm.

In the algorithm, if the number of PBUs in the manufacturing system is less than the system’s capacity, new PBUs will be added to the production line till no more PBUs in queue. The capacity of the manufacturing is determined by the capacity of the storage area because it is assumed that the PBUs are not allowed to wait on the workstations after their workstation operations then shortage of the storage slot will cause the entire system being deadlocked. The time step is variable. It increases from the current time to the earliest start time of the ready-to-go tasks in the task list. Furthermore, operations on the workstations are changeable. Since manual operations are used and workers are assumed to be capable of different operations, the setup cost of an operation on a workstation is ignorable. Below heuristic rule is applied for the algorithm to decide the workstation operations:

**Decision rule for workstation operations**

1. Create a list A for the tasks which require workstation operations
2. Create a list B for the workstations operations of which can be changed
3. Compare list A with list B following below sequence:
   - (1) Assign the tasks in list A to the workstations in list B current operations of which are happened to be the operations required by the tasks. The FCFS rule is followed
   - (2) For the remaining tasks in list A, if the PBUs are currently on the workstations, then change the operations of those workstations to the operations required by those tasks
   - (3) For the other tasks in list A, change the operations of the workstations to the operations required by the tasks following the FCFS rule
4. For those remaining tasks still unassigned in list A, they will be kept and merged with the new ready-to-go tasks at the next time step

After the workstation operations have been arranged, the movement of PBUs will begin. The criteria for triggering a movement are the finish time of the current operation and the availability of the next workstation. For every PBU in the ready-to-go task list, the algorithm decides its movement according to the following rules:

1. If this is a new PBU to the manufacturing system, check whether there is an available workstation for its first operation
   - (1) If yes, the PBU will be loaded and moved to that workstation and start its first operation
   - (2) Otherwise, it will not be loaded to the manufacturing system
2. If this PBU is currently on a workstation, check whether settling is needed afterwards
   - (1) If yes, the PBU will be moved to a storage slot for settling
   - (2) Otherwise, further check whether there is PBU has finished its last operation
     - (a) If yes, the PBU will be considered finished and deleted from the task list
     - (b) Otherwise, further check whether there is an available workstation for its next operation in the process sequence
6. Facility breakdown is not considered.

5. There is enough manpower;
6. The AGV’s travelling route is not considered;
7. The AGV’s travelling time is neglected;
8. The AGV’s travelling route is not considered;
9. There is enough manpower;
10. Facility breakdown is not considered.

In consequence, movements of all operations in the ready-to-go task lists are started at the same time. Their operation finish time is calculated by adding the current time and the operation processing time. The simulation terminates till the required demand has been totally fulfilled.
Table 1 describes the production. Totally there are six product types: M01, M02, M03, T01, T02, and T03. The production quantity is 335 units. There are four elementary operations: P1 - Ceiling frame, P2 - Plumbing and electrical, P3 - Tiling, and P4 - Sanitary fitting and shower screen. Among them, P3 and P4 require settling operations afterwards. The quantities of every products to be manufactured are given and their process sequences are also known. For M01, M02, M03 and T03, the process sequence is: P1 - P2 - P3 - P4. For T01, the process sequence is P2 - P3 - P4. And for T02, the process sequence is P1 - P3 - P4.

<table>
<thead>
<tr>
<th>Process</th>
<th>Time (hours)</th>
<th>Process sequence</th>
<th>Settle</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>3</td>
<td>M01</td>
<td>1</td>
</tr>
<tr>
<td>P2</td>
<td>6</td>
<td>M02</td>
<td>2</td>
</tr>
<tr>
<td>P3</td>
<td>24</td>
<td>M03</td>
<td>3</td>
</tr>
<tr>
<td>P4</td>
<td>7</td>
<td>T01</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T02</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T03</td>
<td>4</td>
</tr>
</tbody>
</table>

The performance of a genetic algorithm depends on several numerical parameters (initial population type, population size, maximum generation number, and crossover and mutation probabilities). However, the problem-specific nature of GA makes it difficult to draw a universal best combination of these parameters for all problems. Therefore, an extensive sensitivity analysis on the numerical parameters has been conducted in this study in order to provide insights about an appropriate GA parameter setting for the investigated problem. It is known that the population size and the maximum generation number have positive effect on the solution. Larger values of them apparently can increase the probabilities of obtaining better solutions yet at the expense of more CPU time. The previous research recommends that the population size is chosen between one and two string size of a chromosome (Alander, 1992). Sensitivity analysis is performed on these plant sizes: S = 30, 40, 50, 100, 150 and 200. The maximum generation number and population size are: Gen = 400, Pop = 200. Values of binary value probability, crossover and mutation probabilities are within the following ranges: Pb = 0.1 to 0.4 in steps of 0.1, Pc = 0.6 to 0.9 in steps of 0.1, and Pm = 0.1 to 0.4 in steps of 0.1. Every GA run repeats 10 times from different initial populations. All the solutions found are preserved in a solution list. The results of sensitivity analysis are presented in Table 2.

<table>
<thead>
<tr>
<th>P0,b</th>
<th>P0,c</th>
<th>P0,m</th>
<th>S = 30</th>
<th>S = 40</th>
<th>S = 50</th>
<th>S = 100</th>
<th>S = 150</th>
<th>S = 200</th>
</tr>
</thead>
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<tr>
<td>0.1</td>
<td>0.6</td>
<td>0.1</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>22</td>
<td>32</td>
</tr>
<tr>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>0.8</td>
<td>0.1</td>
<td>0.4</td>
<td>0.4</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>0.9</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>10</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 2. Effect of binary value, crossover and mutation probabilities on the obtained number of optimal solutions on the Pareto front
Table 3. Optimal solutions

<table>
<thead>
<tr>
<th>n</th>
<th>x1</th>
<th>x2</th>
<th>S = 350</th>
<th>T</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>349</td>
<td>13009</td>
<td>99.94%</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>348</td>
<td>6510</td>
<td>99.85%</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>347</td>
<td>4343</td>
<td>99.79%</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>346</td>
<td>3259</td>
<td>99.73%</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>345</td>
<td>2610</td>
<td>99.62%</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>344</td>
<td>2176</td>
<td>99.58%</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>343</td>
<td>1668</td>
<td>99.43%</td>
<td>0.2</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>341</td>
<td>1453</td>
<td>99.42%</td>
<td>0.2</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>340</td>
<td>1309</td>
<td>99.32%</td>
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</tr>
<tr>
<td>10</td>
<td>10</td>
<td>338</td>
<td>1092</td>
<td>99.21%</td>
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</tr>
<tr>
<td>11</td>
<td>11</td>
<td>337</td>
<td>1012</td>
<td>98.82%</td>
<td>0.2</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>335</td>
<td>878</td>
<td>98.72%</td>
<td>0.2</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>334</td>
<td>824</td>
<td>98.61%</td>
<td>0.2</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>332</td>
<td>733</td>
<td>98.54%</td>
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</tr>
<tr>
<td>15</td>
<td>15</td>
<td>330</td>
<td>661</td>
<td>98.34%</td>
<td>0.2</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>329</td>
<td>630</td>
<td>98.27%</td>
<td>0.2</td>
</tr>
<tr>
<td>17</td>
<td>17</td>
<td>328</td>
<td>602</td>
<td>98.17%</td>
<td>0.2</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>326</td>
<td>552</td>
<td>98.14%</td>
<td>0.2</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>321</td>
<td>458</td>
<td>97.88%</td>
<td>0.2</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>320</td>
<td>444</td>
<td>97.61%</td>
<td>0.2</td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>315</td>
<td>381</td>
<td>97.56%</td>
<td>0.2</td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>314</td>
<td>373</td>
<td>96.82%</td>
<td>0.2</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>313</td>
<td>363</td>
<td>96.80%</td>
<td>0.2</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>309</td>
<td>328</td>
<td>96.68%</td>
<td>0.2</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>307</td>
<td>313</td>
<td>96.60%</td>
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</tr>
<tr>
<td>26</td>
<td>26</td>
<td>304</td>
<td>293</td>
<td>96.46%</td>
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</tr>
<tr>
<td>27</td>
<td>27</td>
<td>303</td>
<td>288</td>
<td>96.05%</td>
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</tr>
<tr>
<td>28</td>
<td>28</td>
<td>302</td>
<td>283</td>
<td>95.71%</td>
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<tr>
<td>29</td>
<td>29</td>
<td>299</td>
<td>269</td>
<td>94.77%</td>
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</tr>
<tr>
<td>30</td>
<td>30</td>
<td>298</td>
<td>265</td>
<td>94.35%</td>
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</tr>
<tr>
<td>31</td>
<td>31</td>
<td>292</td>
<td>238</td>
<td>94.18%</td>
<td>0.2</td>
</tr>
<tr>
<td>32</td>
<td>32</td>
<td>289</td>
<td>232</td>
<td>91.87%</td>
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</tr>
<tr>
<td>33</td>
<td>33</td>
<td>275</td>
<td>189</td>
<td>91.72%</td>
<td>0.2</td>
</tr>
<tr>
<td>34</td>
<td>34</td>
<td>271</td>
<td>180</td>
<td>91.43%</td>
<td>0.2</td>
</tr>
<tr>
<td>35</td>
<td>35</td>
<td>259</td>
<td>157</td>
<td>91.00%</td>
<td>0.2</td>
</tr>
<tr>
<td>36</td>
<td>36</td>
<td>236</td>
<td>126</td>
<td>90.51%</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* given plant size  
* number of workstation slots  
* number of storage slots  
* production time  
* utilization of workstation

Since the capacity of the manufacturing system is determined by the capacity of the storage area, for the same number of workstations due to different number of storage slots, the obtained objective values are different. Typically, the larger the size of the storage space, the better the solution is. A manager can select a suitable plant size and an appropriate number of workstations based on the project targets and the factory’s resource. At last a balanced solution will be arrived at after taking into account of the factory’s real situation. For example, if project time is the key concern, then a larger number of workstations will be chosen. But if manpower is in shortage, then a smaller number of workstations will be considered.

From the above Table 2, it is observed that the obtained solutions follow a pattern for different values of P3, P2 and Pm. More solutions are obtained when the values of binary value probability, crossover and mutation probabilities are small. Hence, P3 = 0.1, P2 = 0.6 and Pm = 0.1 are used. The complete optimal solutions on the Pareto front for the studied case are provided in Table 3.
5. Conclusions and further research

The studied manufacturing system for manufacturing of modular prefabricated products is a very unbalanced production line. A large amount of queues can be generated during the production, leading to the need of a large storage space. Due to the limited plant size given, to balance between workstation area and storage area is necessary. This paper attempts to provide the optimal arrangement of the sizes of workstation area and storage area for a particular production project. The problem is formulated into a multi-objective optimization problem. There are two conflicting objectives: to minimize the production time and to maximize the workstation utilization. This model is solved using NSGA-II and fitness of each individual in the GA population is obtained by simulation. The developed approach is experimented on an industrial case. The results show this is a powerful and efficient approach.

There are some assumptions in the model. The major assumptions are that the fleet size and performance of AGVs are not considered. However, in the real practice, the availability of an AGV and the moving speed of AGVs have impact on the production planning. The manufacturing process of a product cannot move forward if there is no AGV that can be hired for the current moving task. In addition, the speeds of AGVs moving towards different directions are usually different. The speed in side-ways is less than the speed in front-back. So, even for the same route, it can take different traveling time for an AGV. It is unlikely that the ready-to-go moving tasks can start at the same time. In this regard, planning including the factors of AGVs is desired.

As the capacity of the manufacturing system is determined by the storage space, it is also necessary to further optimize the product location layout in the storage area. To save space, it is expected a real-time dynamic path planning system is used for AGVs’ traveling. Reshuffles may be needed before AGV can reach the assigned unit. The cost of reshuffles should be minimized.

Seeing the drawbacks and limitations of current research, the focus of the future research should turn towards an integrated approach by incorporating the AGV fleet size, the AGV moving speed, the AGV routing and storage reshuffling.

Acknowledgement

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References


Abstract: The students’ pre-course perceptions of a subject provide insight relative to their understanding and appreciation of a subject and challenges that the lecturer may encounter. Furthermore, post-course perceptions can be compared with pre-course perceptions to determine the impact of the presentation of the subject, if any. The purpose of the study reported on is to determine the pre- and post-course History of the Construction Industry perceptions of second-year construction management students, based upon a self-administered questionnaire survey conducted in a South African university. The purpose of the subject is to provide construction management students with historical perspectives with respect to the role of construction and the related professions and industrial processes in the progress and development of civilisations. Findings include: the subject History of the Construction Industry is perceived important relative to the other subjects in the BSc (Construction Studies) programme, History of the Construction Industry knowledge areas are perceived important, and with the exception of two activities/functions, History of the Construction Industry knowledge will assist respondents to a major as opposed to a minor extent relative to all the construction management activities/functions. Conclusions include that the students have an understanding and appreciation of the importance of the subject, and that it can be deemed important and relevant. It is recommended that such research be conducted on an annual basis, and an introductory module ‘The role and importance of History of the Construction Industry’ should be evolved.

Keywords: Construction, Education, History, Perceptions, Students

1 Introduction

During the 1960’s and 1970’s, the role of construction professionals was straightforward and clear. Dams were required to stop flooding and to promote hydroelectric power or the construction of advanced roads, highways, railways, and bridges was required for efficient transportation. However, the need for construction underwent a total paradigm shift. The reason being that in society the value of construction changed due to the diverse increase in the implications of construction for the built environment. Due to the complexity of projects, construction professionals are required not only to ensure durability and health and safety (H&S) on projects, but to also be involved with aspects of history and culture (Isohata, 2006).

The literature indicates that students commence courses with pre-conceived notions with respect to the courses, which are possibly influenced by normative views of members of the larger campus community (Heise, 1979, 2002 in Francis, 2011). Furthermore, results of prior research have shown student attitudes toward a course...
before the start of the semester affect student course evaluations (Barke et al., 1983 in Francis, 2011). Research conducted by Barth (2008) in Francis (2011) relative to student evaluations, using factor analysis, determined that prior ‘interest in the subject matter’ was shown to have a significant impact on the overall course ratings.

Given the aforementioned, and the Department of Construction Management’s focus on ‘lecturing and learning’ research in addition to general assessment of courses, programmes, and related interventions, a survey was conducted among construction management students registered for the subject History of the Construction Industry pre- and post-delivery of the module to determine the perceived:

- importance of the subject;
- importance of History of the Construction Industry knowledge areas, and
- extent to which the subject History of the Construction Industry History knowledge will assist with understanding and performance relative to other subjects, and
- construction management activities / functions.

2 Literature Review

2.1 The development of Construction History

History, in a broad sense, can be perceived as the starting point whereby the history of art and architecture followed one after each other. Today, engineering history will also form a prominent role, but since boundaries merge with other professionals in the built environment, the description ‘construction history’ forms a correct terminology. Saint (2005) argues that construction history allows the inclusion of many professionals involved in many great building components such as architects, engineers, builders, and craftsmen. The page and a half manifesto in the opening pages of the first volume of the Construction History, Summerson (1985) proposes that the history of the construction industry can be divided into two components, namely the history of construction technology, and the history of building practice. In simple terms, the history of technology, also known as structural design, can be said to be the study of technological revolution and material improvement (Source & Linked, 1987). It can furthermore be described as a component of problem-solving where the aim is to understand what was done previously to assist in progressing within the subject matter, and not reinvent. On the other hand, building practice can be described as in touch with human behaviour, which includes social, cultural, and economic aspects with reference to building practice (Source & Linked, 1987).

2.2 History of Construction Technology

Due to the industrial revolution, the nineteenth and twentieth century underwent a technical evolution due to the demand for industrialisation. Morley (1987) defines technology as the knowledge of materials, tools, machines, techniques, and the innovation of these processes. However, when comparing the Middle Ages and Western Classical Antiquity to the nineteenth and twentieth century it is apparent that the manufacturing process received more attention than the construction process. Picon (2005) argues that during the nineteenth-century, construction history, with attention to technology, emerged as a field of study and research. The concerns raised were in the form of questions as to how to build and of style, which dominated the scene towards the end of the nineteenth century. Therefore, a direct link to the use of technology to solve design problems can be seen. Hence, Picon (2005) states that the history of construction technology has a direct link to intellectual and cognitive aspects.

2.3 Construction History Building Practice (Cultural)

Picon (2005) describes culture as a system of shared values, representations, and practices, which allow for collective life to be possible. Morley (1987) summarises building culture simply as the individuals, groups, organisations, and industries who work, practice, and produce relating to the construction of the man-made environment. That leads to the question “can construction history teach us something about the culture of a society”? Vinegar (1998) and Campa (2009) state that Viollet-le-Duc, who was a pioneer of the domain in the nineteenth century, believed that the relationship between culture and construction history was self-evident. For example, he believed that medieval urban is revealed within the Gothic style and that Cathedrals serve as a civic gathering space within the city. Picon (2005) furthermore adds that in Dictionnaire raisonné, the author places emphasis on the high rib vault as a direct consequence on the high cost of material and labour, which was a characteristic of urban life. Therefore, Gothic buildings were more than just structure, it represented reasoning.

The linkage between ornamentation and the expression of culture can furthermore be seen in the work of Le Baron, Jenny’s Fair Store Building, which is a question between the steel structure and the ornamentation (Campa, 2009). At a first glance, the link between cultural and construction is vague in modern and contemporary western style of construction. Picon (2005) on the other hand argues that for modern and contemporary construction to be linked to a culture, it is important to understand their impact on architecture and engineering. For example, during the 1950’s and 1960’s, the use of air-filled structures represented the quest for freedom from the past militarist influences. Therefore, it can be said that the history of the construction industry is a well-balanced fusion of both the technical and cultural aspects. It is the analysis of structure and material, but also the understanding of cultural, social, and economic factors.

2.4 What is the role of teaching history?

To implement history successfully, it is very important that the educator has a strong sense of why history must be taught, which leads to informed decisions to teaching content and approaches. History education aims at the development of a student’s historical thinking and reasoning skills by providing the student with historical knowledge, procedures and skills (Ashby et al., 2005; Yılmaz, 2009). Isohata (2006) in turn adds that the main aim of construction history is not to provide students with an introduction linked to other specialist subjects, but to train students in observation / recording of heritage, and the understanding of technology and society. It should be noted that during the 59th annual conference of JSCE by the Committee on Civil Engineering History, the content of the construction history modules was presented by several universities. The content included both technological and cultural aspects (Isohata, 2006).

2.5 Student perceptions of learning history

When mentioning the word history to students, the general reaction is that of a negative perception. Upon asking “Why the negative perception?” the answer quickly returned is that the subject is boring, or irrelevant in contemporary life. However, the fact is that history plays a rather prominent role in society, which includes not only to know your roots, but offers a platform for individuals to make informed decisions regarding present issues and future developments. History also contributes to developing critical thinking and problem-solving skills (Joseph, 2011). When history is taught correctly, it establishes a context to time, art, architecture, literature, philosophy, law, and language.
(Voss, 1998). Furthermore, VanSledright (2009) adds that history strengthens a student’s ability to draw comparisons, reason, and promotes exploration. The negative perspective that students have regarding history education can be manifold. Various authors suggest that the main influence is that many students do not understand why they need to study history. Another explanation to why students lack interest can be ascribed to the way they are taught. In many instances, facts and dates relative to multiple events are fed to the students, which they are required to memorise, and then to recall during a test or examination. A further reason is that there is no relevance to present day existence (Joseph, 2011, 2012).

2.6 Innovations and reflections on teaching history

Nussey (2016) argues that the problem that underpins the teaching of history is that lecturers present the subject as a fixed body of knowledge, with a distinct split between information and interpretation of knowledge. Therefore, there is a need to include multi-perspectives. However, Nussey (2016), Gibb (2013) and Magro et al. (2014) argue that there are four possible techniques to use to improve a student’s perception and outcome in the subject, namely oral history, teaching traits, essay writing, and technology.

McCardle and Edwards (2006) claim that promoting the use of oral assignments, or oral history, help to position the student and promote a dialogue about memory, which furthermore promotes interpreting memories and stories that promote subjectivity, agency and identity formation. This not only enriches students’ perceptions, but provides an experience with respect to engaging in teaching and learning.

McEwan (2002) argues that the teaching traits are the traits that will get the results where the lecturer puts in all the effort to see the results. Gibb (2013) states that the lecturer’s ability to teach effectively depends on time management, style of teaching, and teaching techniques. Although time management may be a strange trait, too often it is seen that lecturers spend time on unnecessary content, which results in lecturers not completing content on time, which in turn results in rushing through content, which has a detrimental effect on the outcome. By adopting a teaching style, which includes using humour, and being visibly passionate about teaching, encourages students to engage in the class. As a teaching technique, it is important that a lecturer should have a certain amount of tenacity when teaching a class of students with different interest, abilities, and backgrounds (Gibb, 2013; Yilmaz, 2008; Jussim and Eccles, 1992).

Apart from using oral methods in the classroom, the introduction of essay writing from an early stage in the module plays an important role in developing the ability to formulate an argument. Although students feel that lecturers mark in a subjective manner, the use of a matrix can assist to overcome that (Gibb, 2013).

Using innovative and recent tools and technological applications can furthermore enhance the student’s ability to excel in the classroom. By incorporating a mixture of media sources such as films, clips, documentaries, illustrations, and cartoons can effectively enhance learning in an interactive manner. The use of mobile technology can furthermore enhance both the teaching and learning experience of a student. The advantage is that it is mobile, portable, and interactive which is easy to use (Magro et al., 2014; Ishohata, 2006; Joseph, 2011).

3 Research Methodology

The sample stratum consisted of construction management students registered for the subject History of the Construction Industry. The students were surveyed during the first lecture and again during the last lecture of the second semester using a self-administered questionnaire consisting of four five-point Likert scale type questions. 32 Pre- and 30 post-module responses were included in the analysis of the data.

4 Findings and Discussion

Table 1 presents the importance of the subject History of the Construction Industry relative to the other subjects in the BSc (Construction Studies) programme in terms of a scale of 1 (not) and 5 (very), and a mean score (MS) between 1.00 and 5.00. It is notable that the post-MS is higher than the pre-MS. The pre-MS is > 3.40 ≤ 4.20, which indicates the perceived importance is between important to more than important / very important. The post MS indicates the perceived importance is between more than important to very important / very important.

Table 1. Importance of the subject History of the Construction Industry relative to the other subjects in the BSc (Construction Studies) programme

<table>
<thead>
<tr>
<th>Stage</th>
<th>Nature</th>
<th>Very</th>
<th>MS</th>
<th>Post</th>
<th>Very</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>5.9</td>
<td>0.0</td>
<td>0.0</td>
<td>5.9</td>
<td>76.5</td>
<td>11.8</td>
</tr>
<tr>
<td>Post</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>13.3</td>
<td>46.7</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Table 2 indicates the pre and post perceived importance of nineteen History of the Construction Industry knowledge areas in terms of MSs between 1.00 and 5.00, and a variance. It is notable that 6 / 19 (31.6%) pre-MSs > 4.20 ≤ 5.00, which indicates the perceived importance is between more than important to very important / very important. However, 9 / 19 (47.4%) post-MSs > 4.20 ≤ 5.00. The post-MSs of the remaining 10 / 19 (52.6%) knowledge areas are > 3.40 ≤ 4.20, which indicates the perceived importance is between important to more than important / very important.

The top nine and for that matter, notable post-module rankings include sustainability experiences (9th), development of plant and equipment (7th), organisation of construction (8th), development of structural forms (6th), development of built environment disciplines (2nd), development of materials and methods (3rd), development of industry structure (4th), development of building standards (5th), development of structural forms (6th), development of plant and equipment (7th), organisation of construction (8th), and sustainability experiences (9th). The aforementioned are notable as they relate to the intention of the History of the Construction Industry module.

Table 2. Importance of History of the Construction Industry knowledge areas

<table>
<thead>
<tr>
<th>Knowledge area</th>
<th>Pre Rank</th>
<th>Post Rank</th>
<th>+ / - Rank</th>
<th>+ / - Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural forms</td>
<td>4.29 4</td>
<td>4.60 1</td>
<td>0.31 3</td>
<td>5</td>
</tr>
<tr>
<td>Development of built environment</td>
<td>4.27 5</td>
<td>4.59 2</td>
<td>0.32 4</td>
<td>4</td>
</tr>
<tr>
<td>Development of materials and methods</td>
<td>4.59 2</td>
<td>4.57 3</td>
<td>-0.03 13</td>
<td>13</td>
</tr>
<tr>
<td>Development of industry structure</td>
<td>3.97 10</td>
<td>4.55 4</td>
<td>0.59 1</td>
<td>1</td>
</tr>
<tr>
<td>Development of building standards</td>
<td>4.47 3</td>
<td>4.40 5</td>
<td>-0.07 17</td>
<td>17</td>
</tr>
<tr>
<td>Development of structural forms</td>
<td>4.71 1</td>
<td>4.40 6</td>
<td>-0.31 19</td>
<td>19</td>
</tr>
<tr>
<td>Development of plant and equipment</td>
<td>3.87 14</td>
<td>4.37 7</td>
<td>0.50 2</td>
<td>2</td>
</tr>
<tr>
<td>Organisation of construction</td>
<td>3.97 8</td>
<td>4.28 8</td>
<td>0.31 5</td>
<td>5</td>
</tr>
<tr>
<td>Sustainability experiences</td>
<td>3.93 11</td>
<td>4.23 9</td>
<td>0.30 7</td>
<td>7</td>
</tr>
<tr>
<td>Development of skills</td>
<td>4.23 6</td>
<td>4.17 10</td>
<td>-0.06 16</td>
<td>16</td>
</tr>
</tbody>
</table>
The aforementioned led to the computation of a variance based upon the post-MS less the pre-MS, 12 / 19 (63.2%) of the post-MSs are greater than the pre-MSs. The positive variances ≥ 0.20 are development of industry structure (0.59), development of plant and equipment (0.50), development of forms of procurement (0.37), development of built environment disciplines (0.32), architectural forms (0.31), organisation of construction (0.31), sustainability experiences (0.30), health and safety experiences (0.21), and development of management (0.20).

Table 3 indicates the pre and post perceived extent to which the History of the Construction Industry subject knowledge will assist respondents with understanding and performance relative to their other subjects in terms of MSs between 1.00 and 5.00, and a variance. It is notable that only 1 / 16 (6.3%) pre-MSs and post-MSs > 4.20 ≤ 5.00, which indicates the perceived extent is between near major to major / major – structural, and materials and methods respectively. 8 / 19 Pre-and post-MSs > 3.40 ≤ 4.20, which indicates the perceived extent is between some extent to a near major extent / near major extent. 9 / 16 (56.3%) of the post-MSs are greater than the pre-MSs. The positive variances ≥ 0.20 are Organisational Behaviour (0.29), Materials & Methods (0.24), and Introduction to Labour Law (0.22).

Table 3. Extent to which the History of the Construction Industry subject will assist respondents with understanding and performance relative to their other subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre</th>
<th>Post</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS</td>
<td>Rank</td>
<td>Rank</td>
<td>+/− Rank</td>
</tr>
<tr>
<td>Materials &amp; Methods</td>
<td>4.11</td>
<td>3</td>
<td>4.37</td>
</tr>
<tr>
<td>Structures</td>
<td>4.50</td>
<td>1</td>
<td>4.20</td>
</tr>
<tr>
<td>Environment &amp; Services</td>
<td>3.97</td>
<td>4</td>
<td>4.10</td>
</tr>
<tr>
<td>Research Methodology / Treatise</td>
<td>3.88</td>
<td>5</td>
<td>4.04</td>
</tr>
<tr>
<td>Construction Management</td>
<td>4.10</td>
<td>3</td>
<td>4.03</td>
</tr>
<tr>
<td>Project Management</td>
<td>3.69</td>
<td>8</td>
<td>3.83</td>
</tr>
<tr>
<td>Site Survey</td>
<td>3.90</td>
<td>6</td>
<td>3.61</td>
</tr>
<tr>
<td>Professional Practice</td>
<td>3.57</td>
<td>9</td>
<td>3.53</td>
</tr>
<tr>
<td>Production Analysis</td>
<td>3.72</td>
<td>7</td>
<td>3.50</td>
</tr>
<tr>
<td>Property Economics</td>
<td>3.18</td>
<td>9</td>
<td>3.37</td>
</tr>
<tr>
<td>Introduction to Labour Law</td>
<td>2.96</td>
<td>12</td>
<td>3.19</td>
</tr>
<tr>
<td>Building Economics</td>
<td>3.07</td>
<td>11</td>
<td>3.13</td>
</tr>
<tr>
<td>Organisational Behaviour</td>
<td>2.85</td>
<td>15</td>
<td>2.93</td>
</tr>
<tr>
<td>Business Management</td>
<td>2.67</td>
<td>14</td>
<td>2.73</td>
</tr>
<tr>
<td>Company Law</td>
<td>2.69</td>
<td>13</td>
<td>2.62</td>
</tr>
<tr>
<td>Commercial Law</td>
<td>2.64</td>
<td>16</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Table 4 indicates the pre and post perceived extent to which History of the Construction Industry knowledge will assist respondents relative to 34 construction management activities / functions in terms of MSs between 1.00 and 5.00, and a variance. It is notable that only 1 / 34 (2.9%) pre-MSs > 4.20 ≤ 5.00, which indicates the perceived extent is between near major to major / major - integrating design and construction.

Thereafter, 21 / 34 (61.8%) MSs > 3.40 ≤ 4.20, which indicates the perceived extent is between some extent and a near major / near major extent. It is notable that no post-MSs > 4.20 ≤ 5.00. However, 19 / 34 (55.9%) MSs > 3.40 ≤ 4.20. In terms of the variance between post- and pre-MSs, 10 / 34 (29.4%) of the post-MSs are greater than the pre-MSs. One (2.9%) the activities’ / functions’ MSs are equal. A further 23 / 34 (67.7%) of the pre-MSs are greater than the post-MSs. In summary 32 / 34 (94.1%) post-MSs > 3.00, which indicates the perceived extent is major as opposed to minor.

Table 4. Extent to which History of the Construction Industry knowledge will assist respondents with the following construction management activities / functions

<table>
<thead>
<tr>
<th>Activity / Function</th>
<th>Pre</th>
<th>Post</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS</td>
<td>Rank</td>
<td>MS</td>
<td>Rank</td>
</tr>
<tr>
<td>Resolving construction problems</td>
<td>4.00</td>
<td>5</td>
<td>3.93</td>
</tr>
<tr>
<td>Resolving design problems</td>
<td>4.13</td>
<td>3</td>
<td>3.93</td>
</tr>
<tr>
<td>Environmental management</td>
<td>3.58</td>
<td>12</td>
<td>3.87</td>
</tr>
<tr>
<td>Integrating design and construction</td>
<td>4.29</td>
<td>1</td>
<td>3.82</td>
</tr>
<tr>
<td>Quality management</td>
<td>3.69</td>
<td>9</td>
<td>3.72</td>
</tr>
<tr>
<td>Innovation</td>
<td>4.13</td>
<td>2</td>
<td>3.70</td>
</tr>
<tr>
<td>Technology development</td>
<td>4.03</td>
<td>4</td>
<td>3.70</td>
</tr>
<tr>
<td>Sustainability</td>
<td>3.73</td>
<td>7</td>
<td>3.66</td>
</tr>
<tr>
<td>Measuring materials</td>
<td>3.70</td>
<td>8</td>
<td>3.62</td>
</tr>
<tr>
<td>Plant and equipment management</td>
<td>3.32</td>
<td>25</td>
<td>3.58</td>
</tr>
<tr>
<td>Health and safety management</td>
<td>3.68</td>
<td>10</td>
<td>3.57</td>
</tr>
<tr>
<td>Procurement</td>
<td>3.31</td>
<td>27</td>
<td>3.56</td>
</tr>
<tr>
<td>Sustainability</td>
<td>3.90</td>
<td>6</td>
<td>3.54</td>
</tr>
<tr>
<td>Preparing site layouts (Planning)</td>
<td>3.57</td>
<td>14</td>
<td>3.48</td>
</tr>
<tr>
<td>Temporary works e.g. support work</td>
<td>3.67</td>
<td>11</td>
<td>3.46</td>
</tr>
<tr>
<td>Production (Site) management</td>
<td>3.47</td>
<td>19</td>
<td>3.46</td>
</tr>
<tr>
<td>Programming and scheduling (Planning)</td>
<td>3.75</td>
<td>12</td>
<td>3.45</td>
</tr>
<tr>
<td>General management</td>
<td>3.30</td>
<td>29</td>
<td>3.44</td>
</tr>
<tr>
<td>Industrial Relations</td>
<td>3.14</td>
<td>32</td>
<td>3.43</td>
</tr>
<tr>
<td>Subcontractor management</td>
<td>3.32</td>
<td>24</td>
<td>3.38</td>
</tr>
<tr>
<td>Productivity management</td>
<td>3.30</td>
<td>13</td>
<td>3.37</td>
</tr>
<tr>
<td>Coordinating</td>
<td>3.14</td>
<td>31</td>
<td>3.33</td>
</tr>
<tr>
<td>Controlling</td>
<td>3.00</td>
<td>33</td>
<td>3.32</td>
</tr>
<tr>
<td>Human resource management</td>
<td>3.40</td>
<td>20</td>
<td>3.20</td>
</tr>
<tr>
<td>Outlining the scope of work</td>
<td>3.47</td>
<td>18</td>
<td>3.28</td>
</tr>
<tr>
<td>Resolving disputes</td>
<td>3.54</td>
<td>16</td>
<td>3.28</td>
</tr>
<tr>
<td>Organising</td>
<td>3.43</td>
<td>21</td>
<td>3.24</td>
</tr>
<tr>
<td>Information management</td>
<td>3.41</td>
<td>22</td>
<td>3.21</td>
</tr>
<tr>
<td>Labour management</td>
<td>3.33</td>
<td>23</td>
<td>3.17</td>
</tr>
<tr>
<td>Supervision</td>
<td>3.54</td>
<td>15</td>
<td>3.15</td>
</tr>
<tr>
<td>Administration</td>
<td>3.63</td>
<td>34</td>
<td>3.08</td>
</tr>
<tr>
<td>Estimating</td>
<td>3.72</td>
<td>36</td>
<td>3.03</td>
</tr>
<tr>
<td>Public relations</td>
<td>3.18</td>
<td>30</td>
<td>2.85</td>
</tr>
<tr>
<td>Information technology</td>
<td>3.31</td>
<td>28</td>
<td>2.82</td>
</tr>
</tbody>
</table>

5 Conclusion and Further Research

The subject History of the Construction Industry is perceived important relative to the other subjects in the BSc (Construction Studies) programme, and more importantly, the perceived importance increased post-delivery of the subject. Furthermore, a similar scenario applies in terms of the importance of History of the Construction Industry knowledge areas. Then, History of the Construction Industry knowledge will assist respondents to a major, as opposed to a minor extent relative to all the construction
management activities / functions, except for two. In terms of the extent to which the History of the Construction Industry subject will assist respondents with understanding and performance relative to their other subjects, approximately 50% of the pre-MSs are lower than the post-MSs, and similarly, approximately 30% of the post-MSs are lower than the pre-MSs. Therefore, it can be concluded that the students have an understanding and appreciation of the importance of the subject History of the Construction Industry, the linkages between the subject and other subjects, the fact that it is intended to provide background, and relate developments in the construction industry, and the rational therefore, and that it can be deemed important and relevant in terms of the programme.

Given that in general the post-MSs are higher than the pre-MSs relative to the importance of the subject, the importance of History of the Construction Industry knowledge areas, and the extent to which the subject History of the Construction Industry History knowledge will assist with understanding and performance relative to other subjects, and construction management activities / functions, it can be concluded that the presentation of the module had an impact on the students’ perceptions.

It is recommended that pre- and post-course perception-based research be conducted on an annual basis, particularly given that many of the post MSs are lower than the pre i.e. to determine if this is a trend. The importance of related knowledge areas and the linkages with other subjects, and construction management activities / functions should be highlighted to raise the level of awareness relative to and the complementary role of the subject History of the Construction Industry in the programme, and to promote the ‘integration’ of knowledge derived from the range of subjects even though an ‘integrative’ (portfolio) project is included in the programme.

Finally, given that the research interrogated the relevance of the subject concerned, the findings have contributed to the ‘lecturing and learning’ research agenda in the department concerned, and the ‘tertiary construction management education’ body of knowledge. The findings are of value to both academics, and students in that follow up interventions in the form of say an introductory module to explain the role and relevance of the subject are likely to contribute to an improvement in performance relative to the subject.

6 References
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A Review of University-Enterprise-Cooperation Research in China: A Quantitative Perspective

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Abstract:
The university-enterprise-cooperation (UEC) has been adopted by many universities in the world to effectively use the high-quality resources of industry, to improve the general competence, practical application of skills, and innovation capability of graduates in engineering education. A significant number of Chinese journal papers have concentrated on the UEC topic, however, there is no literature currently conducting quantitative statistical analysis on the UEC research in China. In order to fill this knowledge gap, 300 high-quality papers closely related with UEC topic were collected through the Chinese CNKI database from 2008-2017. The general development trend of UEC research in the past 28 years was also mapped and analyzed. The most popular topics under UEC theme and the most frequently adopted research methods in UEC research field were also identified. It was found that since the first UEC publication in 1990, the number of UEC publications in China experienced a steady increase in the last decade, under the background of the strong promotion from the Chinese government for the application of UEC model, and active practice of UEC of universities and educators in China. Course development (55.37%) and practical resource development (19.79%) were two of the most popular research topics in the UEC field. The elaboration research method was adopted by more than half (55.03%) of UEC papers, followed by case study (17.92%) and comparison (7.86%). The findings of this study are valuable for researchers and practitioners to better understand the development status of UEC research in China.

Keywords:
Course development; Practical resource development; Research method; Research topic; University-enterprise-cooperation (UEC)

1 Introduction

In recent years, the practical adoption of the University-Enterprise-Cooperation (UEC) has been highlighted by educators and government agencies in China, and as a result the research on this topic has also gradually increasing. However, currently no literature explores the research progress and trend of UEC in China. This paper uses the Chinese journal database, CNKI, as the source and adopts a quantitative analysis method to answer the following three questions:

(1) What is the development status of UEC research in Chinese journals on chronological basis?
(2) What topics are the focus of UEC research in Chinese journals in the 10 year period from 2008-2017?
(3) Which research methods are frequently adopted by UEC researchers in the 10 year period from 2008-2017?

In order to answer the above three questions, 300 papers (30 papers each year) published in Chinese journals with UEC theme were derived and reviewed by the authors, to collect the information, such as research topic and research method of each paper, followed by statistical analysis of the result. The findings of this study are valuable for researchers and practitioners to better understand the development and trend of UEC research in China. This study is also helpful for the universities or colleges offering the construction management discipline, to find a suitable cooperation approach between the universities and enterprises, with reference to the general UEC models in China.

2 Literature Review

The UEC refers to a new form of education approach and thinking which focuses on the cultivation of graduation talents with high-level of innovation capability and practical skills, through the full use of resources from both the university and enterprise (Liu and Zhong 2011). UEC is an important mechanism to enhance the general competence, practical application skills and innovation capability of engineering graduates in modern university education (Yang et al. 2017). As one of the important forms of cooperation between the university and industry, UEC is a win-win mode for both the universities and enterprises, since, on one side, it will benefit the university to improve the general quality of their graduates, and on the other side, it will help the enterprise select the right talents they need in a more efficient way. Hence, UEC is an effective model to cultivate excellent engineers and management talents, and as a result many universities and educators in China, as well as in the world pay special attention to UEC in modern education (Li et al. 2015).

In recent years, the Chinese government agencies have also attaches great importance to UEC in higher education. For example, the Ministry of Education has stated many times in their issued guidance documents of university graduates' training, for example, "high attention should be paid to UEC with the aim to improve the practical capability of the students", 'in order to cultivate the students' practical application skill, problem analyzing and solving capabilities, we should strengthen the close cooperation between the university and industry, and provide more practical training and internship opportunities to the students through the common platforms established by the joint efforts of the universities and enterprises" (Xiao and Fan 2017).

Construction management is a practice-oriented discipline (Zhang et al. 2018). According to the latest data from the Chinese Baidu website, more than 430 universities and colleges offer the undergraduate program of construction management discipline in China. With the adjustment of economic structure and acceleration of construction industry development, the construction management graduates of some Chinese universities or colleges are struggling to find a job or secure a job with a promising career opportunity. On the contrary, many construction enterprises and real estate
developers complain that it is difficult to find suitable talents with a high-level of competence in terms of industry development awareness, strong problem analyzing and solving capabilities, communication skills and teamwork spirit. Hence, currently a contradiction between the talent supply (universities) and demand (enterprises) does exist in China, which needs a paradigm shift in terms of the education approach and thinking to significantly improve the general quality of construction management graduates, to better meet the requirements of the modern construction market and industry.

In educating excellent construction engineers and managers, the enterprises have the resources which universities do not possess. For example, they are sensitive to the construction market development trends, they understand more comprehensively the market requirements and demand of the engineering talents, they have advanced equipment and manufacturing technology, they have many experienced engineers and technicians, they also have a real engineering practice and innovation environment, and they established a special enterprise culture (Lin 2013b). All these ingredients are very helpful in improving the working capability and general competence of construction management graduates. Practical learning based on real projects can significantly improve the learning performance, such as better understanding of the topic and theory, improvement of problem analyzing and solving capabilities, communication skill, innovation capability, and accumulation of real hands-on experience (Liu et al. 2012). Therefore, the universities which offer construction management programmes should consolidate their education base through the cooperation with suitable enterprises, to create a better environment of educating future competitive construction management graduates.

In order to fully depict the background of UEC, it is also necessary to introduce the paradigm shift of undergraduate education in the whole world in the last 28 years, which is from "teaching paradigm" to "learning paradigm", or "teacher-centered paradigm" to "student-centered paradigm". Under the new paradigm ("student-centered paradigm"), the purpose of education of a university is not limited to teaching, but also to providing an excellent learning environment which fosters the students self-learning or learning in the most effective way (Lin 2017). In the new learning paradigm, new learning approaches emerged and are also adopted by more and more teachers in the universities. These learning approaches include Problem-based Learning, Case-based Learning, Project-based Learning, and Experimental Learning (Lin 2013a). However, most of the teachers in engineering universities and colleges are lacking practical experience in engineering practice, and they have limited capability to solve the engineering problems in the real-world, which makes it difficult for them to effectively adopt these new learning approaches. Most of the time, in this case, problems and cases are not collated and derived from real engineering practice or enterprise operation, which means these problems and cases are imagined or compiled by the teachers. These aspects have a negative impact on the cultivation and improvement of students' general competence in the engineering discipline. Through the cooperation of university and enterprise, the high-quality resources of the enterprise, such as real-world construction problems, knowledge gained in successful or failed projects, can be directly used in the classroom, which will make the new learning approaches being effectively adopted in the university education. Hence, from the perspective of new learning paradigm shift in recent years, it is also necessary to bridge a close connection between the universities and enterprises in the construction management field.

Broadly speaking, the universities and colleges all over the world have a long history of adopting different ways of cooperation with enterprises in the cultivation of engineering talents, to make up for their weakness in practical education and vocational training. Specifically, there are the German BBS (Berufsbildenden Schule) model, the UK Sandwich model, and the Australia TAFE (Technical and Further Education) model. In terms of the BBS model, the capability requirements and standards of the graduates are jointly defined by the universities and enterprises. The universities or colleges are responsible for teaching professional knowledge and skills with a specific discipline, and the enterprises are mainly responsible for the training of students' practical working skills, and as a result the discipline theory and practice form an integral part which is effective to improve the general competence of graduates. As to the "Sandwich" model in UK, the overall learning process is divided into three stages. In the first stage, the students learn basic theory in universities or colleges, followed by the next stage during which they work in an enterprise to learn practical knowledge and develop practical working skills. Then in the third stage, they return to the universities or colleges to complete their studies and obtain a graduation certificate. In Australia's TAFE model, the universities or colleges work closely with the industry. The TAFE universities or colleges generally have a board of directors. Most of the time, the chairman of board of directors and the majority of board members are experts from the enterprises or frontiers of the industry. The enterprises participate in the overall process of educating the graduates. Most of the universities or colleges establish a strong practice or internship base in the cooperative enterprises (Lin 2012). In all the three models, i.e. BBS, Sandwich and TAFE, a broad and close cooperation between the universities or colleges and enterprises or industry is the common thinking to improve the competence of their graduates.

3 Research Method

In order to achieve the three objectives of this paper, a research framework similar to Zhang et al. (2016) in reviewing the PPP research status was adopted. Generally, the research framework comprises the following three stages:

(1) Stage I: UEC (Xiaoqi Hezuo in Chinese) were used as the search keywords to identify the journal papers published through CNKI database, which is the most comprehensive data base of research publications in China. In order to ensure the quality of publications, the papers selected for analysis were based on the download frequency in descending order of the papers published in the same year. Usually, the researchers in China rely on the classification of Class-A journals (well-known first-tier Chinese journals recommended by Peking University Library) to determine the quality of the paper in Chinese journals. However, in the ten years' period, the journals in the Class-A clusters have changed every 3-4 years, which means some journals were in the Class-A clusters in 2013, but they were removed from the clusters in 2016. Hence, the download frequency of the papers was an easier standard to get higher-quality research papers on UEC theme.

In addition, the relevance of the research topic with the UEC in filtering the valid papers was considered. After downloading the papers one by one in descending order following the download frequency, a quick review (a review of the abstract of the paper) was conducted to determine whether the paper was related with UEC theme. If it was not related with the UEC in education field, it would be removed from the valid samples. Then the next paper in the frequency sequence from CNKI database was downloaded and quickly reviewed to determine whether this paper was suitable for analysis.
From Table 1, it can be found that since the first UEC publication in 1990 in China, the number of UEC publications experienced several rises and falls before 2001, whereas after 2002 the number of publications has been increasing steadily, with only minor decreasing in 2016 and 2017. Specifically after 2007, the number of UEC publications has been rising significantly. However, this analysis is only for reference, since lots of irrelevant literature on the issue of cooperation between universities and enterprises were also included, without manual filter.

From the above development status of UEC research in Chinese publications, it appears that UEC research has become a "hot" topic in China in recent years, with the strong promotion of the Chinese government agencies and many universities and educators active involvement. In the latest ten years, the Chinese government agencies have highlighted the importance of UEC as an effective way to improve the general quality and practical working capability of university graduates, and have taken many measures to promote the cooperation between the universities, enterprises and industries. Under this background, many universities and educators in China have actively utilized the high-quality resources of the enterprises, to improve the quality of learning environment and correspondingly improve the learning performance and general quality of the graduates. The regulations issued by the Chinese government agencies and specific requirements on UEC are summarized in Table 2.

### Table 1. Number of UEC publications from 1990-2017

<table>
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<tr>
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<tbody>
<tr>
<td>Number of publications</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>15</td>
<td>17</td>
<td>19</td>
<td>18</td>
<td>20</td>
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<td>10</td>
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<td>15</td>
<td>16</td>
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<td>26</td>
<td>27</td>
<td>28</td>
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</tr>
</tbody>
</table>

### Table 2. The regulations issued by the Chinese government agencies and specific requirements on UEC

<table>
<thead>
<tr>
<th>Year</th>
<th>The regulations issued by the Chinese government agencies</th>
<th>The specific requirements on UEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>The Ministry of Education issued a guideline on the implementation of the &quot;undergraduate teaching quality and teaching reform project of higher education&quot;</td>
<td>B: stated that the students' practical working skills and innovation spirit should be significantly enhanced; and the practice base in the enterprise should be developed for the students to broaden the students' practice and internship channels.</td>
</tr>
<tr>
<td>2007</td>
<td>The Ministry of Education issued a brief guideline on the undergraduate teaching to improve teaching and learning quality in a comprehensive way</td>
<td>B: stated that the close cooperation should be strengthened between the universities and enterprises for teaching and research, and the students' practice and internship channels should be expanded, with the support from the enterprises and institutions in the joint development of practice bases.</td>
</tr>
<tr>
<td>2007</td>
<td>The Ministry of Education issued a guideline on the reinforcement of the &quot;quality project&quot; for undergraduate specialty discipline development</td>
<td>B: stated that the university should actively conduct practical training and social practice activities… and explore the mode of learning with the cooperation between universities and enterprises… and develop the students' practice and internship bases with the efforts from the enterprises and institutions… and explore new ways to develop teachers with the joint efforts from the universities and industry. The university should actively promote the disciplinary teachers to conduct research with the input from enterprises and industry, and invite the outstanding experts and senior managers in the industry as the guest lectures to deliver the courses.</td>
</tr>
<tr>
<td>2008</td>
<td>The Ministry of Education issued a brief guideline on the undergraduate teaching quality and teaching reform project of higher education</td>
<td>B: stated that the students' practical working skills and innovation spirit should be significantly enhanced; and the practice base in the enterprise should be developed for the students to broaden the students' practice and internship channels.</td>
</tr>
<tr>
<td>2010</td>
<td>Outline of the national medium and long-term educational reform and development plan (2010-2020)</td>
<td>B: stated that the university should actively conduct practical training and social practice activities… and explore the mode of learning with the cooperation between universities and enterprises… and develop the students' practice and internship bases with the efforts from the enterprises and institutions… and explore new ways to develop teachers with the joint efforts from the universities and industry. The university should actively promote the disciplinary teachers to conduct research with the input from enterprises and industry, and invite the outstanding experts and senior managers in the industry as the guest lectures to deliver the courses.</td>
</tr>
<tr>
<td>2015</td>
<td>General Office of the State Council issued a guideline on the reform of innovation and entrepreneurship education in universities and colleges</td>
<td>B: stated that the students' practical working skills and innovation spirit should be significantly enhanced; and the practice base in the enterprise should be developed for the students to broaden the students' practice and internship channels.</td>
</tr>
<tr>
<td>2015</td>
<td>The State Council issued a notice on the promotion of the development plan of first-class universities and disciplines</td>
<td>B: stated that the university should actively conduct practical training and social practice activities… and explore the mode of learning with the cooperation between universities and enterprises… and develop the students' practice and internship bases with the efforts from the enterprises and institutions… and explore new ways to develop teachers with the joint efforts from the universities and industry. The university should actively promote the disciplinary teachers to conduct research with the input from enterprises and industry, and invite the outstanding experts and senior managers in the industry as the guest lectures to deliver the courses.</td>
</tr>
</tbody>
</table>
4.2 Research topics of UEC papers in Chinese journals

In the content analysis process, the research topics of each UEC paper were identified and then statistical analysis was conducted. The results were shown in Table 3.

The theme of course development means that the university and enterprise may jointly develop disciplinary curriculum, course outline, new disciplinary course, new disciplinary reference book, or the university may invite the expert from enterprises as guest lecturers to deliver lectures to the students or to jointly supervise the graduate course design with university teachers. Within this approach, the valuable intellectual resources, e.g. the management/working experience of the expert from the enterprise, is effectively utilized in the teaching process.

As to the practical resource development, the enterprises either donate funding to develop the laboratory at the university, or provide internship/part-time working opportunities to the university students, to create a better practical learning environment for the students.

In terms of the teacher’s practical skill development, the enterprises either provide part-time working opportunities to the university teachers or real-world cases and lessons learned in the management/production process, to develop the practical working capabilities and improve the sense of industry awareness of the university teachers.

Under the theme of joint research, the teachers of universities and experts from enterprises collaboratively conduct research on specific topics, which may be funded by the enterprises, by the government, the universities or other agencies.

Table 3 Research topics of UEC papers in Chinese journals

<table>
<thead>
<tr>
<th>Year</th>
<th>Item</th>
<th>Course development</th>
<th>Practical resource development</th>
<th>Teacher’s practical skill development</th>
<th>Joint research</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2012</td>
<td>Number of topics</td>
<td>122</td>
<td>58</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>40.80%</td>
<td>22.04%</td>
<td>14.09%</td>
<td>13.47%</td>
</tr>
<tr>
<td>2013-2017</td>
<td>Number of topics</td>
<td>141</td>
<td>40</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>61.35%</td>
<td>17.35%</td>
<td>13.09%</td>
<td>8.28%</td>
</tr>
<tr>
<td>2015-2016</td>
<td>Number of topics</td>
<td>252</td>
<td>96</td>
<td>68</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>50.37%</td>
<td>19.78%</td>
<td>13.09%</td>
<td>10.90%</td>
</tr>
</tbody>
</table>

Note: most of the papers have more than one research topics.

It can be found from Table 3, in the past decade course development (55.37%) was the most popular research topic in UEC field, followed by practical resource development (19.79%), teacher’s practical skill development (13.89%), followed by joint research between the universities and enterprises (10.95%). The findings highlight course development and practical resource development as the most popular form of UEC in China. Comparing with the two five-year periods, the research topics only have slight changes in terms of the percentage of each UEC topic.

4.3 Research methods adopted by UEC researchers in China

In the construction management field, four typical research methods are frequently adopted by researchers: literature review, case study, interview and questionnaire survey. Based on the content analysis results, various research methods used in UEC literatures are summarized and shown in Table 4.

Table 4 Number of research methods adopted by UEC papers

<table>
<thead>
<tr>
<th>Year</th>
<th>Item</th>
<th>Elaboration</th>
<th>Case study</th>
<th>Comparison</th>
<th>Modelling</th>
<th>Questionnaire survey</th>
<th>Literature review</th>
<th>Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2012</td>
<td>Number of research methods</td>
<td>64</td>
<td>27</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2013-2017</td>
<td>Number of research methods</td>
<td>55.00%</td>
<td>17.20%</td>
<td>7.04%</td>
<td>8.92%</td>
<td>8.92%</td>
<td>5.55%</td>
<td>1.27%</td>
</tr>
<tr>
<td>2008-2017</td>
<td>Number of research methods</td>
<td>55.37%</td>
<td>19.79%</td>
<td>13.89%</td>
<td>10.95%</td>
<td>5.52%</td>
<td>4.63%</td>
<td>1.24%</td>
</tr>
<tr>
<td>2008-2016</td>
<td>Number of research methods</td>
<td>55.00%</td>
<td>17.05%</td>
<td>7.00%</td>
<td>7.23%</td>
<td>7.23%</td>
<td>5.44%</td>
<td>1.26%</td>
</tr>
</tbody>
</table>

Note: some papers adopted more than one research methods.

It can be found from Table 4 that the majority (91.33%) of the papers used only one research method in the last decade, and among the 300 UEC papers, the elaboration research method was adopted by more than half (55.03%) of UEC papers, followed by case study (17.92%) and comparison (7.86%). In the two five-years periods, there are no significant changes on the research methods adopted by UEC researchers in China.

Here, elaboration, which is commonly used in construction management research field in China, refers to narrate, discuss, or depict the study without using other methods to support or validate the research findings (Zhang et al. 2016). In construction management field, more research methods can rigorously validate the research findings, which make the study more convincing (Zhang et al. 2016). From this point of view, improvements should be made for Chinese researchers to employ various research methods in the UEC field.

5 Conclusions and Further Research

With the strong promotion from the government agencies in China from 2007, the publications on the UEC topic has been steadily increasing in the last decade. This study aims to map the overall research status of UEC publications in China, and to identify the most popular research topics under UEC theme and the most frequently adopted research methods in the literatures. 300 high-quality journal papers closely related with UEC topic were collected from 2008-2017 for statistical analysis, based on the result of both qualitative and quantitative content analysis.

It was found that that since the first UEC publication in 1990 in China, the number of UEC literature published experienced both rises and falls before 2001, whereas after 2002 it has been increasing steadily. Specifically after 2007, the number of UEC papers has been rising significantly, with only minor decreasing in 2016 and 2017. Course development (55.37%) and practical resource development (19.79%) were two of the most popular research topics in the UEC field from 2008-2017. As to the research methods adopted by UEC researchers in China, more than half (55.03%) of UEC papers employed the elaboration method, followed by case study (17.92%) and comparison (7.86%) during the same period. These findings address the knowledge gap in the existing UEC literature, and present a practical contribution, since this study may help
Some limitations exist in this study, which deserve future research in this field. Although a brief review of the overall paper was conducted in the data collection process when determining the quality of a specific paper, the 300 research papers utilised may not be considered the highest quality published over the last decade, since the authors primarily followed principle of the descending order of download frequency as the threshold to determine the quality of those papers, which means higher quality papers with a lower download frequency may not be included in the research. On the other hand, comparing thousands of UEC papers published in the same period, the 300 sample papers may not represent the overall status and development trend of UEC research in China. In future research, more high-quality UEC papers will be collected for analysis to derive a more rigorous research findings.

Additionally, the authors plan to collect more industry data of UEC and research funding data focusing on UEC, to make a comparison study, since this data is not currently available.

6 Acknowledgement

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7 References

Improving hospital design process to support patient's recovery in the Kingdom of Saudi Arabia

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Abstract:

The design and planning of hospitals affects the safety and health of patients during their occupancy. Lack of attention to the inter-relatedness of hospital design and patient health early in the hospital design planning process may lead to adverse incidents, such as medication errors, spread of disease, death, and psychological suffering. While studies have found evidence that hospital design can affect patient health, insufficient research has been carried out regarding the full impact of the design process on the occupancy stage or how the process can be managed to further promote patient wellbeing and the recovery process. To investigate the design and occupancy phases of public hospitals in the Kingdom of Saudi Arabia (KSA), inductive and deductive approaches are proposed, along with case studies, questionnaires, and interviews with designers and users of public hospitals in three cities in KSA. It is expected that the feedback loop generated will improve hospital design by putting patient wellbeing and recovery back at the heart of hospital design.

Keywords:
adverse incidents, design flaws, design team, patient recovery, physical and psychological impact.

1. Introduction

Healthcare systems have been defined as complete networks of organisations, resources, techniques, and facilities that provide healthcare in a specific geographical space (Health Care System 2009).

Interestingly, a World Health Organization (WHO) report showed that patients at a healthcare facility may be more exposed to adverse incidents (AIs) than persons in nuclear plants or on board aircrafts (WHO 2002). For air travel, the potential for an AI is one in one million; for healthcare facilities, it is one out of every three hundred (WHO 2002), with most occurring at hospitals (West 2006; WHO, 2002). In a hospital setting, AI is defined as an incident in which harm befalls a patient during the provision of healthcare and may involve infection, falls resulting in injury, or problems with medications or medical devices (AIHW 2015). AIs may impact patients physically, psychologically, and financially (Adams et al. 2009). The focus of the present research is AIs in tertiary care hospitals (150–500 beds) as they represent the majority of Saudi public healthcare facilities (General Directorate of Statistics & Information 2013).

Designing an environment that supports the recovery process is considered essential to patient safety (Schweitzer, Gilpin, and Frampton 2004) and protection, accelerating the healing process, and preventing AIs that might impact the psychological (Zimring, Joseph, and Choudhary 2004) and/or physical health of patients (Joseph and Rashid 2007). Inadequately designed environments may cause AIs such as infection and medical errors that can critically affect patient health (Zimring, Joseph, and Choudhary 2004). Despite continuous improvement in the management of hospital operations, the number of AIs has not decreased since 1999 (Kohn, Corrigan, and Donaldson 2000). This has opened up the potential for these issues to be anticipated and addressed in the design of the facility itself.

In addition to the four processes needed for all building (preparation, design, construction, and operation and maintenance), hospital design includes identification, concept design, design development, and technical design, as shown in Figure 1a. At least theoretically, devoting greater attention to the early stages of the hospital design process can prevent many AIs (see Figure 1b).

In response, a research project has been set up to study this matter further. This paper reports on-going doctoral research aiming to develop a framework for hospital design that can facilitate healing in public hospitals in the KSA. To achieve the aim, the following objectives have been set:

- to critically analyse the contemporary design process of public hospitals in the KSA in order to identify the factors of patient health and safety in the occupancy stage
- to study the direct and indirect impacts of design decisions on healing in order to identify the roles of responsible parties during the design process in preventing AIs
- to compile case studies of design flaws and supportive features that impact patient healing and identify the direct and indirect impacts on physical and psychological health.

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- to compile case studies of design flaws and supportive features that impact patient healing and identify the direct and indirect impacts on physical and psychological health.

Figure 1a. Design flow chart and mapping of the research problem.

Figure 1b. Design flow chart and mapping of the research problem.
• to formulate and propose a new perspective towards hospital design in public hospitals in the KSA so that patient wellbeing and healing are fostered

This research project will contribute to the literature by promoting patient health at the heart of hospital design. It will examine the provision of conducive environments that can be embedded in the early stages of hospital design in order to provide a safe and protective atmosphere that will positively affect the psychological and physical health of patients. The aim of this paper is to present the bridge between the built environment and the healthcare domains as the research gap, with a view to improving the design process of hospitals in KSA to create better future hospitals.

2. The proposed research methodology
The first stage of this research is an in-depth literature review. The first stage of this research is an in-depth literature review. Hart (1998) described a literature review as “the selection of available documents (both published and unpublished) on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed”. Researchers using a literature review as source of data that provides a clear understanding of research gaps and problems details by gaining knowledge of relevant or recent researches studies in a specific area (Burns 1997).

Available and relevant works for the literature reviews will be searched and studied to identify the most important criteria that link between design process and healing process. Such as, the design processes flaws, designed environment issues, design thinking strategies, hospital design principles, sensory system of patient and AIs that impact the healing process in the context of the Saudi hospital design process (see Figure 2). This paper presents the on-going literature reviews for two domains: (a) contributing in the improvements in the built environment design, through construction (stages of establishing a new hospital and skills in management) and architecture (design process flaws and features) tools; (b) healthcare domain, identifying impacts of AIs originated from hospital design issues to improve patient safety and better supporting of healing process (see Figure 3).

The subsequent data collection involves two strategies. The first, the inductive strategy (Grix 2010), involves two phases: Phase 1 includes literature reviews (Hart 1998), case studies (Creswell and Plano Clark (2007); Yin (2009), observations, and archival studies (Schell 1992). These tools will be used to compare current design practices in the KSA to other well-developed practices and to shed light on the level of consideration given to patient health during hospital design. The findings in this phase will form the basis for the interview questions in the second phase, in which interviews will identify the relevant environmental factors and sources of AIs, including their impact on patient’s health. Interview questions will be distributed to the participants (healthcare providers) involving hospital patients in three different public hospitals in the KSA who were selected due to their track record of exposure to the hospital environment (Gilboy et al. 2012). In the second, deductive, strategy (Yin 2013), the questionnaires will be formulated from the analysed data in the inductive stage to establish the relationship between design and patient’s health and to ascertain the effect of decisions made by participants and responsible parties in the design process. The questionnaires will be distributed to the parties responsible for hospital design. The descriptive statistics (Trochim 2006) and correlations (Hill and Lewicki 2006) are envisaged to determine the strength of the relationship between design process and patient recovery.

3. Healthcare in the Kingdom of Saudi Arabia
The healthcare sector in KSA is within the responsibility of the Ministry of Health, which is the primary government agency committed to the provision of preventive, curative, and rehabilitative healthcare for the population of the KSA (Almalki, FitzGerald, and Clark 2011). The Ministry of Health is also responsible for the management, planning, financing, and regulation of healthcare facilities. The government of the KSA has made a concerted effort to deliver planned healthcare facilities. In 2014, according to the Central Department of Statistics and Information (CDSI), the Saudi healthcare sector accounted for nearly 5.7% of the total gross national product (Ministry of Finance 2015), making the KSA one of the largest healthcare sector budgets in the Arabic Gulf (Damrah 2013).
Recently, Saudi Arabia has focused on patient safety through the reduction of AIs or medical errors during direct interventions (Almasabi 2013) by applying healthcare accreditation standards (Al Awa et al. 2010) that cover patient safety practices related to some patient outcomes (Thorlow and Merwin 2009). However, the KSA still suffers from increasing AIs as one of the developing countries in which the risk of patient harm is up to 20 times greater than in developed countries. In other words, one out of every ten patients receiving care at a KSA hospital is likely to suffer an AI (WHO 2012).

This study focuses on how the creation of an environment conducive to fewer AIs can be embedded in the early stages of the hospital design process in order to provide a safe and protective atmosphere that positively affects the psychological and/or physical health of patients, thus avoiding AIs originating from design issues. In addition, the focus here is on fostering supportive events within the patient environment to facilitate the healing process. To provide a clear understanding of the research gap (the lack of attention to the link between the design process in the built environment domain (see Figure 1a) and the healing process of patients in the healthcare domain (see Figure 1b), and to highlight the research problem: AIs can be prevented by design. Figures 1a and 1b display the research problem cycle in relation to both domains.

In a study of Saudi hospital buildings, Al-Ghamdi, Andrew, and Joyce (2011) presented the design issues impacting maintenance and operation phases in the following categories: selection of materials, climate conditions, structural designs, written specifications, architectural design, construction drawing, architectural drawing, design team, harmful human behaviours, and administration of design team defects. These categories reflect the missing factors in the design process addressed in this study. Furthermore, compared to design processes elsewhere, such as the US, the users’ participation in the design stage is another missing factor. Thus, these factors were considered to be indirect interventions (Brady et al. 2009) to patient environments that led to AIs in Saudi hospitals and impacted patient’s health.

4.1. First perspective: The psychological health of patients

Boredom, stress, depression, weariness, loneliness, and aggression are psychological factors that impact patient health (Amp, Harris, and Maxwell 2008). This study aims to investigate the theoretical possibility of reducing these factors by modifying the environment design in the early stages of the process. For instance, Nelson et al. (2005) recognised that reducing sources of noise in the patient’s environment and using natural lighting, music, natural views, and artwork can have positive impacts on the psychological health of patients. Zimring, Joseph, and Choudhary (2004) found that environmental design has a direct impact on patient stress levels. Thus, minimizing noise and light reduces stress, as does providing private rooms; reducing the sources of stress in the patient’s environment can lead to improved health outcomes (Bobrow and Thomas 2000; Urlich et al. 2004; Muto et al. 2003). In addition, higher noise levels affect patient relaxation (Bayo, Garcia, and Garcia 1995) and have an adverse impact on sleep quality and, therefore, on recovery (van de Glind, de Roode, and Goosensen 2007).

4.2. Second perspective: The physical health of patients

An appropriate environment reduces patient exposure to potential physical dangers such as falls, injuries, infections, and death. The hospital design process has been found to be instrumental in improving patient health by decreasing the sources of infection and medical error (Zimring, Joseph, and Choudhary 2004). For example, the rate of infection is lower for critically ill infants in single-bed rooms (Walsh, McCullough, and White 2006), and fewer injuries and falls happen in safer environments (Zimring, Joseph, and Choudhary 2004). The causes of falls in intensive care units include slippery floors, poor placement of handrails, inappropriate door openings, and poor furniture height (Brandis 1999). Moreover, a room that is not designed to allow for adaptation to the changing needs of patient care can contribute to increased medication errors and patient falls that may delay the healing process (Bobrow and Thomas 1994; Gallant and Lanning (2001)).

These perspectives point to an important relationship between patient health and environmental design issues (see Figures 1a and 1b). Therefore, avoiding potential incidents and facilitating positive outcomes will be considered in this research as pathways to accelerate patient recovery. Improving the hospital design process for the stated purpose of this research includes a review of the design phase requirements for a treatment environment, while focusing on the healing process-driven design factors and challenging the ways of thinking in the traditional design process.

5. The missing link: The impact of hospital’s design

Hospital design and patient health have a unique relationship. With an increase in the number of adverse patient incidents in hospital buildings (Dentzer, 2011), many researchers, including Ulrich et al. (2008), Joseph and Rashid (2007), Nelson et al. (2005), Bobrow (2000), and Gallant and Lanning (2001), have highlighted the detrimental effects of poorly designed hospitals on patient recovery. The evidence clearly indicates the significant impact on patient health outcomes if health considerations are not integrated in the patient environment during the hospital design process (The Center for Health Design 2012). A review of the previous discussion shows that many events can impact a patient’s health under the following assumptions: (1) The resulting incidents can be traced back to environmental design issues that potentially affect both physical and psychological aspects of the patient’s healing process. (2) The occurrence of adverse incidents can be avoided and positive events fostered by paying more attention at the early stages of the design process. (3) These events can have direct or indirect effects on patient wellbeing through the patients’ interactions with the environment. (4) The nature of the AI is indirectly related to the design of the hospital and healing process of the patient.

There is little research concerning the impact of the design process of healthcare facilities in the KSA on the psychological and/or physical health of patients, and it is expected that this study will help to bridge the gap in this important area. Improving the
design process to create more conducive environments that will support patient’s faster healing and recovery is central to this research. This study is expected to primarily benefit patients, employers, employees, and organizations of healthcare accreditation standards who care for, work, design, and manage on behalf of patients, as well as the companies who provide medical and non-medical furniture, equipment, and materials used in patient environments.

Recently, the Saudi’s Health Minister announced the results of an investigation into a fire in Jazan General Hospital, which killed 25 people and injured 107. The minister stated that the fire arose from defects in the design and implementation of the building, which led to the rapid spread of smoke and difficulty in the evacuation (Jazan 2016). The AI could have been prevented at an early stage of the design process, but evidence shows there was a significant lack of considerations about patient recovery process in the KSA among the design teams. While a great deal of research has been conducted worldwide with regard to patient’s health and hospital design, this type of research can be considered rare in the KSA, where most studies have been written from maintenance and construction perspectives that concentrated on minimizing costs (Al-Hammad, Assaf, and Al-Shihah 1997; Ikhwan and Burney 1999; Al-Ghamdi et al. 2011). Little research has been conducted in the KSA into the impact of healthcare facility design on the psychological and physical health of patients, and it is expected that this study will help to bridge the gap in this important area. Improving the design process to create environments that are free of design flaws and create positive events in patient well-being that will promote healing and recovery is central to this research. The information that the study is expected to deliver and its significance are detailed in Table 1.

Table 1: Expected outcomes

<table>
<thead>
<tr>
<th>Aim: To improve patient health by identifying design team responsibilities for planning healthy environments in Saudi hospitals</th>
<th>Significance of the study (outcomes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify the factors of patient health and safety in the occupancy stage within the design process, to better understand how these affect healing and improve patient health.</td>
<td>Encourage responsible decision-making among the participants in every stage of designing a new hospital, by addressing the ways that design can support patient health.</td>
</tr>
<tr>
<td>Identify the roles of responsible parties during the design process in preventing AIs and creating positive events.</td>
<td>Increase knowledge among design professionals about the relationship between design and patient health, with a view to improving design.</td>
</tr>
<tr>
<td>Identify design flaws that are sources of AIs and affect patient health.</td>
<td>Create future hospitals that are free from design flaws.</td>
</tr>
<tr>
<td>Identify the factors with greatest influence on the decisions made by responsible design parties in terms of supporting healing.</td>
<td>Improve hospitals by shifting their design towards patient health and safety, rather than just a location for medical services.</td>
</tr>
</tbody>
</table>

This study expects primarily to benefit:
- Participants in the planning and design process
- Companies who provide critical systems, medical and non-medical furniture, equipment, and materials for hospitals
- Patient health and safety

This research set out to investigate the relationship between hospital design and patient health for specific public hospitals design and occupancy perspectives. Subsequent to the completion of this research, further studies can be conducted in other types of healthcare facilities, from different perspectives, so that a holistic framework to improve hospitals in KSA can be developed. The currently proposed research will provide a solid platform for the future development of such a holistic framework.

For the purpose of this research, improving hospital design is defined as a review of the design process for a treatment environment, focusing on healing factors and design team responsibilities, and challenging the traditional perspectives in architectural design.

The research hypotheses are as follows:
- An improved design process will result in a more conducive environment and reduce/minimise the occurrence of AIs in KSA hospitals.
- The provision of a more conducive environment and reduce/minimised occurrence of AIs better supports the wellbeing and recovery process of patients.

6. Conclusion and further research

This research has been designed to investigate the relationship between patient’s health and environmental design in design phase specifically for public hospitals from the built environment perspective. This paper presents the first stage of the research, i.e. the literature review stage. The findings from this stage demonstrate the impact, and hence importance of hospital design towards the patient’s recovery process. After all, the main purpose of hospital buildings can be argued to be providing the built environment for health care provision to support patient’s recovery process. With this in mind, the subsequent phases of the research involve conducting primary data collection and analysis to develop a framework to improve design process of hospital buildings in KSA. The outcomes of this research are expected to improve design practices by putting patient’s wellbeing and recovery process at the heart of the design process. Further studies in other types of healthcare facilities and from different perspectives in other phases (construction, operation, and maintenance) may extend this research to provide a more holistic understanding in delivering public hospitals that are fit for purpose, that is, to support patient’s wellbeing and recovery process.

7. References

A conceptual hybrid OSM-BIM framework to improve construction project performance

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Abstract

Performance improvement has always been an important agenda in the construction industry. Newly emerged concepts such as Off-site Manufacturing (OSM) and Building Information Modelling (BIM) have been revolutionary movements in the construction industry. However, these methods have not fulfilled their full potential in practice yet. These techniques can be independently applied in construction projects, but an integrated application of them would contribute to the fulfillment of their full potential and true benefits in the industry. Hence, a new hybrid OSM-BIM system (HOBS) is proposed for performance improvement. This paper aims to review the current state of BIM and OSM techniques to conceptualize a hybrid OSM-BIM framework that formulates their potential interactions and enhances performance in construction projects. An extensive literature review will be conducted to meet the following objectives: 1- To highlight construction performance variables to be addressed. 2- To discuss standalone attributes of each technique contributing to the overall project performance. As the constructive capabilities and attributes can support and equip a project from the perception level to the construction level. The current paper is expected to not only lay the foundation for exploring the interactions to improve the performance of this system through planning and managerial stages but also provide solid evidence to encourage the professional and project owners to adopt it. Therefore, client demand will increase, which is vital to the deployment of the system in the construction industry.

Keywords: OSM and BIM framework, OSM capabilities, BIM capabilities, OSM and BIM interactions, Construction performance.

1 Introduction

Fragmentation in construction projects has been recognized as the root of inefficiencies. The need for the resolution of the inefficiencies has paved the ground for the emergence of Information Technologies (ITs). Construction industry has experienced three eras in IT: computerized drafting, electronic and internet contacting tools, and techniques and tools integration (Arnold & Javernick-Will, 2012). In the recent decades, the professionals and authorities have strongly focused on improving data sharing and collaboration among project stockholders and the crews in addition to accelerate the achievements of the other concepts (Segerstedt & Olofsson, 2010). BIM and OSM are the newly emerged techniques that have attracted researchers’ attention. These two techniques have been discussed to be capable of supplementing each other to improve the construction industry (Abanda, Tah, & Cheung, 2017). The limited literature in this area encourages more research studies on further constructive discoveries of the deal between OSM and BIM. There are a limited number of the research discussing the potential contribution of the two techniques.

This article aims to investigate the standalone attributes of the two techniques from the view of project performance to propose a pathway seeking any potential interactions between the two techniques. Observation and evaluation through the other aspects of a new achievement can reveal more evidence of practicality to encourage the users for the technology adoption, specifically, in the construction industry holding a resistant nature to change. The current paper is grounded based on the following questions: What are the capabilities supporting the successful establishment of a hybrid OSM-BIM system? To what extent do those capabilities satisfy the aspects of overall project performance? What are the barriers against the successful establishment of the system? Therefore, this paper hypothesizes that some capabilities of the two techniques play overlapping roles to supplement each other. Figure 1 shows the overall hypothesis.

This paper is a part of a larger research to develop the pathway that leads to some practical interactions and systematic adoption of this new system for future OSM construction projects.

2 Scoping review

Three scopes including BIM, OSM, and performance in construction were considered in order to gather the required information supporting the title of the current study. The key words used to search the articles were Building information modeling, Off-site manufacture, performance in construction, and potential BIM interactions. The questions by which the papers were selected were “Did the papers address BIM capabilities and OSM attributes? Did the papers discuss their implementation? What are the aspects of project performance in construction industry and how are the aspects achieved through OSM and BIM?” If the abstract of the papers generally answered each question by taking a glimpse, then the papers would be selected to review in detail. The authors seek to potentials bridging and pairing up the two techniques for a concurrent application. This paper is a foundation to hypothesize and address the potential
3 Backgrounds

3.1 Project performance variables

The need for performance followed by profit margins has caused new technologies to emerge in recent years, although the nature of construction industry has resisted their adoption. The dynamic and challenging nature of construction projects results in inefficiencies within the projects due to the complicated communication line, complicated process, large volume of detailed data, and a lack of practical and effective integration of stockholders (Holt, 2015). Therefore, the level of the expected performance satisfying the clients would not be achieved.

Jha and Iyer (2006) categorized project performance criteria as time, cost, quality, safety, and no-dispute. Please see Figure 2. The variable of no-dispute is rooted in stockholders’ satisfaction. Gunathilaka, Tuuli, and Dainty (2013) added more variables as technical performance, planning performance, user satisfaction and productivity/efficiency, and considered them as project success criteria.

![Figure 2. The variables of project performance](image)

3.1.1 Budget performance

Budget or cost performance refers to the achievement in compliance with the estimated budget plan for a project. It occurs once the total expenses of a completed project would not exceed the estimation. It is a quantitative performance indicator which is measurable in construction projects (Cho, Hong, & Hyan, 2009).

3.1.2 Time performance

Time performance refers to the achievement in observing the time baseline in accordance with the initial schedule of projects. This variable is set to avoid project time overrun and extension for project completion. This is a quantitative performance indicator in construction projects (Cho et al., 2009).

3.1.3 Quality performance

It is an achievement once all specifications are in compliance with the required quality standards. Cho et al. (2009) highlighted that quality performance is not measurable but evaluable as a qualitative performance indicator.

3.1.4 Safety performance

This indicator refers to the achievement of reasonable safety considerations to control possible risks in order to avoid or lower the chances of any incidents or damage (Nevhage & Lindahl, 2008) within an organization including construction organizations.

3.1.5 Stockholder satisfaction

It refers to the stockholders’ expectation regarding receiving a program or product that covers their necessities and interests (Susnienė & Vanagas, 2007). To be more specific, stockholder satisfaction refers to the achievement level in compliance with serviceability at which every party’s expectation from the other project participants is observed. The expectation may be any required operational contribution that the other parties must make so that the project can progress. Each stockholder plays an effective and contributing role within a project toward the final results.

Basically, in order to meet project performance indicators, newly emerged technologies have stepped forward to simplify process complexity, which might be the root of the issues. Among the new technologies, BIM and OSM have obtained considerable reputations. Various degrees of offered benefits have been reported from different countries once the techniques were in practice in such a way that a general consensus cannot be concluded.

Therefore, how to practice the techniques is vital to achieve an acceptable result. As far as OSM is concerned, the possible inconsistencies between manufacturing and construction contractors’ activities can exacerbate the inefficiencies in construction sites.

3.2 Off-site manufacturing

Off-site manufacture (OSM) approach is a modern technique in which off-site constructed components are produced and attached to on-site activities. In fact, the off-site components are produced in a controlling manufacture environment and then transported to and positioned into a construction site (Blismas, 2007).

3.3 Standalone potential capabilities of OSM

Due to the nature of resistance to changeability in construction, researchers have been arguing the potential benefits of OSM. Ismail et.al. (2012) believed that the three most influential factors related to management, consisting of “good collaboration, effective communication channel and team member involvement”, could play leading roles toward a successful adoption to take full benefits of the technique’s capabilities in projects.

Sustainable Built Environment National Research Centre (SBEenrc) in Australia believes that OSM technique would offer great opportunities to the construction industry within the upcoming decades. It predicted that the demands for affordable housing would be double by 2021 compared to 2012. Thus, studies on the pathway of responding to the demands satisfying time, cost, and quality are necessary. It also reported that the UK as
a pioneer in fostering and taking advantage of OSM had a noticeable improvement in the housing program. It means that significant environmental, economic, and social benefits have been achieved via OSM (SBEnrc, 2015). Figure 3 illustrates the main potential capabilities of OSM.

3.3.1 Automation & series production

Optimization of time, cost, and quality in the construction industry has often been proposed through automation and series production in the factory environment where the construction components are made (Duc, Forsythe, & Orr, 2014). Products are made in a controlling manufacture environment in such a way that the activities are heavily centralized. Thus, the foundation for the usage of automated machinery equipment is indirectly provided in the construction site. Automated off-site manufacture has been recognized as having more potential revenue through mass customization (Benros & Duarte, 2009) compared to non-automated OSM. Not only have the aspects of time, cost, and quality been observed but also safety satisfaction has been achieved through automation.

3.3.2 Faster investment return

Mostafa, Dumrak, Chileshe, & Zuo (2014) believe that “The economic-related factors such as consumer price index, changes in the interest and inflation rates are the key driving factors to the demand and supply of houses”. Dormant capital, trapped investment, and longer investment return are the issues that significantly affect the earlier mentioned factors. As OSM is capable of shortening project completion time (Goulding, Pour Rahimian, Arif, & Sharp, 2015), it is predicted that OSM overcomes these kinds of increase in the final cost issues. Therefore, the project would be more attractive to the buyers, as the final cost is very competitive. This highlights faster investment return for the investors (SBEnrc, 2015).

3.3.3 Employment opportunities

It is observed that off-site component production and its business-related activities in the US fostered the growth of employment opportunities (Eastman & Sacks, 2008) along with other potential benefits. OSM offers steady long-term job opportunities as factory-based employments even to remote regions (Arif, Goulding, & Rahimian, 2012; Blishnas, 2007).

3.3.4 Sustainability

The manufactured components of buildings can contribute to the resolution of time, budget, and quality inefficiencies. Therefore, there is a belief that OSM stepped into the betterment of sustainability by reducing waste (Due et al., 2014). OSM as an end-user value achiever can be deemed a remarkable contributor to sustainability via satisfying Lean and Agile concepts (Mostafa et al., 2014). Mostafa et al. (2014) also highlighted that the key point of Lean technique is waste elimination, while Agile focuses on market satisfaction. It is observed that the ultimate price of the final production for end-users (Those who use the product; e.g. home occupiers) would be more economical than the production in traditional methods (Eastman & Sacks, 2008). Therefore, such claims as social (users’ comfort), economic (lower price due to less material consumption and less project overhead costs), and environmental sustainability (less waste-related outcome) can be made in OSM.

3.3.5 Safety

Safety improvement as a continuous challenge is highly recognized in OSM-based projects by optimized construction management. It is highlighted that a tidier construction site results in the betterment of site management (Goulding et al., 2015). Also, safety measures for working at heights or lifting and loading materials and components are much more controllable and applicable in a factory environment. Thus, a better working condition is provided in factory-based activities resulting in health and safety improvement (Nahmens & Ikuma, 2011).

A suitable level of OSM application not only expedites a project as a catalyst but also makes it economical. An early decision toward OSM-related activities and an efficient process would eliminate inefficiencies and avoid any disturbance in the project (Gibb 2001). The uptake level can vary in the project based on the characteristics and situation of the project.

3.4 Building Information Modelling (BIM)

Building Information Modelling (BIM) is the process of developing and applying a simulated model of planning, designing, construction and operation of a building. The model contains a collection of digital data and rich information about all details related to a project during its life cycle. The BIM model originated from a smart 3-dimensional CAD which is automatically adaptable to any change and is connected to a shareable database performing as a common source among the parties involved in a project. As there are different levels of details for a BIM model, sometimes, it might be designed for a building only for visualization and analysis of safety cases or for the maintenance of the project (Jung & Joo, 2011).

3.5 Standalone capabilities of BIM

It can be stated that a BIM full package contains various tools, each tool with its own practicability in different schemes within a project. BIM package can be imagined as a general tool kit containing different tools. A wrench, as a tool in BIM package, is usable to tighten a nut. Structural components need to be attached to one another in order to
erect the steel structure (steel skeleton) of a building. In this regard, the wrench is usable to tighten the nuts to keep the stability of the structure which refers to the technical performance of the structure. As reflected in the research by Chong, Lee, and Wang (2017), Olatunji (2012), and Beveridge (2012), Figure 4 presents eight categories as the main BIM capabilities applicable at different levels of BIM uptake in the project life cycle.

This unique collection of the constructive capabilities has enabled the professional for the BIM adoption not only in building but also in infrastructure projects (Chong, Lopez, Wang, Wang, & Zhao, 2016). These capabilities are even capable to lead those who adopt BIM to step in an efficient and effective contract administration (Chong, Zin, & Chong, 2012). Chong et al. (2012) prototyped an electronic dispute resolution (e-DR) that optimizes the contract administration. They grounded the prototype on a guideline containing all the data of agreements between the experts involved in a project.

3.5.1 3-D modelling

This capability offers a general volumetric shape of the elements in structural, architectural and instalments (mechanical and electrical) designs. In fact, the perspective of 2-D drawings is visualized via 3-D modelling.

3.5.2 Measurement/Estimation

Offering the quantity of materials with very high accuracy and predicting their total cost are possible by a BIM model. This is one of the main stages in BIM.

3.5.3 Planning/ Scheduling

BIM planning is the ability to develop a digital Work Breakdown Structure (WBS) which prioritizes activities and links them to each other. It can be stated that sequencing capability lies in planning while scheduling capability refers to assigning a duration to the activities. These capabilities can be followed by the capability of monitoring a project progress along with the possibility of rescheduling activities.

3.5.4 Clash detection

Safety measurements refer to BIM capabilities of automated safety measurement, alerting fall situation from heights and highlighting the best access to the components automatically adjust themselves to the new state of the structure. As a building project comprises a lot of components in structural, architectural, mechanical and electrical designs, the chance of design interference is so high while the drawings are being interpreted. BIM offers chances to detect conflict by combining the 3-D models of the designs, which is a very remarkable capability.

3.5.5 Constructability

A BIM model is able to be updated based on every change in the model. It means that the components automatically adjust themselves to the new state of the model. Thus, the assessment of any variation in the outcome is possible, as BIM is a smart model which reflects constructability.

3.5.6 Site coordination

Sequence clarification via a BIM model gives site coordinators more chances of recognizing the required trades, materials, and equipment to prepare the commencement and execute every construction activity better. This point reflects the ability of site coordination.

3.5.7 Safety measurements

Facility management refers to the ability to manage the operation of building in case there is a need to extract the data of the existing building. A digital BIM model can be deemed as a foundation for perfect facility management. As an example, knowing about the in-built components is possible if the removal of a part of a building is required.

3.6 The level of BIM uptake

As a building project comprises a lot of components in structural, architectural, mechanical and electrical designs, the chance of design interference is so high while the drawings are being interpreted. BIM offers chances to detect conflict by combining the 3-D models of the designs, which is a very remarkable capability.
same as what the UK did for level 2 BIM uptake, has been resulted in partially BIM adoption officially (Migilinskas et al., 2013).

3.6.2 Barriers on OSM side

The most common barriers have been reported to be longer duration of a project and its excessive costs due to modifications. The relevant excessive costs in OSM-based projects (costs which are not applicable to non-OSM projects) are assumed to be the most arguable issues for OSM uptake (Blismas & Wakefield, 2009). Blismas, Pasquare, and Gibb (2006) categorized material, labor, and transportation costs as the direct and most costly exercises, while site facilities, crane use, and rectification of works are taken into account as the indirect costs. The mentioned costly items together with consistent management and safety measures are the determinant factors of OSM uptake. Through the literature review, the barriers of OSM projects are revealed to be fragmentation among participants, high initial capital cost, reluctance of insurers and financial providers, excessive cost compared to non-OSM projects, and insufficient accurate drawings. Every single barrier negatively affects projects and creates the chance of hindering the practicability of the techniques. Therefore, as an attempt to remove the barriers on both sides, BIM and OSM, it is reasonable to consider the development of a hybrid OSM-BIM system.

4 Discussion

The current study attempts to suggest the development of an OSM-BIM system. The chance of the potential supplementary and overlapping capabilities as the potential OSM-BIM interactions (POBIs) to enhance project performance has been observed and highlighted. On the one hand, the great capabilities of the two newly emerged techniques make them worthwhile to be used; on the other hand, as discussed in Section 3.6, raise arguments among the professionals about the usefulness of the applicability of the attributes and capabilities. BIM has been discussed to possess some potentials to reinforce off-site manufacture. The suitable levels of BIM uptake has been claimed to be capable of resolving the barriers reported in OSM projects to meet project performance.

Based on the literature provided in the current study, BIM is able to step in rectifying the potential barriers encountered in OSM-based projects. In regard to fragmentation of the participants (designer, manufacture, and construction contractor), the nature of information sharing platform of BIM links the participants. Thus, the construction industry takes a determinant step toward project performance once the inefficiencies reported due to the fragmentation issue are removed. BIM can offer the exact specifications to keep the required quality when producing the components which is an important consideration from manufacturer’s perspective. BIM also can address how to merge the components to meet the expected functionality within the delivery and operation stages. Therefore, there would not be any chance of functionality failures to be hidden. What is means is that the assurance of a reasonable construction delivery encourages the stockholders and the investors. Furthermore, a perfect feasibility assessment is possible through a systematic, smart, and digital environment of a project. This assessment can be followed by the accuracy in planning and scheduling, clash detection, measurement and estimation, contributing to project performance. This range of offers through BIM trims any excessive costs and optimizes the budget assigned to an OSM project. As a result, a better initial capital cost may be concluded which encourages the finance provider.

The current study hypothesized and predicted some constructive interoperability as interactions between the two techniques. Therefore, this article conceptualized the claims with the purpose of examining them through an empirical study in the future. As can be seen, the potential interactions are flagged in Figure 5. The figure tries to show that the two techniques are capable of tackling the barriers and moving toward bridging the potential capabilities to achieve a range of interactions that optimize project performance. In fact, the question is on how to conceptualize the interactions. It is also shown that the interactions need to be systematically applied to fully benefit the projects. The systematic adoption would be achieved through questioning how, where and when to implement the detected interacting capabilities, where the inbounding points of applying the interactions are within an OSM-BIM-based project. Therefore, the systematic adoption presented in Figure 7 refers to a system through which all the detected, nominated interactions can be effectively applied in the design and construction stages.

5 Conclusion and Further Research

The scope of this study lies in the fields of BIM, OSM, and project performance. This study conceptualized a framework for a new hybrid OSM-BIM system to enhance
project performance. Through the literature review, the capabilities and the attributes of BIM and OSM (See Figures 3 and 4) directly and indirectly affecting performance were discussed, respectively. In addition, the barriers raising arguments about each technique were briefly pointed out in Section 3.6. The potential constructive interactions were inspired by analysing and evaluating the capabilities and attributes of the techniques in the consideration of performance. Figure 5 suggests that the two techniques are capable of going beyond the barriers moving toward a range of potential OSM-BIM interactions (POBIs) at the design and the construction stages. The design stages refer to considerations corresponding to the design for manufacture assembly and construction delivery (the construction site activities). As reflected in Figure 5, the interactions are assumed to be more effective under systematic adoption. Systematic adoption can be defined as a system through which the interactions would be correctly applied at the right time and stages under a collaborative involvement of the participants. This study is a foundation toward detecting the potential technical interactions which need to be followed by systematic adoption, applicable in planning and managerial schemes.

6 Acknowledgement

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Interaction: Re-Purposing Surveillance Infrastructure to Support Urban Densification, and Propagate Sustainable Urban Spaces

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Abstract:
Our inability to capture useful energy from the mass mobility of increasingly densified populations moving through the built environment, in particular when behaviour can be predicted, highlights a critical gap in existing interdisciplinary links and application of knowledge, and a forfeiture of significant opportunities to translate this untapped resource into the sustainable development of cities. Aiming to harnessing such an untapped sustainable energy source, as research was set to predict probability and distribution of population movement patterns to support design decisions based on urban spatial relationships of density and movement patterns with the view to harvest the kinetic energy of its inhabitants to cogenerate power. This information has the potential to be used to develop sustainable design strategies for compact living particularly in cases in Australia where cities are economically and geographically pressured to densify. This paper proposes a strategic and sustainable development through opportunities for co-generation in harvesting of human energy and outcomes that positively impact on the built environment of future cities and society. This research is of significance in the exploration of urban environments and architecture, form critical components that are directly impacting densification strategies and upon the perceived safety in urban public realm, underpinning the backbone for successful social interactions in the current and future cities.

Keywords:
Architecture, Densification, Geostatistics, Infrastructure, Sustainability

1 Introduction
Population growth increases economic and resource demands upon cities, requiring sustainable adaptations and initiatives, shifts in priorities, proximities, and compact living. Of concern to many large, and populous cities are social cohesiveness, density and safety. This is particularly at the forefront in highly developed and specialised Western societies where a number of key commentators suggest that the persistent trend of decrease in "intermediate-level institutions such as community groups... and organisations" and as a consequence society relates increasingly as a collective of individuals and a "decline of ‘secondary’ social control activities" (Jones and Newburn 2002, 140). Moreover Jones and Newburn (2002, 141) draw attention to the significant decline of ‘secondary social control occupations’ which have diminished modern capacity for social control. In a London policing case study Jones and Newburn (1998) established that private security companies undertook that which was formerly the responsibility of “caretakers, receptionists, teachers, prefects and park-keepers” and not by a public police force. Furthermore, the reduced scope and existence of former public officer’s such as “bus conductors, railway station masters, train guards, and ticket inspectors, for example, has profoundly reduced “sources of secondary social control” (Smith and Clarke 2000: 177–8). It has been proposed that:

“there has been a marked decrease in employment in a range of occupations providing ‘natural surveillance’ and other low-level controls as a corollary to their primary functions. In part, this has been a consequence of the development and spread of new labour-saving technologies such as self-purchasing ticket machines and automatic barriers, CCTV, and automated access control...the ‘rise’ of private security has been on the back of [such] reductions in (or, at least, restrictions on the growth of) public policing” (Jones and Newburn 2002, 140).

In response, this research intends to utilise Geostatistical modelling with the aim to predict probability and distribution of population movement patterns and occurrence and provides quantitative statistical data that supports design decisions based on urban spatial relationships of density and movement patterns to harvest the kinetic energy of its inhabitants to cogenerate power. This findings from this research can be used to develop sustainable design strategies for compact living particularly in cases in Australia where cities are economically and geographically pressured to densify. A strategic and sustainable development strategies is proposed in this paper through identifying opportunities for co-generation in harvesting of human energy and outcomes that positively impact on the built environment of future cities and society. The final findings are expected to support practitioners in exploring our urban environments and architecture and supporting decision making regarding densification strategies and upon the perceived safety in urban public realm, underpinning the backbone for successful social interactions in the current and future cities.

2 Literature Review

2.1 Existing Understanding of Surveillance and Surveillance Theory
It has been widely argued that without natural surveillance; seeing and being seen resulting from the presence of authority and other people, digital and other electronic surveillance methods are largely ineffective in reducing or dissuading crime but serve to gather intelligence for solving crime. Raymond Unwin, Lewis Mumford, Jane Jacobs are but a few prominent commentators who initiated this position. Recently, Gehl 2010, and Cozens 2011 among many others, argue that such forms of surveillance alone do little to promote positive behaviours establishing a perpetuation of relevance of earlier attestations in contemporary society and modern cities. Similarly, Welsh and Farrington (2002) and Goodwin (2002) echo a continuity of these findings through their research. Otherwise referred to passive surveillance, contemporary rates of rapid of densification of cities provide significant opportunities to harness this principle—the relationship between urban spaces, compactness and population, in conjunction with digital data to harness mass movement patterns into opportunities for harvesting of cogeneration energy for use in our cities, and to mitigate problematic spaces in the urban environment, creating spaces that promote socially acceptable behaviours.

This research examines international exemplars of densified cities that successfully encourage sustainable collective social activities with the purpose of uncovering relationships between patterns in architecture and resulting behaviours through quantitative statistics derived from existing surveillance technology networks. This will provide new perspectives and understanding of the relationships between urban
Internet of Everything (IoE) has the capacity to track the movements of spaces in the public domain. A highly understanding Bentham’s perspective on the power of individual and behavioural norms are greatly impacted by onsets and litigation, and a society that no longer behaves as it might patterns, can inform urban design and the shaping of cities. The purpose of undertaking modelling, as a tool for understand and predicting human movement and behavioural in conjunction with urban spatial parameters. This study proposes that geostatistical geostatistical modelling is to highlight targeted areas of significant opportunity for energy harvesting technologies in our cities. This project argues for the application of innovative cutting-edge interdisciplinary research principles such as Geostatistical modelling of non-sensitive surveillance data, in conjunction with Geographic Information Systems (GIS) embedded in urban planning and architectural modelling, Building Information Modelling (BIM), and telecommunications towers mobile phones exploit users and carriers of the device as a way of locating users with a high degree of accuracy and thus as a surveillable tracking instrument. Add to this, mobile phones also have “digital visual and sound recording capabilities, and connection to the internet. A consequence of the convergence of surveillance technologies is the greater ability of surveillance users to compile detailed pictures of members of the public” (New Zealand Law Commission, 2008, 136).

Similarly, the Internet of Everything (IoE) has the capacity to track the movements of anyone on location that is connected to its Wi-Fi network, through GPS or telecommunications triangulation. With this, anyone on campus can be tracked and their movement patterns analysed. With analytics, predictability offers a powerful medium to ‘orchestrate’ meaningful and useful sequences, pathways, spaces and experiences for individuals. In a way that is similar to police facilities and other government organisations, essentially all areas of the urban environment and the buildings and systems within it are being monitored – a phenomenon referred to as “hyper-surveillance” which poses various side effects including a potential risk for criminal, and civil investigations and litigation, and a society that no longer behaves as it might normally do. Considering this, society receives little respite from the omnipotent ‘gaze’ or scrutiny within any urban environment, whether it is within buildings or in public spaces. International studies in Europe, U.S, and Australia produce evidence suggesting that hyper-surveillance technologies provide little, if any, measurable data that demonstrates an impact on the societal behaviours when compared with physical presence of authority. It can be argued, therefore, they exist to capture evidence of committed crime, with little correlation between increased surveillance capacities and an proactive reduction in crime. Social and behavioural norms are greatly impacted by the shaping of cities. The implementation of cost effective surveillance technology, although is ineffective in encouraging acceptable behaviour, does however, enable data collecting which facilitates in design decisions that achieve shifts in behaviour. Here, research suggests that relying on such surveillance does not dissuade unwanted behaviour as there is no physical presence of authority but a network of discreet cameras. With respect to this paper, understanding Bentham’s perspective on the power of surveillance and the way that surveillance and built form shapes behaviours, this research adapts surveillance initiated behavioural principles and the urban form to facilitate mass movement of people through spaces in the public domain. The orchestrated consideration of pathways, nodes and destinations specifically intended to harness and store human energy from movement through cities for adaptive reuse to power our environment. The concept of behavioural self-modification (psychological) as set out by Jeremy Bentham results within spaces due to a ‘state of being’ under the constant examination of authoritative figures, being either physical authority (Police) or government organisations, CCTV cameras, and other digital technologies which have the means to develop a digital fingerprint or profile of individuals. To be successful as Bentham had prescribed, the premise requires a permanent shift in psychology in which a belief is formed that one is under constant surveillance and disproportionate relationships of power. Behavioural modification as defined by Bentham above is not the scope of this research, rather, it is to shift societal behaviours at a macro-level by shaping mass movement patterns of pedestrians transitioning through the city.

Contemporary attitudes towards urban-level surveillance of its population, within most cities, has shifted to acceptance and thus the implementation of a number of cutting edge technologies to undertake surveillance at various levels. This is increasingly the case in most developed cities and is undertaken at the expense of the presence of

environment and behaviours of its inhabitants through the analysis of surveillance data in conjunction with urban spatial parameters. This study proposes that geostatistical modelling, as a tool for understand and predicting human movement and behavioural patterns, can inform urban design and the shaping of cities. The purpose of undertaking geostatistical modelling is to highlight targeted areas of significant opportunity for energy harvesting technologies in our cities. This project argues for the application of innovative cutting-edge interdisciplinary research principles such as Geostatistical modelling of non-sensitive surveillance data, in conjunction with Geographic Information Systems (GIS) embedded in urban planning and architectural modelling, Building Information Modelling (BIM), and telecommunications towers mobile phones exploit users and carriers of the device as a way of locating users with a high degree of accuracy and thus as a surveillable tracking instrument. Add to this, mobile phones also have “digital visual and sound recording capabilities, and connection to the internet. A consequence of the convergence of surveillance technologies is the greater ability of surveillance users to compile detailed pictures of members of the public” (New Zealand Law Commission, 2008, 136).

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physical figure of authority (police or similar), and with this, the premise of behavioural modification is fundamentally flawed. This oversight has been determined and published, yet this ‘strategy’ continues to be largely disregarded considering CCTV and other digital methods of surveillance continue to be advocated by government and private interests. CCTV and other forms of digital surveillance techniques successfully record and collect evidence of crimes that have already been committed or are about to be committed for the inspection of authorities. While some criminal incidents are observed in real-time under the scrutiny of the authorities, and some are missed while even being recorded, the overwhelming majority of surveillance data captured serves little purpose and is archived. This research proposes, however, that this dissused surveillance could be used to provide critical information and data to allow for better design strategies and municipal initiatives to encourage community cohesiveness and positive behaviours and with it increased community participation and increased pedestrian density in urban spaces and concurrently increased imply that surveillance. This paper seeks to bridge the gap in an apparent paucity in research in how these technologies can be used positively shape society, design of cities that work to create a safe environment and also allows for trend data the assists decision-making around opportunities for harvesting of human kinetic energy at a valuable resource to power our cities.

3 Research Methodology

This research primary focus is on understanding the collective behaviours in relation to given architectural, sociological and psychological parameters requiring a combination of both qualitative and quantitative methods. This research will be valuable for obtaining empirical data in relation to a subject where insufficient knowledge and inadequate research exists (Polit and Hungler 1985, 272) structured into “research for design” and to increase knowledge base in a related area (Downton 2003). Methodologies include, literature investigation, research review, site investigation and direct observation analysis, followed by a raw data analysis of trends and patterns, these are discussed below.

3.1 Literature Investigation and Research Review

Review of research on harnessing human power through pressure driven electricity, otherwise referred to as “Piezoelectricity” was undertaken to better understand the potential and limitations of the use such technology and materials in the urban environment and the ability to harvest human kinetic energy. Research of published works pertaining to contemporary design rationale of the densified cities to be observed pertaining to use of space to fulfill specific functional requirements and the principles of built environment design implemented in an attempt to achieve the desire outcomes. Texts such as Michel Foucault’s literature relating to control architecture and the ideals of philosophers provides an instrumental account of the historical approaches to architecture and greater built environment control philosophies which arguably, continue to influence existing ideologies and the way in which urban environments are formed. Government and semi government reports and publications which offer findings and design, policy and recommendations have been sourced from various departments and state records libraries, internet sources, national and international data repositories. Many local development and planning policies are published electronically and also held public library reference sections. National and International census and statistics are sources such as the Australian Bureau of Statistics also provided a valuable resource of data, illustrating patterns and trends over time. The Heritage Council offered proved a valuable resource of historical data, which directly assisted in developing a broad knowledge relative to the objectives of this research and general understanding of the context being researched. Information from additional sources such as census data, government statistics and existing recordings were considered incorporated where required next to statistical modelling. This stage of the research forms the basis of research findings reported in this paper. Subsequent stages proposed for this research are briefly discussed below.

3.2 Site analysis

Site analysis was conducted to attain a illustrative understanding of the constraints of context. This research undertook an unobtrusive 7-day visual observational study of highly populated urban spaces with high density national and international cities which included: Kuala Lumpur Malaysia (Jalan Bukit Bintang), Singapore (Orchard Road) Barcelona, Spain (La Rambla near Carrer de l’Hospital), Brisbane (Queen Street Mall), Italy (Via Toledo, Naples), New York (Grand Central). Observations were conducted 1. Monday-Friday daytime (9.00am-5.00pm), 2. Monday-Friday, afternoon-nighttime (5.00pm-12.00am, 3. Saturday & Sunday daytime hours (9.00am-5.00pm), and Saturday & Sunday afternoon-night-time (5.00pm-12.00am), to collect empirical data on human movement and circulation with respect to directional flow patterns. Site analysis focused on gathering specific information, including: location, context, physical constraints, architectural form, layout, and surveillance capabilities. Actual density, trends, patterns, frequency and movements were determined through extrapolative means and observation data gathered. Environmental conditions pertaining to materiality, lighting, and season formed part of the qualitative information that was used to interpret empirical data thus, allowing for a learned inference as to the impact on the empirical material. Methods of documenting findings include time lapse audio visual, photography, tabulated data gathering through field observations, flow diagramming and measurements, sketches.

3.3 Geostatistics

Geostatistics uses a set of statistical methods that applies the theory of regionalised variables to spatial data. It includes both random and structured components of spatial variability (Sinclair, 2002). While it was originally applied to mineral resource estimation, today it is used more widely in areas of environmental studies, forestry, fisheries, and hydrogeology and elsewhere. The theory of Geostatistics is applied with the purpose of optimising estimates, providing also a measure of error variance. It uses the degree of spatial dependence and similarity of two samples, in addition to the concept of random function. The random function describes the probabilistic spatial distribution of a variable (Sinclair, 2002). As opposed to classical statistics, geostatistical theory uses spatial information attached to data emphasizing the underlying model. The model describes the continuity of natural phenomena mathematically, using adaptations of the regression theory (Isaaks, 1989). The fundamental tool of geostatistical analysis is the variogram. It is a measure of spatial similarity of the regionalised variable, also known as autocorrelation. The variogram (Fig. 1) can be used to optimise mapping sampling schemes from point data (Burrough, 1998).
Kriging is a set of methods (OK, SK, IK, MIK etc.) applied in geostatistical analysis that minimises estimation error. The method, coined on Danie Kriege’s thesis for resource estimation for South African mines led to the basis of geostatistical theory. Essentially, Kriging is a method of interpolation that provides an unbiased estimator dividing data into deterministic variations or trends, and spatial—autocorrelated and uncorrelated noise (Burrough 1998).

The purpose of applying kriging methods is to obtain the best possible estimate at an unknown point of the data sets. The example in Fig. 2 of ordinary kriging interpolation with environmental application and illustrates the distribution of radionuclides and predicted values that are beyond the limits of a sustainable environment and human health at unsampled locations (Dindaroğlu 2014). GIS working in conjunction with Geostatistics provides geo-registration of data, logical operations, multiple map layers and effective tools for data display. Despite their different approach, GIS links statistics with Geostatistics, and providing a powerful set of complementary tools. Thus, the following section provides a brief overview of the breadth of hyper-surveillance and effective tools for data display. Despite their different approach, GIS links statistics with Geostatistics, and providing a powerful set of complementary tools. Thus, the following section provides a brief overview of the breadth of hyper-surveillance instruments in everyday life, its purpose, it adaptation, and limitations. This is by no means an exhaustive essay on surveillance theory but intends to provide rationale given the quantity of underutilised data available, and that such disused data could prove to be a valuable resource.

### 3.4 Data Analysis – Raw Data Analysis (Trends and Patterns)

The incorporation of pragmatic data sources with observations from site analysis reinforced existing data and known truths which was substantiated through quantitative statistics (Geostatistics). This specific branch of quantitative statistics evolved more specifically the use in geography-based disciplines, however, these have successfully been applied to a number of geospatial disciplines in particular, when master-planning of spatial networks in alignment with geographic information systems. Geostatistics has been defined as the “branch of statistical sciences that studies the spatial and temporal phenomena. The discipline capitalises on spatial relationships in order to model possible values of variable(s) at unobserved, un-sampled locations,” (Caers 2005) in other words Geostatistics seeks to analyse data to predict probability distributions and determine trends and patterns of occurrence. Thus, for the purpose of this paper, using non-sensitive data (surveillance-derived statistics) of patterns of behaviour at known locations, we are able to produce an interpolation map that offers “best predictor” of similar data at unknown locations also referred to as a User-Centred Surveillance Analysis Predictive Modelling (SA—PM) Framework (see Fig 2). Several temporal

### 4 Findings and Discussion

#### 4.1 City Structure

The physical layout, masterplan and design of different cities play a significant part in the success or inability to efficiently survey its streets and inhabitants. For example, mediaeval cities designed around pedestrian proximities offered significant opportunities for passive surveillance. Gehl (2011, 101) highlights that mediaeval cities allowed for blended interactions between a diversity of inhabitants arising out of the densely populated and compact nature of such cities. The design of these traversed an array of functions and typologies, demonstrating successful integration and segregation of people and occupations, requiring negotiation, cooperation and tolerance. The integration-orientated approach to structuring such cities present both opportunities and challenges yet other city structures seek to separate disparate functions into distinct precincts resulting in a divided city comprise of “mono-functional areas”. Cities that reflect this development strategy is largely supported by a societal shift to an overreliance on vehicular transport and the resulting road infrastructure. The grid city layout facilitated rail networks and the motor vehicle, representing the physical manifestation of a societal shift in development and human triumph that conquered the restrictions of natural form. Other cities were formed to highlight significance of government, power, divinity and military, each with key characteristics that include such elements as concentric orders importance from the centre, radial design, and procession boulevards. Historically, cities also formed out of need for defence including walled cities, fortification, and confusion for example the maze-like canals of Venice. It was explained that: “It is not the lack of pedestrian traffic and residence that has prevented the establishment of more intimate and better used public spaces, but rather the decision to have many dispersed roads and paths instead of a more concentrated street network such as that found in old cities. In the entire history of human settlement, streets and squares have been the basic elements around which all cities were organised. History has proved the virtues of these elements to such a degree that, for
most people, streets and squares constitute the very essence of the phenomenon ‘city’” (Gehl 2011, 89).

Architecture provides the physical structure that shapes our cities, proximities and interstitial spaces and concurrently, in modern cities they provide a physical armature that augments the capabilities of digital surveillance technologies including CCTV, biometric scanning, recognition technologies and the like.

4.3 Harvesting of Human Kinetic Energy

Technology for human energy harvesting that could drive future cities and achieve long-term sustainability exists in the form of Piezoelectricity, or “pressure-driven electricity” (discussed later in this paper) yet is still being researched and perfected to achieve efficiencies and economies of scale. For the purpose of urban design and architecture, existing technology allows for application of Piezoelectricity through floor, wall and other services and finishes to which pressure is applied. This could be in the form of people walking on, sitting, touching, pressing, or driving upon specific and strategically positioned materials. This research argues that while a degree of research involving CCTV in public space and the link to crime exists, little, if any, research on the effects of hyper-surveillance has been undertaken which relates to the understanding of its effects on greater societal behaviours of citizens themselves who are under constant observation in urban spaces. The aim here is to utilise surveillance data to understand how design strategies shape behaviours in both intended and unintended ways. Moreover, how intended shifts can be applied to the predictability in human mobility and transition through urban forms to provide opportunities for potential increased efficiencies in harvesting / cogeneration of human kinetic energy.

The connection between densification and the ability to generate thresholds for mass public transport is also well established and understanding trends of human mobility is likely to benefit “sustainability gains that can be realised are related to improvements of the fuel efficiency of public transport equipment, improved regulations and enforcement and the construction of environmentally friendly mass transit systems” (Jenks and Burgess 2004, 1). From a city-design perspective, improvement in sustainability for public transport results in a reduction in reliance on motor vehicles, and with it, expenditure on road infrastructure which segregates cities, and creates physical and implied boundaries between precincts and people, thus what is required is an increase in the “land-use mix index and restructuring the street networks and urban design to be more pedestrian friendly” (Sung and Oh 2011, 70). In Australia, planners and government continued to refer to “‘healthy growth’ when a city grows at 2.3% each year, without mentioning that this would mean doubling every 30 years”, which is higher than the growth rate in Asia (currently set at 1.1% per year) resulting in an Australian population growth that parallels a Third World country (O’Connor and Lines 2008, 6: 77). The following two quotes provide an insight into the perilous nature of current trends, and this highlighting the need to reshape and rethink the way we use and develop relationships with purpose, design and integration of functions and density in cities: [1] There is an extraordinary paradox in Australia between our perception of the human population, levels of education and environmental issues. Ours is one of the richest nations, biologically, in the world. It is also one of the most environmentally degraded nations in the world. Australians are relatively well educated, but we are not well educated in issues associated with human population size and long-term ecological sustainability (Foran and Poldy 2002 cited in Goldie and Betts 2014, 9). [2] There are additional environmental major impacts that arise from large and rapid increases in human population size. As examples: (1) Based on figures calculated in 2002, around 200 tons of natural resources must be moved each year to maintain each Australian at current standards of living – 2.5 times higher than for a person in the USA and five times greater than for an individual in Japan. The environmental impacts of additional resource use and movement associated with each extra person have been outlined above. (2) Every extra person in Australia is responsible for about an additional 24 tonnes of CO₂ emissions per capita, per year. That is twice the OECD average and four times the world average (Hughes 2014 cited in Goldie and Betts 2014, 9).

Rather than surveillance theory itself, which is largely researched and published, this study specifically focuses on utilising the proposition that surveillance technologies, in conjunction with GIS information embedded in architecture, built form and urban design (and BIM models) to understand behaviours and trends of human mobility which in turn will provide critical knowledge for the design and re-design of future and existing urban environments leading to better decision-making on the use of materials, textures and finishes that aim to provide for improved spatial utilisation and efficiency. With this the following section provides a brief overview of the Geostatistical methodology, its purpose, it adaptation, and limitations. This is by no means an exhaustive essay on Geostatistics but intends to provide the explanatory framework for highlighting how GIS information already utilised and embedded in most disciplines of built environment projects, modelling software and mapping, in addition to non-sensitive surveillance data can be utilised to inform future design as a decision-making tool.

5 Conclusion and Further Research

The placement of the physical structures also shapes our cities and frames the urban spaces that nourish everyday life between buildings. These structures inform inhabitants about the affordances, pathways and activities within and serve also as the infrastructure to which many surveillance instruments are affixed. Research in the U.K and U.S, as well as Australia, find that CCTV footage is ineffective in preventing crime and shaping behaviours but can be valuable in gathering data that allows researchers to better understand how spatial parameters effect human behaviour through patterns and trends allowing for predictability and probability. CCTV data and the sources of what could be considered surveillance data, such as telecommunications triangulation and GPS tracking, and a powerful networks of the Internet of things that captures everyday movements on the ‘grid’ could also provide significant opportunities to understand how to better design cities for inclusivity and mobility through the urban environment, and to harness mass movement patterns into the harvesting of cogeneration energy for use in our cities, and to provide safer and more socially sustainable public space. In undertaking a review of relevant existing literature, what has become apparent is that there is much research involving CCTV in public space and the link to crime, slightly less on the effects of surveillance on societal behaviours, and little, if any, on the effects of such surveillance on mass populations under constant surveillance in urban spaces of modern cities, and none on how this untapped resource could be used to inform design that not only adds to safety but also harnesses energy. Existing under prolonged hyper-surveillance conditions is considered to be unhealthy and in light of this, this research argues that the collective attitudes/behaviours and responses to the built environment of citizens in highly densified cities can be mapped out and with this trends and patterns produced which can contribute to design decisions that shape spatial-behavioural relationships and allows for the analysis of mass movements which can drive the harvesting of cogeneration energy for use in our cities, and to provide safer and more socially sustainable public space. Moreover, modern electronic surveillance systems are
strategically placed within urban spaces and the architecture of the private and public buildings. Considering that ever increasing density of our cities, the monumental shift in populations from regional to urban areas, and with this an increase in population by the billion, the variety of systems, spaces, materials and surfaces within urban environments also offer an incalculable opportunity to embed human kinetic energy harvesting technology such as Piezoelectricity, or "pressure-driven electricity." This energy once harvested could be transferred to the municipal great or direct use within our cities and society. The built environment, be it urban space, or the architecture of public and private buildings, provides the complementary backdrop for strategic placement of electronic surveillance systems. Considering that ever increasing density of our cities, the monumental shift in populations from regional to urban areas, and with this an increase in population by the billion, the variety of systems, spaces, materials and surfaces within urban environments also offer an incalculable opportunity to embed human kinetic energy harvesting technology such as Piezoelectricity, or "pressure-driven electricity." This energy once harvested could be transferred to the municipal grid or used directly within our cities.

Surveillance architectures within the built environment, whether they are physical, digital or a system, have the capacity to evoke behaviour modification responses that may be detrimental to functional intent. This suggests that as an authoritative and controlling instrument, significant dedicated research is required to acquire sufficient understanding of cause and effect, and with this, decision-making. Although some research is conducted within the realms of some disciplines, considerably more is required from the disciplines of architecture and urban design where a heavy practice-focus persists. Here, those who design the very environments and specify materiality and systems discussed in this proposal have the unique opportunity to challenge current knowledge and attain a new understanding from increasingly diverse perspectives, including design intent and resulting post occupancy research and utilising surveillance data for purposes beyond surveillance itself but to understand patterns and trends that support design decisions that help promote safety, inclusivity, provide a sense of community, and has the potential to harness mass movement patterns into the harvesting of cogeneration energy for use in our cities, creating a more socially sustainable public space. Outcomes of such research could also help guide municipal planning and development policy. While inference can be made between different hyper-surveillance environments, problematic levels of urban-level surveillance already exist, suggesting further specific investigation of data from such systems is likely to allow for capacity around building intelligence to determine patterns of behaviour as it relates to national and international examples of densified urban spaces and built form. Through increased capability of built environment professionals, this body of knowledge provides critical new and innovative mechanisms by which to consider how cities can be forward planned, formed, further developed, and in-filled with higher density strategies to achieve safe and sustainable spaces. Understanding trends and population mobility through surveillance data and other digital means as a design tool, empowers designers to make more efficient decisions around placement of materiality and technologies that support the harvesting of human energy. Harvesting technologies can be aligned as a series of related nodes and systems that support each other and create synergies.

6 References


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Abstract:
Due to globalisation, cultural diversity has grown at workplaces. Cultural diversity is bound to exist in construction project environment because of the nature of the industry, where plethora of construction professionals are involved from the inception to handover, especially during design and execution stages. Understanding and managing cultural diversity can provide several advantages and may become crucial for project success. On the other hand, if they are not well managed then it can create issues that may negatively impact the project success. The influence of culture can be studied at different levels such as industry, organisation or project levels. This research was undertaken to look for empirical evidence of a relationship between cultural orientations and project performance in an organisation. Integration, cooperation, goal-orientation, flexibility, and people orientation are used to characterise the cultural diversity. For the purpose of this study, three project teams of a global design & construction consultancy organisation formed the sample unit for analysis. An exploratory study using questionnaire survey was conducted to determine the perceptions of employees in their respective teams about their project performance and their cultural orientation as well as to establish correlation among them, if any. The findings of the study indicate that cultural differences in the organisation is statistically negatively correlated with project performance. In particular, goal-orientation of the employees tends to limit the project performance while flexibility among the team members enhances the project performance.

Keywords:
Cultural diversity, flexibility, globalisation, goal-orientation, project performance

1 Introduction
Culture as well as cultural diversity are main concern for every organisation across the industries (Kivrik et al., 2008). Trompenaars and Turner (1997) portrayed culture as follows:

“A fish only discovers its need for water when it is no longer in it. Our own culture is like water to a fish. It sustains us. We live and breathe through it. What one culture may regard as essential, a certain level of material wealth for example, may not be so vital to other cultures.”

In the era of globalisation, cultural differences influence work in multi-national projects, particularly it impacts project performance. Members of the team coordinate and closely work with people or teams working beyond national boundaries; or their team itself made up of members from several nations or culturally diverse background.
Understanding cultural differences and successfully managing it in an organisation can provide several advantages for the project outcome. Effective management of diversity can increase work productivity, positively affect creativity and innovation and problem solving. Subsequently, it plays a vital role in improving overall performance and enhances competitive advantage of an organisation.

Cultural diversity is bound to exist in construction project environment because of the nature of the industry, where plethora of construction professionals are involved from the inception to handover and use of varied procurement systems, especially during design and execution stages (Kivrak et al., 2008). Improper management of cultural diversity may lead to problems such as workplace conflicts, decline in productivity and resource inefficiency that shall have negative implications on the project performance. It has been attempted to seek empirical evidence for relationship between cultural orientations and project performance in an organisation involved in construction. An exploratory study using questionnaire survey indicates that cultural differences in the organisation is statistically negatively correlated with project performance. Salient findings of this study is reported in the article.

2 Literature Review

A review of literature on characterisation & influence/impact of cultural diversity & project performance as well as relevant research in the construction domain is presented in this section.

2.1 Cultural Diversity

Culture is a common method of processing data or interpreting the information within people. This can affect any business if there are cultural barriers. The collaborative dependency is because of the fact that “they constitute a connected system of meanings: a shared definition of a situation by a group” (Trompenaars and Turner, 1997). These set of beliefs and shared ideas have repercussions on the way one member interact with others within the organisations. A study on cultural diversity management model for Indian organisations identified the following dimensions: differentiation between social groups, risk taking, individual’s social relationships and time orientation (Kulkarni, 2012). Popescu et al., (2014) proposed tools for evaluating management of diversity in cross-cultural project teams.

Kandler and Laland reported that both independent invention and the modification & refinement of established innovations influence cultural dynamics & diversity (Kandler and Laland, 2009). Cultural diversity also has an effect on creativity. Diversity in creativity and cognitive style exists between and among ethnic and cultural groups; there are as many within-group as between-group differences (Oades-Sese and Esquivel, 2011). There exists a relationship between cultural diversity and economic growth. (Ager and Brückner, 2013). Also, it has been established that workforce diversity can improve productivity (Saxena, 2014).

2.2 Project performance

Performance of a project within an organisation is the measure how good the project has done in achieving project objectives. Pinto and Slevin identified ten critical factors responsible for successful project implementation. They are: project mission, top management support, plan/project schedule, client consultation, personnel, technical tasks, client acceptance, monitoring & feedback, communication and troubleshooting mechanisms. (Pinto and Slevin, 1987).

The factors that predicate project success were initially derived from the Integrated Building Process Model developed at Penn State by Sanvido in 1990. Later on, these factors were tested on sixteen projects and the following four factors were found to be critical: (1) a well-organised & cohesive facility team, (2) contracts administration, (3) past experience and (4) timely & valuable optimisation information (Sanvido et al., 1992). A conceptual critical success factors model for construction projects suggested by Gudiene et al., (2013) in seven major groups, namely external factors, institutional factors, projects related factors, project management/team members related factors, project manager related factors, client related factors and contractor related factors.

Atkinson (1999) investigated success criteria other than the iron triangle (time, cost and quality), such as stakeholder benefits. It considered the delivery stage also as a criteria for success. Chan and Chan (2004) proposed a set of key performance indicators (KPI) that includes objective & subjective indicators for measuring the success of construction projects. A cross cultural comparative study was conducted between software practitioners in Chile and those from USA. (Pereira et al., 2008). Responses from both groups of practitioners indicate that there is a relationship between team-work and success; results also indicate that there are similar perceptions related to the importance of job satisfaction and project success.

According to Ozguler (2016), developing a multi-cultural project management process using the following steps can also increase the project’s success rate: Assess the multi-cultural competence level of the organisation; assess the multi-cultural competence level of the project managers; design an organisational cultural map; assess the existing project management process; create an improvement plan; develop multi-cultural project management process; and follow the multi-cultural project management process. Further considerations in project success like stakeholder perception, human side, and financial approach were studied by Stebysen (2017).

Lam et al. (2008) reported the determinants of successful design and build projects in Hong Kong and concluded that project nature, effective project management action, and adoption of innovative management approaches are the critical success factors. Radujkovic and Sjekavica clearly differentiated project success and project management success and proposed a framework for project management success (Radujkovic and Sjekavica, 2017).

2.3 Cultural diversity and project performance in construction

Ofori and Toor (2009) investigated cross cultural leadership and management in construction. They reported that there is a need for a more interdisciplinary and interactionist perspective to unearth the complexity of cross-cultural issues (Ofori and Toor, 2009). According to Murata (2013), managers use ‘flexible leadership styles’ to cope with the cross-cultural environment to leverage the sustainable competitive advantages embedded in cultural diversity. Kim et al., (2015) investigated the impact of cultural differences on motivating factors within foreign laborers in construction sites and also studied their effects on productivity. Grisham (2006) proposed XLQ model for evaluating cross cultural leadership and also discovered that conflict management is key to success for construction project managers.

From the above review of literature, it can be observed that cultural diversity has a direct or indirect effect on the project performance and the evidence for the same from construction projects is limited. Hence, there is a need to conduct further investigation to establish the interaction among the factors influencing the cultural diversity and project performance.
3 Problem Description

Many studies have demonstrated that there is growing awareness of the role of the softer issues such as culture in project performance in the construction industry. Globalisation and liberalisation opened new avenues for business and there are plenty of international construction projects. They are tagged as international projects because of the geographical location of execution or composition of stakeholders involved. This leads to people from various cultural/ethnic groups coming together to successfully complete the project. Therefore, it is important to address this question – “Does cultural orientation vary from project to project and how does it impact the outcome of any project?” Hence, the primary aim of this research work is to investigate the effect of culture on construction project performance. It has been attempted to characterise the cultural diversity and project performance using the factors identified from the existing literature as presented in Figure 1 & Table 1. Integration, cooperation, goal-orientation, people orientation & flexibility have been used to measure the cultural orientation in an organisation. In order to measure the performance of the project, six performance indices were selected. These are satisfaction with the project process, commercial success, opportunities in terms of future business, learnings from the project, satisfaction among the various stake holders, and overall performance. Also, it has endeavoured to establish the extent of relationships among these factors.

4 Research Methodology

This section outlines the research methodology adopted for undertaking this study (Figure 2). An extensive literature review has been conducted to arrive at the conceptual framework as described in the previous section that includes the identification of factors influencing cultural diversity and project performance.

Questionnaire survey along with semi-structured interviews have been used to collect the data from the sample. Factors of both the dimensions of the research framework, cultural diversity and project performance formed the basis for questionnaire design. The questions were formulated covering every aspect of the factors selected for the study.

Table 1. Factors influencing cultural diversity and project performance

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural Diversity</td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td>Encouraging the input of different parties or members in project process during its life cycle.</td>
</tr>
<tr>
<td>Cooperation</td>
<td>Avoiding the conflict and aligning the team members or project participants to a common objective of the project and creating a collaborative environment.</td>
</tr>
<tr>
<td>Goal-orientation</td>
<td>Creating a goal orientation culture and the highest priority is given to the final results.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>How often or to what extent the innovative approaches are welcomed and also rewarded during the process of any project. It also includes risk taking behaviour or attitude of the employee.</td>
</tr>
<tr>
<td>People-orientation</td>
<td>It describes whether the issues of people are given more priority and what opportunities they are given to gain new learnings during the process.</td>
</tr>
<tr>
<td>Project Performance</td>
<td></td>
</tr>
<tr>
<td>Economical</td>
<td>Commercial success, Opportunities in terms of future business.</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>Satisfaction with the project process, Learnings from the projects.</td>
</tr>
<tr>
<td>Business opportunities</td>
<td>Opportunities in terms of future business.</td>
</tr>
<tr>
<td>Lessons learned</td>
<td>Learnings from the project.</td>
</tr>
<tr>
<td>Relationships</td>
<td>Satisfaction of the stakeholders.</td>
</tr>
<tr>
<td>Overall</td>
<td>Overall project performance.</td>
</tr>
</tbody>
</table>

Figure 2. Research Methodology

The questionnaire used in the study consists of three sections.

Part A: Questions to capture demographic information about the respondents and project details.

Part B: Questions to assess the cultural orientation on 5-point Likert scale.

Part C: Questions to measure the project performance on 5-point Likert scale.

The respondents were guided to respond to Part B & Part C with reference to the same project that they worked in the past.
The organisation chosen to conduct the study is a multinational organisation headquartered in Australia and has numerous divisional offices in several parts of India and rest of the world. The organisation was recently acquired by an organisation from Singapore. The nature of the organisation in terms of its presence and ownership itself made a good choice for the sample so that it may prove to be an organisation with culturally diverse workforce. Diversity not only in terms of workforce but also geographically. The organisation have its presence in 40 countries located across Asia, Australia, North America, Middle East, UK and Africa. It employs a talent pool of 13,500 workforces across the globe. In India, its office is located in Gurgaon, Haryana. It provides technical services for a project and delivers consultancy services to a wide-ranging sectors including Transport, Water Resources, Environment, Built Environment, Energy, among others.

For the purpose of the study, sample were three project teams (Team A, Team B, Team C) working on different projects from different divisions of the organisation. The questionnaire was distributed to these groups who formed the subject of the study. Responses were marked by the members of the team. Thus the relationship stated in the framework was tested on three teams of the same organisation and participants of the survey were mutually exclusive i.e. no two person taking the survey were working on more than one project out of the three project teams in consideration. The questionnaire was floated to 40 members. Out of which 27 responses were received. Thus the response percentage was approximately 68%.

Data collected through questionnaire survey was collated and tabulated in MS-Excel and trend charts and graphs were plotted to interpret the findings of the data. A 5-point Likert Scale was used to collect the data about the perception of the project team members in the three samples about the cultural orientation and the project performance in their respective teams and subsequently establishing the correlation between the two dimensions.

4.1. Ratings for extent of cultural diversity and project performance

In order to analyse to the responses, the ratings in Table 2 are used to represent the extent of cultural diversity and project performance. These ratings primarily capture the collective effect of the factors influencing the cultural diversity (or project performance) as presented in Table 1. For example, Integration is one of the factors influencing the cultural diversity that characterises Encouraging the input of different parties or members in project process during its life cycle. If the variability of measurement of this attribute is very high among the project team members then it can be understood that the team is highly diverse with respect to Integration. It has been attempted to assess such contributions from the all factors to the cultural diversity and the composite score is used for rating. Similarly, ratings are arrived at for the project performance also.

### Table 2. Ratings for cultural diversity and project performance

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural Diversity</td>
<td>5.0-3.0</td>
<td>Highly Diverse</td>
</tr>
<tr>
<td></td>
<td>3.0-1.5</td>
<td>Moderately Diverse</td>
</tr>
<tr>
<td></td>
<td>&lt;1.5</td>
<td>No Diversity</td>
</tr>
<tr>
<td>Project Performance</td>
<td>5.0-3.5</td>
<td>High Performance</td>
</tr>
<tr>
<td></td>
<td>3.5-2.0</td>
<td>Moderate Performance</td>
</tr>
<tr>
<td></td>
<td>&lt;2.0</td>
<td>Poor Performance</td>
</tr>
</tbody>
</table>

### Table 3. Cronbach Alpha coefficient of data collected

<table>
<thead>
<tr>
<th>Team</th>
<th>Cultural Diversification</th>
<th>Project Performance</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.86</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.81</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.76</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>

### 4.2 Statistics used

For the purpose of testing reliability of data, Cronbach Alpha coefficient is used. Pearson correlation coefficient is used to determine to what degree the cultural diversification and performance of the three teams are statistically correlated.

5 Data Analysis, Results and Discussion

5.1. Reliability Analysis

Data collected from three teams of the sample organisation has been tested for reliability using Cronbach Alpha coefficient. The resultant coefficients are presented in Table 3. Since all the coefficients are all above 0.70 and therefore acceptable for further analysis.

### Table 3. Ratings at macro level

<table>
<thead>
<tr>
<th>Team</th>
<th>Cultural Diversity Average Score</th>
<th>Project Performance Rating Average Score</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.97 Moderate</td>
<td>3.56 High</td>
<td>-0.89</td>
</tr>
<tr>
<td>B</td>
<td>3.23 High</td>
<td>3.44 Moderate</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3.30 High</td>
<td>3.48 Moderate</td>
<td></td>
</tr>
</tbody>
</table>

It can be observed that project team A is rated as moderate in cultural diversity and that project’s performance has been rated as high. On the other hand, teams B & C are high in cultural diversity and the respective performance of the projects are rated low. It implies that there exists a relationship between cultural diversity and project performance and they are negatively correlated.

5.3 Relationship between factors influencing cultural diversity and project performance

It has been attempted to understand if there is a different relationship between the factors influencing the cultural diversity and the project performance. The factor level scores and rating for cultural diversity factors and micro level ratings are presented in Table 5. It can be noticed that there is a variability in the level of impact of the factors of cultural diversity on project performance. Hence, a correlation analysis has been conducted between factors influencing cultural diversity and project performance. The results are presented in Table 6. It is observed that flexibility is positively correlated with the project performance while integration, cooperation, goal-orientation and people-orientation are negatively correlated.
A micro level analysis shows that various factors contributing to the project performance. It would also be interesting to study the effect of cultural diversity on project performance. There is limited literature on the effect of cultural diversity on project performance whereas flexibility is moderately positively correlated. These are in line with the work reported by Murata (2013) and Grisham (2006). It implies that goal-orientation and integration among the project stakeholders must be critically looked into for improving the project performance. Also, it has been inferred that efforts must be taken to improve the flexibility as it can positively influence the performance of the project as reported by previous researchers (Ofori and Toor, 2009).

6 Summary and Conclusions
Culture and cultural diversity are some of the major concerns for every organisation across the industries. Cultural diversity is bound to exist in construction project environment because of the nature of the industry. Understanding cultural differences and successfully managing it in an organisation can provide several advantages for the project outcome. There is limited literature on the effect of cultural diversity on project performance. It has been attempted to investigate the same with data from the teams of a multi-national organisation involving design and project management. The results revealed that there exists a negative relationship between cultural diversity and project performance. Also, it has been observed that some of the factors influencing cultural diversity such as goal-orientation and integration are very highly negatively correlated with the project performance whereas flexibility is moderately positively correlated. This provides some insights for the project managers to manage the cultural diversity in project teams right from team formation. The data used in the study is from three project teams of a single organisation that limits the generalisation of the findings. If such study is extended to multiple organisations and variety of projects then the outcome would help in much deeper understanding of the interaction among the factors. It would also be interesting to study the effect of every factors contributing to the cultural diversity on the factors influencing the project performance. In conclusion, it can be stated that studies on cultural diversity in construction projects would facilitate better performance.

7 Acknowledgement
We acknowledge the contribution of Richu George Varghese, Research Associate, RICS School of Built Environment, Delhi NCR in this research work.

8 References

5.4 Discussions
The data analysis and the results revealed that there is a relationship between the cultural diversity and the project performance. Also, this relationship is negatively correlated that implies that greater the cultural diversity lower the project performance. This is in contrast to the findings of Ozguler (2016), where it was reported that developing a multi-cultural project management process can increase the project’s success rate. A micro level analysis shows that various factors contributing to the cultural diversity impacts the project performance differently. For example, goal-orientation and integration are very highly negatively correlated with the project performance whereas flexibility is moderately positively correlated. These are in line with the work reported by Murata (2013) and Grisham (2006). It implies that goal-orientation and integration among the project stakeholders must be critically looked into for improving the project performance. Also, it has been inferred that efforts must be taken to improve the flexibility as it can positively influence the performance of the project as reported by previous researchers (Ofori and Toor, 2009).

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Students attending employment interviews or carrying out work placements lacked skills and attributes to fulfil a management role. Furthermore, a perception has formed, confirmed in forums in which industry liaison takes place, that students attending employment interviews or carrying out work placements lacked skills and attributes to fulfil a management role.

In recent years, the academic programme within the Nelson Mandela University Department of Construction Management has struggled to engage with students to prepare them adequately for the rigours of the first year of study, and undergraduate programme. In particular, an inability to manage themselves, strategise, plan, evolve tactics, and take action, which in turn should have contributed to their ability to study, undertake assignments, and projects, has increased failure rates and negatively impacted retention rates, impacting on successful completion of the programme.

Furthermore, a perception has formed, confirmed in forums in which industry liaison takes place, that students attending employment interviews or carrying out work placements lacked skills and attributes to fulfil a management role expected of them. This weakness in the way graduates communicated their abilities and applied knowledge gained during the course of their studies required an intervention at the earliest opportunity in the education process.
Given the aforementioned, and the Department of Construction Management’s focus on ‘lecturing and learning’ research, a survey was conducted among participants of a first-year orientation one-day team building event, styled on the ‘Amazing Race’ television programme, which was introduced at the commencement of the first year of study.

The objectives were to determine the impact on their ability to:

- manage themselves, work as a team, and interface with each other, and
- strategise, plan, evolve tactics, and take action that would lead to their team winning the ‘race’.

The aim of the research being to identify whether the intervention developed confidence in their abilities, enhanced communication amongst them, and provided an opportunity for them to test alternative thought processes, thereby better preparing the students for the challenges of first-year and the undergraduate programme.

2 Literature Review

2.1 Empowering the individual

“Construction management programmes need to empower graduates to manage the business of construction” (Smallwood, 2006), which requires that the learning environment develops their ability to manage themselves, work as a team, and interface with each other. In addition, their ability to strategise, plan, evolve tactics, and take action, thus becomes a critical learning practice that will manifest itself in the ability to perform in the workplace, a necessity particularly within the global construction sector, where skills are in short supply (Turner & Townsend, 2017).

Experience and anecdotal evidence indicate that undergraduate students encounter challenges in terms of completing the academic programme within the allocated study time. Work-ready graduates make positive contributions to the industries within which they work (Borg et al., 2018), and thus developing confident students to enter the workplace becomes an important function of university education. This exposes traditional pedagogy and teaching to critical questioning, with the focus on intellectual critiques not helping students to cope with everyday realities, responding, and learning, that are the essence of practice (Cunliffe, 1999).

Confidence evolves from a better understanding of the work environment and this is partly a result of a student’s life experiences and competency of the tasks and activities within that realm. Competency embodies the capacity to transfer skills and abilities from one area to another, and competencies are the characteristics of managers that lead to the demonstration of skills and abilities (Smallwood & Emuze, 2011). An inability to master these competencies sufficiently whilst within the higher education domain, through vacation work or practical skills learning undermines the confidence of students to be able to perform within the work environment (Jackson, 2015). However, as Kamardeen (2013) notes, confidence is also accomplished by helping students establish positive expectancies for success, which means exploring practices that increase interface time with one another, and explore other boundaries outside the current teaching and learning environment, thus providing opportunities to tackle any deficiencies. An aspect to this is an understanding of the challenge of managing others in the field and applying those concepts learned in the classroom (Farrow, 2016), which requires that students be exposed to the management of others whilst in higher education, which may be enhanced by team building exercises.

Jackson (2015) states that “it is important to be refining, developing and practicing your skills, not simply starting to learn them”, which further emphasises the need to get students out of the classroom and into a pseudo work environment. There is also an idea that all millennial students need active learning (Farrow, 2016) as they have become less exposed to workplace environments and participation in physical labour activities. By enhancing these through the types of activities included in a team-building event, construction management programmes are improving graduates’ suitability for appropriate employment. This is in addition to students attempting to gain experience through vacation work, which is undermined by a lack of practical skills.

Furthermore, the dramatic changes in social, economic, and environmental issues experienced since the turn of the millennium has forced construction management programmes to produce more prepared personnel (Lee et al., 2011). Simply put, students need to be able to think critically and solve problems effectively. Merely having knowledge or information is not enough (Snyder & Snyder, 2008).

In addition, as the Enhancing Student Employability Co-ordination Team (ESECT) at the Higher Education Academy argue, to enhance employability, it is necessary to ensure that practices that foster understanding, skills, efficacy, beliefs and metacognition (appropriate personal manner) are employed in higher education programmes (Vorke & Knight, 2007). Relevant course materials that demonstrate applications of theories to real world issues (Kamardeen, 2013) need to be included within the curriculum.

2.2 Learning in context

When addressing inadequacies of both students and programmes, it is important to understand what they will be expected to deal with when they enter the workplace. “Students with a science background are more likely to emphasize operation learning while those coming from arts tend to emphasize comprehension learning.” (Warburton, 2003) However, students in Construction Management need an education ‘that balances operation and comprehension learning’ as they in essence need to straddle these different spheres of learning to be able to manage a project team who may incorporate professionals from both spheres of learning.

The nine recognised functions in an organisation, and five functions of management work, provide further insight relative to the knowledge and skills required by construction managers (Smallwood, 2006). However, this only introduces the theoretical challenges of the discipline and not the practices as experienced in the field. As Hmelo-Silver et al. (2007) state: “learning the concepts and theories of a discipline is best situated in the context of the practices of that discipline”. This is exacerbated by the students generally not having experienced an environment where they can relate theory to practice, which has led to an increased need to engage with students on site visits, as “curricula must support student learning and personal development through providing a meaningful and motivational context.” (Edstrom, 2012)

In addressing specific core competencies, based upon their contribution to project success relative to their importance, it can be concluded that aptitude, attitude, team player, focus are critical core competencies to client success (Smallwood & Emuze, 2011). Envisaging an environment outside the classroom with a unique set of physical and mental challenges to enhance these competencies becomes a strategy to introduce construction management students to a collaborative problem-solving environment. This, whilst also enhancing their ability to strategise, plan, evolve tactics, and take action within a practical
environment in which actions result in consequences for them and team mates, a pseudo project environment.

Mo et al. (2007) emphasise that skills include an ability to think across disciplines, team working, and social and environmental awareness. Learning this in the traditional classroom environment is challenging, not least due to students being unable to articulate their thoughts, nor communicate with their lecturers or one another, and an overreliance on smart phones as the only source of information coupled with an inability to read and discuss the findings of their investigations with their peers. Students, in general, find it challenging to communicate and work in a team particularly in the early years of their studies (Bogdanovic et al., 2016).

The survival of any organised human activity depends largely on a person’s ability to communicate with others (Zulch, 2016). In construction, due to the fragmented make-up of project teams and adversarial nature of the business, communication is a critical component to keeping ‘cooperation in an organisation’ (Martin, 2007). Business employees need to communicate effectively, get along well with their co-workers, embrace teamwork, take initiative, have high work ethic, and portray professionalism (Robles, 2012). In particular, decision-making and problem solving are core communication skills that a manager needs in order to make a well-informed decision (Zulch, 2016), skills which first-year students’ require to manage themselves in order to complete their studies.

2.3 Developing soft skills

Skills are the ability to translate knowledge into an action that results in the desired performance (Zulch, 2016). Employers identified problem-solving skills (e.g. critical thinking skills) as an important factor when assessing new graduates’ employability (Finch et al., 2013). Problem solving incorporates a range of competencies including critical thinking skills, creativity, leadership skills and adaptability. To be effective in the workplace, and in their personal lives, students must be able to solve problems to make effective decisions, therefore, they must be able to think critically (Snyder & Snyder, 2008).

Business educators need to understand the importance of interpersonal skills including communication, integrity, and courtesy for their students and include soft skills in their curriculum (Robles, 2012). Some of these skills include effective communication, adaptability, time management and interpersonal skills (Cavanagh et al., 2015) as well as being independent, able to manage and lead others (Dacre Pool & Sewell, 2007). It is these soft skills that enhance students’ ability to strategise, plan, evolve tactics, and take action, which in turn contributes to their ability to study, undertake assignments, and projects. In addition, as already highlighted, effective student learning occurs when instructional models incorporate social and psychological dimensions in the design of curriculums (Kamardeen, 2013).

Employers value skills that transcend specific roles and occupations (Finch et al., 2013). Current and future business leaders are emphasising the development of soft skills (Nealy, 2005) as these skills are critical for productive performance in today’s workplace (Robles, 2012). These skills are at the very core of the challenges that students face in their first year when competing deadlines will test their ability to manage their time and themselves to achieve an effective outcome across all subjects, a skill they may not have acquired during their school careers (Chidzonga, 2014). Universities must therefore emphasise the development of soft-skills within all their programmes, as soft skills are more highly valued than an academic qualification by many employers (Finch et al., 2013), and soft skills and behaviours have been increasingly recognised as contributing to the attainment of work readiness (Borg et al., 2018).

3 Research Methodology

Given the challenges recorded in the introduction, the department arranged a team-building event involving the first-year students at a resort near to the university during orientation week. The event entailed seven activities, hoop, blindfold object hunt, hike, puzzle, letter matrix, three stick triangle, and conveying of a golf ball. Each of the activities entailed one or more of the following: strategising; planning; evolving of tactics, and taking of action.

The researchers employed a quantitative approach using a self-administered questionnaire to determine the students’ perceptions with respect to the intervention, the rationale being that the researchers had adopted the same research method, and administered a similar questionnaire for an honours level study. All twenty-one students from the first-year cohort who could attend the team-building event completed the questionnaire a few weeks after the event. The questionnaire consisted of thirteen questions, twelve closed ended, using either a five-point or a six-point Likert scale question. Due to paper length constraints, this paper reports only on the findings relative to nine of the questions, as these were central to the intervention. The three questions not reported on were skills, and core competencies related. A measure of central tendency in the form of a mean score (MS) between 1.00 and 5.00 (five-point), and 0.00 and 5.00 (six-point) was computed based upon the percentage responses to the points on the respective scales to enable interpretation of the responses and to rank variables where necessary. Weighting of responses is as per the figures recorded within parentheses: did not (0); minor extent (1); near minor extent (2); some extent (3); near major extent (4), and major extent (5).

4 Findings and Discussion

Table 1 indicates the extent to which the team building activities impacted on participants in terms of percentage responses on a scale of 1 (minor) to 5 (major), an additional point ‘did not’ and MSs. Given that there are effectively six points on the scale, the MSs are between 0.00 and 5.00, the midpoint being 2.50. It is notable that all the MSs are > 2.50, which indicates that in general the team building activities impacted more of a major than a minor extent on participants. However, a review of the MSs in terms of ranges provides a more detailed perspective. 6 / 7 (85.7%) MSs are > 3.34 ≤ 4.17, which indicates the impact can be deemed to be between some extent to a near major extent / near major extent: your ability to communicate with your 1st year colleagues; building confidence in your own abilities; your ability to complete a task; enhancing alternative thought processes; your ability to be creative, and improving your time management skills. Only 1 / 7 MSs is > 2.50 ≤ 3.34, indicates the impact can be deemed to be between a near minor extent to some extent / some extent - removing you from your ‘comfort zone’.

Table 1. Extent to which the team building activities impacted on participants

<table>
<thead>
<tr>
<th>Impact</th>
<th>Response (%)</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your ability to communicate with your 1st year colleagues</td>
<td>0.0</td>
<td>23.8</td>
<td>4.0</td>
</tr>
</tbody>
</table>

243.
Table 2 indicates the extent to which the team building activities enhanced participants’ various abilities in terms of percentage responses to a scale of 1 (minor) to 5 (major), an additional point ‘did not’, and MSs. It is notable that all the MSs are > 2.50, which indicates that in general the team building activities enhanced participants’ various abilities more of a major than a minor extent. It is notable that no MSs > 4.17 ≤ 5.00 - enhancement is between a near major extent to a major extent / major extent. All the MSs are > 3.34 ≤ 4.17, which indicates the enhancement is between some extent to a near major extent / near major extent.

Table 2. Extent to which the team building activities enhanced participants’ various abilities

<table>
<thead>
<tr>
<th>Impact</th>
<th>Response (%)</th>
<th>MS</th>
<th>Ran k</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U</td>
<td>Did</td>
<td>Minor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Strategise</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Plan</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Take action</td>
<td>0.0</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Evolve tactics</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Respondents were then required to indicate the extent to which the individual team building activities enhanced participants’ ability to strategise, evolve tactics, take action, and plan relative to each activity.

Table 3 indicates the extent to which the team building activities enhanced participants’ ability to strategise. It is notable that all the MSs are > 3.00, which indicates that in general the team building activities enhanced participants’ ability to strategise to a major as opposed to a minor extent. It is notable that no MSs > 4.20 ≤ 5.00 - enhancement is between a near major extent to a major extent / major extent. All the MSs are > 3.40 ≤ 4.20, which indicates the enhancement is between some extent to a near major extent / near major extent. The blindfold object hunt, hike, and conveying of golf ball activities predominate.

Table 3. Extent to which the team building activities enhanced participants’ ability to strategise

<table>
<thead>
<tr>
<th>Impact</th>
<th>Response (%)</th>
<th>MS</th>
<th>Ran k</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U</td>
<td>Minor</td>
<td>………….</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blindfold object hunt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hike</td>
<td>0.0</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Conveying of golf ball</td>
<td>4.8</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Puzzle</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3 Stick triangles</td>
<td>9.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Letter matrix</td>
<td>4.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hoop</td>
<td>9.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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Table 3. Extent to which the team building activities enhanced participants’ ability to strategise

<table>
<thead>
<tr>
<th>Impact</th>
<th>Response (%)</th>
<th>MS</th>
<th>Ran k</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U</td>
<td>Minor</td>
<td>………….</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blindfold object hunt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hike</td>
<td>0.0</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Conveying of golf ball</td>
<td>4.8</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Puzzle</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3 Stick triangles</td>
<td>9.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Letter matrix</td>
<td>4.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hoop</td>
<td>9.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Table 7. Extent to which the team building activities enhanced participants’ ability to take action

<table>
<thead>
<tr>
<th>Activity</th>
<th>Minor (1)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Major (5)</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puzzle</td>
<td>0.0</td>
<td>4.8</td>
<td>19.0</td>
<td>47.6</td>
<td>28.6</td>
<td>4.00</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Conveying of golf ball</td>
<td>0.0</td>
<td>4.8</td>
<td>19.0</td>
<td>52.4</td>
<td>23.8</td>
<td>3.95</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3 Stick triangles</td>
<td>0.0</td>
<td>0.0</td>
<td>28.6</td>
<td>52.4</td>
<td>19.0</td>
<td>3.90</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Hoop</td>
<td>0.0</td>
<td>4.8</td>
<td>23.8</td>
<td>47.6</td>
<td>23.8</td>
<td>3.90</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Hike</td>
<td>0.0</td>
<td>4.8</td>
<td>28.6</td>
<td>38.1</td>
<td>28.6</td>
<td>3.90</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Blindfold object hunt</td>
<td>0.0</td>
<td>4.8</td>
<td>33.3</td>
<td>28.6</td>
<td>33.3</td>
<td>3.90</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Letter matrix</td>
<td>0.0</td>
<td>4.8</td>
<td>33.3</td>
<td>33.3</td>
<td>28.6</td>
<td>3.86</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 provides a summary of the extent to which all the activities enhanced the four abilities of participants based upon the extent to which the individual team building activities enhanced participants’ ability to strategise, evolve tactics, take action, and plan, in terms of MSs and ranks. In terms of the enhancement of all seven abilities (mean MS), hike (MS = 3.82) was ranked first, followed closely and jointly by blindfold object hunt, puzzle, and conveying of golf ball (MS = 3.79), 3 stick triangles (MS = 3.73), letter matrix (MS = 3.63), and hoop (MS = 3.50). It is notable that there is only a MS difference of 0.09 between the first and fifth ranked mean MSs. Then, in terms of the mean MS / ability, take action (MS = 3.93) is ranked first, followed by strategise (MS = 3.69), and then jointly by plan, and evolve tactics (MS = 3.48). The overall mean MS is 3.64 (> 3.40 ≤ 4.20) - the enhancement is between some extent to a near major extent / near major extent.

Table 7. Summary of the extent to which all the activities enhanced the four abilities of participants

Abstract:
The uniqueness of projects at different locations with environmental conditions triggers the complexity of construction activities and costing. Project costs consist of direct costs and indirect costs. Traditional Costing Systems (TCSs) calculate direct costs based on the unit price of materials and labour, but does not typically calculate overheads in details. Overheads are usually estimated by allocating percentage of direct project costs. This may pose an issue in the era of globalisation, where the market price information is very transparent supported by computer technology and the competition of construction project resources becomes very tight. Only where the volume of materials and time of labour can be calculated, contingency costs can be allocated against risks. In doing so, the importance of precise cost allocation becomes an important tool to optimise profit margins by carefully controlling the project overhead costing. A research project was set up to explore the concept of utilising Activity Based Costing (ABC) to control construction projects overheads. This paper presents the outcomes of implementing Integrative Literature Reviews (ILRs) aiming to introduce an adaptation of Activity-Based Costing (ABC) system, from Manufacturing Production Lines (MPLs) into Constructing Activity Processes (CAPs). The advantages of Activity Cost Drivers (ACDs) are demonstrated to be implemented through the ABC system. The findings presented here provide a platform for the subsequent phase of the research aiming to implement ABC system to control overheads in construction projects. A successful implementation of the ABC system is expected to significantly increase cost certainty in managing construction projects.

Keywords: ABC system, activity cost driver, construction project, cost management, overhead

1 Introduction

1.1 Background
Every project has the possibility to develop its unique characteristics and supply chain (Alarcón, et al., 2009). Modern clients, complexity of design and operation, fragmentation of work packages and diverse activities require integrated coordination between management involved, during activity of construction (CIOB, 2009). Condition of project involves higher investment and advanced technology along with human resources (knowledge, skill, experience, and attitude). This will inevitably increase the indirect cost (overhead) relatively faster than direct costs (material and labour).
Materials and labour as variable cost components are very easy to budget properly. Contingent costs are the amount of reserve costs assumed to be used to cover the project risk. Project profits are usually added a certain amount or percentage arbitrarily. Thus, project overhead becomes a very important aspect and an object cost manipulation opportunity to gain additional benefits. The overhead cost of the construction project is defined to allocate the project overheads to support the implementation of projects, which cannot be distributed directly to certain activities, and is not commonly accumulated from each activity cost component (CIOB, 2009).

Overhead costs tend to increase faster than direct costs in accordance with project complexity (Assaf et al., 2001; and Jaya, et al., 2010a). Therefore, the overhead of the project will be an important cost component that requires appropriate cost management, control methods, tools and techniques that cannot be satisfied by traditional costing systems (Cokins, 2001; Cooper and Kaplan, 1994; and Freedman, 2013) and current accounting principles (Daly, 2002; and Hicks, 1999).

The Activity-Based Costing (ABC) system is a cost accounting methodology that can be used to measure the cost of resources, activities, work, projects and services as cost objects (Ståkina, 2009). The concept and philosophy underlying the ABC system is that jobs, products or services require activities, and activity require costs (Cokins, 2001; Cooper, 1988; Daly, 2002; Drury, 2008; Hicks, 1999; Innes, et al., 1994; and Kaplan, and Anderson, 2007). The underlying philosophy of the ABC system has features relevant to the construction project process, such as reliable cost accounting, management methods, multiple cost pools, multiple cost drivers, multiple cost components, and transparent cost tracking (Jaya, et al., 2010a). The system also presents important aspects, such as: activity cost, management, and control (Jaya, et al., 2010b). Concepts, definitions, philosophies, features, cost drivers, and management aspects of the ABC system can be used to develop Cost Management and Controlling Practices (CMCPs) to improve the project overhead generating system during the construction phase.

1.2 Statement of the Problem

Traditional costing systems may be well established and appropriate to estimate direct costs, such as materials and labour (Daly, 2002). Indirect costs (overhead) are mostly allocated by rough estimates for construction cost by percentage (CIOB, 2009 and RICS, 2009). Overhead allocated percentage of material costs or labour costs, may not have relevant basis/reasons (Kim, and Ballard, 2001). The percentage of overheads allocated based on material costs, machine operating hours, or direct labour hours can lead to significant cost distortions (Cokins, 2001; Cooper and Kaplan, 1988; and Giammalvo, 2007). The combined overheads in total cost accumulation become somewhat ambiguous (Kim and Ballard, 2001; and 2005) so that overheads will be more relevant if allocated to individual cost objects for each construction project activity (Jaya, et al., 2010b).

Overhead is understood as an indirect cost that has different cost behaviour with the allocation of direct material and labour costs (Andersen, 1917), it should be specifically considered in allocating activity costs in a separate way (Wallace, 1934). According to (Cokins, 2001), overhead calculations dependent on material and labour computations will cause distortion problems in the form of ‘hidden profit of over-costed’ up to two folds, as well as ‘insensible loss of under-costed’ up to ten times.

The construction project is unique, its activity is numerous and varied, most of its activities are very difficult and complex. The complexity and difficulty of construction operations followed by the pro-rata allocation of project overheads on construction activity may create the problem of determining and allocating costs to construction activities. The construction project seems to have a problem with prorate overhead allocation, in other words, the potential loss is unknown.

Other issues related to construction project overheads are at the operational level (Kerzner, 2009); eliminating some components of project overheads appears to be the easiest way to reduce costs when project budgets are exceeded. On the other hand, project overhead tends to increase significantly (Assaf et al., 2001) and becomes a critical cost component to support overall construction activity (CIOB, 2009). Therefore, the current project overhead is not transparent, inaccurate, and has uncertain relationships with activity during the construction phase. This requires a relevant and effective cost accounting management system.

The current Cost Accounting Management Approaches (CAMAs) focuses on recording and reporting regular financial transactions such as monthly payments. This approach is criticized for focusing too much on preparing periodic reports to senior management and external parties. This cannot provide satisfactory improvements to Cost Management and Controlling Practices (CMCPs).

‘Project Benefit’ may be increased through ‘Δ cost saving’ resulting from effective management and control mechanisms over project overhead during the construction stage. The amount of cost savings added to the initial profit plan is referred to as ‘Project Benefit’ (Figure 1-1).

![Figure 1-1: Problem of Cost Management and Controlling Practices (CMCPs) in the Construction Project Source: Adjusted from (Jaya, et al., 2010b)](image-url)

Most contractors usually prefer to make a profit by planning cost components very carefully and tend to keep the cost plan below the project revenue (Figure 1-1). In the construction business, either as a major contractor or a specialist subcontractor, it typically calculates the ‘Total Cost Components’ plan and tries to establish an initial ‘Profit’ by setting allocation of the implementation of total cost plan to the ‘Revenue’. The initial profit of the project will be enhanced by limiting ‘Actual Project Expenses’ to be as smallest as possible and bellow the implementation of cost plan. The additional benefits of this project are contributing through careful control of overhead during the construction operations.

Activity-Based Costing (ABC) systems can develop cost relationships in a transparent manner based on causal relationships, between the resource cost behaviour (especially project overhead) with practical knowledge of the activity and complexity of the construction process, in order to plan minimum costs to generate maximum benefits (Figure 1-1).

2 Research Methodology

Integrative Literature Reviews (ILRs) formed references that studies, critiques, and syntheses in such an integrated way that it is relevant to a new idea or topic, so as to produce a new framework and perspective on adaptation of Activity-Based Costing
3 Literature Review

The concept of traditional costing was initiated in England in the middle part of the 18th century, when the industrial engineers and cost accountants such as Josiah Wedgwood (in 1754) developed a cost accounting system to minimise the risk of bankruptcy during the time of recession (Giroux, 1999). A fundamental change began at the end of the 20th century, and was initiated by the Consortium for Advanced Management – International (CAM-I) as the beginning of the contemporary ABC concept (refer to Cooper and Kaplan, 1988; Drury, 2008; Hicks, 1999; and Kaplan and Andeson, 2007). The development of the ABC system continuously improves the cost accounting methods and weaknesses. Although the sophisticated ABC system has most notable backers such as the US Marine Corps and a number of commercial applications of business-intelligent software (Nayab and Scheild, 2011), however, (Kaplan and Andeson, 2007) introduced a new strategy of proportionate cost accounting techniques that overcomes a shortcoming of the initial costing system through an ABC’s time-driven basis.

3.1 Concept of the ABC System

The initial concept of the ABC system was suggested through ‘two-stages’ of production costing process in manufacturing. The two-stage processes of the ABC system were introduced by Cooper and Kaplan (1988): in the first stage - costs are assigned to cost pools, and in the second stage - cost pools are assigned to products. Different authors explain the two-stages of the ABC system in different ways with a similar purpose. Innes, et al. (1994) explained that activities consume resource costs, and products consume activities. Hicks (1999) defined costs as being assigned to an organisation’s activities, and activity costs are eventually assigned to jobs, products or services. Innes, et al (1994) also stated that overheads are charged to cost pools, and cost pools are attached to products. Drury (2008) described accounted overhead costs are allocated to activity cost pools, and those activity costs are assigned to cost objects. The ABC system can therefore be defined in regard to these two stages of allocating costs in construction projects.

3.2 Definition of the ABC System

The ABC system is defined by Turney (1994a) as ‘a [cost accounting] methodology that measures resources, activities, and cost objects’. This definition accommodates three important components of project costing: resource costs, activities, and cost objects. Cost objects require activities, and activities incur costs. The contemporary ABC system exists for multiple measurements and this should be consistent with the standard requirement for monitoring project processes and performances (refer to Kerzner, 2009) such as, performance measurements and process assessments. The performance measurements support organisation strategies and operations for economic performances related to resource costs, activities, and cost objects, while the process assessments should make the organisation directly able to fulfill comprehensive ways of work being done for the compromised quality, time, and cost of work performance (Turney, 1994b).

Freedman (2013) defined the ABC system as the overhead cost allocation through a cost accounting method on the basis of activity cost drivers to particular activity pools and cost objects. This definition indicates that specific project overheads can be assigned to construction activities on the basis of cost drivers. Several activities can be grouped into unit, batch, project, or facility levels to trace costs to the group of activities. The project overhead costs can therefore be distributed more accurately into these particular groups of activities (Jaya, et al., 2010a).

Roth and Bortick (1994) defined the ABC system as ‘the glory of better management decision making’ on the basis of knowledge of the real product costs, being able to identify cost drivers, establishing driver-cost relationships and implementing the drivers. Project managers need a cost accounting system and cost information to manage and control project progress and cost performance. Consequently, the ABC management systems may enable continuous improvement in many objectives: to eliminate waste, reduce lead-time delivery, increase quality, reduce cost; develop people to improve skills, and increase productivity and moral. The ABC system represents relevant features to project costing and management, they are: reliable cost accounts, cost pools, diverse cost drivers, multiple cost objects, and transparent cost tracers for improving the CMCPs of construction project overheads (Jaya, et al., 2010b).

3.3 Philosophy of the ABC System

An underpinning philosophy of the ABC system is defined by Hicks (1999): as ‘the jobs, products, and services an organisation provides, [that] require it to perform activities, and those activities cause it to incur costs’. This definition is used to underline further applications of the ABC system in construction projects, and highlights important features: e.g., overhead cost accounts, activity cost pools, diverse cost drivers, multiple cost objects, and transparent cost tracers (Jaya, et al., 2010b). Furthermore, construction project overheads should be properly identified and accurately assigned on the basis of activity cost drivers in order to improve the Cost Management and Controlling Practices (CMCPs) during the construction stage (Jaya, 2014). The following section discusses activity cost drivers in construction projects.

3.4 Activity Cost Drivers

The ABC System identifies several categories of cost behaviours within the complex nature of processes, such as direct-variable costs, e.g., unit costs; direct-fixed costs, e.g., batch and project sustaining costs; and indirect-fixed costs, e.g., facility sustaining costs (Beaulieu and Mikulecky, 2008). Various cost drivers have been set to serve them to construction manufacturing production systems, while specific adjustment is required to adapt them to the construction process. The hierarchy of construction activities and their cost drivers are provided in Table 3-1. It highlights the applicability of activity cost drivers in construction projects, namely: unit-level, batch-level, project-sustaining, and facility-sustaining.
4 Findings and Discussion

4.1 Adaptation of the ABC System in Construction Companies

The ABC system is not new to the construction industry and its organisations. However, the system was very rarely used in construction companies, at about 9.5 per cent used the ABC system in general accounting department (Innes, at al., 1994). This indicates that, the ABC system have not been properly introduced into the construction project management.

Construction companies could use the ABC system to maintain the competitiveness of project bidding (Giammalvo, 2007), in line with market prices. Contractors could win the bid but still lose money if the project is priced below market prices, or lose the bid and miss the opportunity to earn profits if the project is priced above competitive markets. Thus, the ABC system can become a leading method to estimate cost and process controls encourage managers to manage construction operations effectively, identify cost inefficiencies, and undertake appropriate decision and action (Marchesan and Formoso, 2001).

The corporate culture of construction companies in the project cost management practice would seem to have changed due to the progress of cost accounting systems and management developments. It might be assumed that cost information systems recently focused on financial accounting reports to satisfy senior management and external parties, whereas today, it could be extended to measure internal organisational activities, such as construction processes, the cost performance of projects and anything that requires effective management and controls for project costs and informed decision making. The application of the ABC concept and development of the ABC system in construction projects may give opportunities and powerful drivers for cost management systems at a managerial level with a transparent system and clear cost ‘cause-and-effect’ relationships, to change their roles on how personnel ‘think and act’ (SAP -AG, 2000). Therefore, the following section introduces the adaptation and application of the ABC system for the cost management and control mechanisms in construction projects.

4.2 Implementation of the ABC System in Construction Projects

A chronological process of adaptation of the ABC system in a construction project is carried out during the literature review and observation stage then represented through a diagram in Figure 4-1.

Table 3-1: Identification of Activity Cost Drivers

<table>
<thead>
<tr>
<th>Activity hierarchy</th>
<th>Cost driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit-level activities</td>
<td>Depress hire fee</td>
</tr>
<tr>
<td>Resource planning</td>
<td>Number of planning hours</td>
</tr>
<tr>
<td>Facility-sustaining activities</td>
<td>Rental office</td>
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<td>Project-sustaining activities</td>
<td>General plan</td>
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<td>Hand-off</td>
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Unit level is an activity cost driver that assigns costs by the unit of output basis, where costs are traced for every unit of output. Good examples of unit level activities include: site helpers and equipment depreciation. Table 3-1 provides an example for this category of unit level cost driver: the unit of time (e.g., hour, day, week, month, or year) becomes a cost driver for depreciation. The ABC method in this context employs resource cost drivers in similar ways to allocating direct costs.

Batch level is an activity cost driver that assigns costs by the batches of output basis, where costs are traced for every batch of output, regardless of the batch size of project outputs. Selected examples for batch level activities include: procurement batch (e.g., purchase order placement, material received, suppliers payment), delivery batch (e.g., delivery to site), process/task batch (e.g., setup equipment, mobilisation, quality inspection), and hand-off batch (e.g., external quality inspection). Table 3-1 represents an example for this category of batch level cost driver: the number of inspections may become a cost driver for this particular type of inspection activity.

Project-sustaining is an activity cost driver that assigns costs by the particular existence of project output bases, where costs are traced for every output of the project, regardless of the unit and batch numbers of products. Examples for project sustaining activities include: general planning, resource planning, cost planning, and cost control planning. Table 3-1 provides an example of the category of project sustaining cost driver: the number of resource plans may become a cost driver for a resource planning activity.

Facility-sustaining is an activity cost driver that assigns costs by the facility-base employed for output, where facility costs support the whole project and entire organisation. Examples for facility sustaining activities are: rental offices and general administration costs. These activities are not directly related to the specific construction activities. Table 3-1 shows the rental office activity can be assigned by facility-sustaining cost drivers which seems to be traceable; per ‘square-footage’ (Beaulieu and Mikulecky, 2008). Therefore, construction projects cannot avoid those inevitable costs.
The literature review has discovered the ABC concept (e.g., Cooper and Kaplan, 1988), definition (Turney, 1994a), and philosophy (Hicks, 1999). Relevant features of the ABC system are identified, such as reliable cost accounting, certain cost hierarchies, diverse cost drivers, multiple cost objects, transparent cost tracers, and effective cost management systems (Jayal, et al., 2010a); and it is important that aspects of the ABC system are highlighted such as accountable project overhead costs, particular construction activities, effective cost management and appropriate controlling methods (Jayal, et al., 2010b), according to a process flow-view of the manufacturing production principle (e.g., Kim and Ballard, 2001). The construction process can be assumed as behaving in an identical way to the basic production principles of manufacturing (e.g., input – process – output) in regard to the ABC concept, definition, and underpinning philosophy of the ABC system. The ABC system was considered in Manufacturing Production Lines (MPLs), where manufacturing jobs, products or services are identically adapted in Construction Activity Processes (CAPs) to the jobs, projects and services (as the construction outputs), require activities (construction processes), and these activities consume resource costs (construction inputs).

The process of construction activities and manufacturing production lines would appear to have utilised a similar procedure (inputs – processes – outputs, and evaluations). They involve similar features (e.g., cost accounting, cost hierarchies, cost drivers, cost objects, cost tracers, and cost management and control); and rely on similar aspects (e.g., costs - activities - products/ projects, management and control). These activity-based systems provide clear process views and transparent cost flows to cause-and-effect relationships between costs, activities, and jobs, projects or services. Therefore, construction process views would provide a systematic approach to relate project costs with scheduled activities transparently to manage and control them effectively (e.g., to implement the competencies, discover inefficiencies, reduce unnecessary costs or non-value-added activities) to improve productivities for completed projects, in order to increase project benefits.

Project costs may include profits, contingency, direct, and indirect costs (Aretoulis, et al., 2006; Giammalvo, 2007; and Stikina, et al., 2009). Project profits can be measured as excess revenue against project costs. Contingency is an undefined provisional sum of money for unknown activities (CIOB, 2009). Direct cost includes materials and labour which are directly associated to activities, whereas indirect overheads are not clearly related to particular activities. However, project overheads are perceived as potential costs which should be fairly predicted to maintain project activities (Sturisna, et al., 2004). In this way, the role of the ABC system can facilitate accurate distribution of project overheads to every activity (Giammalvo, 2007), and it can reduce unexpected costs (Kim and Ballard, 2001). Therefore, the ABC system would be suitably adapted and applicable in the construction process' (Figure 3-1).

5 Conclusion and Further Research

The ABC system was found to hold potentials to control overheads in construction projects. Although there are various criticisms of ABC system exist, it was demonstrated here that implementing ABC system in construction projects should generally improve its financial control, particularly of the overheads. However the ABC system has not been widely used to control the main core of activities of construction projects. This is exacerbated by the fact that a management and control of project overhead is not explicit and inaccurately estimated by the Traditional Costing Systems (TCSs) and current Cost Accounting Management Approaches (CAMAs). The ABC systems carry the potential advantages of Activity Cost Drivers (ACDs), which can be implemented in the process of construction projects, such as: unit-level, batch-level, project-sustaining, and facility-sustaining. These may improve awareness and taking decision of project managers, to every level of activity cost behaviours; monitoring expenditures periodically, evaluating costs accurately, controlling deficit and saving actual costs of individual construction activities. Therefore, the ABC systems should be suitably implemented, for further research, in order to improve the management of project overheads through application of effective tools and techniques, called the Cost Management and Controlling Practices (CMCPs) during activities of the construction projects. Further research include in-depth investigation of real construction projects within case study setting to test how ABS system can provide real benefits to construction projects, particularly in controlling overheads.

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Abstract:

On the onset of a construction project, an estimation of what constitutes efficient labour output is set as the basis for the project. This target is not often matched by the observed/actual labour productivity output on construction projects. The observed labour productivity outputs on construction projects are often used in establishing whether a construction project is successful, and this observed output is seldom compared to the target set at the onset of the project thus resulting in a conclusion that the project is inefficient based on only one observation. This study examines the factors causing the variation between estimated and actual labour productivity observed on construction projects. The aim of this study is achieved through a critical review of literature pertinent to labour productivity standards, estimates and actual outputs. The study found that actual labour productivity observed on construction projects differs significantly to targets set as the benchmark on the onset of the construction project and industry standards, and project complexity causes these variations, material shortages, environmental conditions, geographical context, unrealistic programmes, rework and lack of equipment. Based on these findings, the study concludes that labour performance on construction projects operate amidst circumstances that are not always factored in at the pre-construction development stage. As a result, future studies that test this proposition and evaluates the contextual factors that impact on labour productivity on construction projects using empirical data is recommended.

Keywords:

Complexity, Efficiency, Labour, Productivity, Standards

1 Introduction

One unit of measure used across the construction industry to measure the success and the performance of a project is labour productivity (Alinaitwe et al., 2005). Tran and Tookey (2011) describe labour productivity as output obtained divided by input expended to achieve the output. Labour productivity is commonly expressed mathematically as equation (1):

$$\text{Productivity} = \frac{\text{Product output/ labour input (cost or cost per hour)}}{\text{Equation (1)}}$$

Another measure of actual labour productivity that is commonly used in the industry is that of labour performance rate (Kadir et al., 2005). Moselhi and Khan (2012) however, argues that due to the complex nature of construction projects, there is no one definition that is considered standard in the industry for labour productivity. Durdyev and Mbachu (2011) recommend that for an objective analysis and comparative purposes post-project...
considered and accounted for to draw an accurate desired labour productivity. It is

representations repository

actual labour is

Global performance of labour productivity in

261.

ductivity estimates on

The productivity of

This estimation is based on the assumption that the scope, cost and time of a project are

projects range between 25-40% of the construction project (Alinaitwe et al., 2005). However, there is difficulty in measuring labour productivity as most organisations do not have a defined matrix of efficient labour performance measurement techniques (Alinaitwe et al., 2005; Crawford and Vogl, 2006).

During the pre-construction development stage of a project, estimators, planners and construction managers estimate labour productivity based on a variety of factors not limited to historical experience based on past projects (Proverbs et al., 1999; Alinaitwe et al., 2005). According to McKinsey Global Institute (2017), globally, the performance of labour in the construction industry is the least productive compared to that in other sectors of the economy. Over the past 20 years, the productivity in the construction industry reported an average growth of 1% (Barbosa et al., 2017). Furthermore, Barbosa et al. (2017) view the inability of the construction industry to report an increase in labour productivity to the industry’s inability to transform some of the activities to technological and more mechanised methods of execution.

This study investigates the benchmarks/estimates set for labour productivity as a performance indicator on construction projects and the actual labour output observed on construction projects using a systematic literature review. It also examines whether there are factors identified in literature causing variations between the estimated and actual labour productivity on construction projects.

2 Overview of labour productivity estimates and output

Labour estimation is the approximation or prediction of labour rates and labour performance determined for a particular construction project (Proverbs et al., 1999). This estimation is based on the assumption that the scope, cost and time of a project are known (Proverbs et al., 1999; Alinaitwe et al., 2005). Juxtaposing estimated labour productivity, actual labour productivity is described as the output observed after the completion of a construction project. This is the resultant output achieved on a project over a set period with a specified cost value (Niazi and Painting, 2017). It has however been observed that estimated labour and actual labour output seldom equate each other on construction projects (Park, 2006).

An analysis of the differences between estimated and actual labour output cannot be holistically observed without considering factors used at the pre-construction phase of a project in establishing labour estimate (Park, 2006). A conceptual framework developed by Park (2006) asserts that in estimating labour productivity, a set of variable inputs have to be analysed in context with the environment under which a project is developed to establish a baseline or benchmark. This, he purports gives an indication of factors to be considered and accounted for to draw an accurate desired labour productivity estimate. In so doing, actual labour productivity can be tracked and measured from a known basis after the project is completed, and in some cases, intermittently as the project progresses (Park, 2006).

Park (2006) further highlights that project environment and level of management efforts are pertinent in the estimation of a baseline for the productivity of labour. Baseline productivity informs the observed productivity and the final productivity estimates on construction projects. Labour estimates are determined using different procedures across organisations and projects especially given the varying nature and complexities of construction projects (Xia and Chan, 2012). Factors found to be commonly used as determinants of estimating labour productivity are construction methods, availability of construction material, project complexities and environmental factors (Alinaitwe et al., 2005; Park, 2006; Alinaitwe et al., 2007; Hughes and Thorpe, 2014). These factors are found to be common through literature and thus pertinent to the objective of this study as they directly affect the productivity of labour on construction site.

Analysing an estimation of labour productivity in isolation to how actual labour is derived gives a distorted conclusion to what happens in practice (Lim, 1995). It is fundamental to analyse further the measures used, and factors that affect actual labour productivity expended on construction projects. It is only post-construction of a project that actual labour productivity yielded by a project is measured and quantified. This study advances that these productivity estimates vary from the actual advanced on construction projects due to factors not considered by Park (2006) and the emergence of other unexpected factors encountered during construction. With the understanding that estimated labour productivity seldom matches the actual productivity observed on a construction project, a focus on the different factors that give rise to this variation is vital to the understanding of this phenomenon.

3 Research Methodology

A thorough review of scholarly articles was adopted for this study. Given that construction productivity, construction labour productivity and the measurement of labour/construction productivity are constructs that are complex and include both theoretical models and practical practices observed in industry, a refinement of literature was required. Furthermore these constructs have different meanings and are interpreted in different ways by different scholars, therefore there is a need at this part of the research to properly define these constructs. Furthermore, the following search terms were used in filtering the focus of the study to the specific literature search: Construction project complexity; Labour efficiency in the construction industry; Labour performance in the construction industry; Global performance of labour productivity in the construction industry; The productivity of construction projects; The productivity of construction labour performance; Construction labour standards

Literature was populated and sourced from Google Scholar and University of Cape Town’s electronic library and dissertations repository (http://uct.library.uct.ac.za). The study includes peer-reviewed articles, conference proceedings, construction council reports and dissertations. However, there are exclusions to the literature search. Journal articles that are not peer-reviewed were
excluded from the search. Furthermore, for a comprehensive literature search, citations that are included in relevant peer-reviewed articles for this study were also analysed and included in the search. This is to ensure overlooked relevant peer-reviewed articles omitted with the use of key terms are also analysed as additional search. The sources of selected articles for the study are listed in Table 1.

Table 1: Sources of peer-reviewed articles, conference proceedings, dissertation and construction industry council reports.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Year of Published</th>
<th>Number of articles</th>
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<tbody>
<tr>
<td>Journal of Construction Engineering and Management</td>
<td>2000, 2016</td>
<td>2</td>
</tr>
<tr>
<td>Construction Innovation</td>
<td>2012, 2014</td>
<td>2</td>
</tr>
<tr>
<td>Journal of Civil Engineering and Management</td>
<td>2007</td>
<td>1</td>
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<tr>
<td>Acta Structilta</td>
<td>2011</td>
<td>1</td>
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<tr>
<td>McKinsey Global Institute (MGI)</td>
<td>2017</td>
<td>1</td>
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<tr>
<td>Construction Industry Development Board</td>
<td>2015</td>
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<tr>
<td>Building Research and Information</td>
<td>2006</td>
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<tr>
<td>Construction Economics and Building</td>
<td>2011</td>
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<tr>
<td>Journal of Civil Engineering and Management</td>
<td>2007</td>
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<tr>
<td>International Journal of Construction Management</td>
<td>2015</td>
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<tr>
<td>Structural Survey</td>
<td>2005</td>
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<tr>
<td>Construction Economics and Management</td>
<td>1997</td>
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<tr>
<td>International Journal of Productivity and Performance</td>
<td>2009</td>
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<td>Work Study</td>
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<td>Proceedings of the 8th Annual Conference, :</td>
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<td>Association of Researchers in Construction Management</td>
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<tr>
<td>International Conference on Infrastructure</td>
<td>2016</td>
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<td>Development in Africa</td>
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<td>Building and Environment</td>
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<td>Journal of Civil Engineering</td>
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<tr>
<td>Procedia Engineering</td>
<td>2011</td>
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<tr>
<td>Australasian Journal of Construction Economics and Building</td>
<td>2011</td>
<td>1</td>
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<tr>
<td>Engineering, Construction and Architectural Management</td>
<td>2012</td>
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<tr>
<td>Understanding the Construction Business and Companies</td>
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<td>in the New Millennium</td>
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Table 1 shows that more articles were sourced from International Journal of Project Management, followed by Journal of Construction Engineering and Management and Construction Innovation.

4 Findings and Discussion

Through the analysis of literature, it is evidenced that the conceptual framework that represent the variation in the estimated and actual labour productivity obtained on site is represented in Figure 1 below. Figure 1 depicts the factors that construction organisations consider to be significant when estimating labour productivity. However during production, a set of other factors not considered come into play and impact the estimate factor thus giving a variance in the estimated and obtained labour productivity.

Based on the above, different methods used to determine labour productivity, especially when employing Equation (1), it is important to understand the factors that bring about the variations between estimated and actual labour productivity output on a construction project. Motwani et al. (1995) assert that a close to accurate estimation of what labour productivity should be, mainly if used as a performance indicator can often be established. However, Lim (1995) and Park (2006) established that varying factors impact actual labour productivity and seldom matches the estimated output. It is of importance to assess the various factors that impact on the performance of labour productivity to critically analyse the cause of variation between estimated and actual labour productivity especially those that emanate during the production/construction stage. These factors are explained in the following sub-sections.

4.1 Dynamism of a construction site

Love et al. (2002) established that the dynamism of a construction site has a direct impact on actual labour productivity. Dynamic construction environment refers to the organisation/project’s ever-changing environment (Love et al., 2002). In establishing this, Love et al. (2002) viewed a construction process from the perspective of systems and the response mechanism to the dynamic nature of the project and how with each change, a notable impact is evidenced on the project. These changes are not limited to design, specifications and requirements from the clients that would give rise to variations between estimate and actual productivity of labour (Kaming et al., 1998; Love et al., 2002; Alinaitwe et al., 2005). Furthermore, these changes have a significant impact on management and execution of a construction project thus making it even difficult to measure the productivity of labour. Any change in the construction inputs during the construction process and the effect thereof will impact on the productivity of labour thus prompting the variation in actual labour from the estimated.
4.2 Environmental Context/Conditions

An environment context refers to the place and area in which a construction project is being developed. This also relates to the organisational context (Park, 2006). Motwani et al. (1995) note the need to distinguish between the environmental context under which planned and actual productivity are achieved. As such planned environment is concerned with the estimation and external with the outside construction environment (actual output). Park (2006) argues that the environmental context in which a project is being developed, needs to be estimated based on conditions of that particular environment, and how it impacts on the productivity of labour. This Park (2006) asserts that if combined with management efforts to be employed on projects, will aid in establishing the benchmark for performance and hence an estimate for labour productivity.

Park (2006) extends on this by postulating that climatic conditions have a significant effect on the development and constructability of a project and also impacts directly on labour productivity. Due to labour intensive nature of the construction industry, exposure to natural elements decreases the productivity of labour, particularly under excessive heat or cold weather (Motwani et al., 1995; Park, 2006). Furthermore, Park (2006) also attributes the fatigue and demoralisation of labour as being direct results of severe weather impacts and thus responsible for the variation between estimate and actual labour output.

4.3 Project Complexity

Project complexity refers to the characteristic of a project comprising of many interacting parts (Xia and Chan, 2012). Furthermore, this also relates to the project’s sequence of activities and how they are connected forming an overview of the construction project. Mawdesley and AL-Jibouri (2009) stress that defining, measuring and comparing actual productivity on construction projects is very difficult due to different projects exhibiting varying levels of complexity. Moselhi and Khan (2012) validate this in reporting that construction projects are not monolithic and each project exhibit varying complexities especially between infrastructure and housing projects, the two can’t be assessed against each other. Project complexity poses a challenge to accurately predicting and yielding desired labour productivity (Motwani et al., 1995; Okorafor et al., 2016).

However, as it has been observed that measuring construction complexity is difficult, scholars use different factors to attempt quantifying labour productivity (Sveikauskas et al., 2016). These factors used to gauge complexity are project size, project scale and geological scale (Xia and Chan, 2012). As an industry practice often employed in measuring project complexity, Sweis (2000) argues that historical data from projects of a similar nature can be used to get labour estimate of a project thus guaranteeing the same labour output will be achieved. Notwithstanding this, Moselhi and Khan (2012) refute this argument stating that each development is complex in nature and size and as a result the yield of labour productivity will not be the same and has to be estimated according to the parameters of the project itself.

4.4 Geographical Contexts

Geographical contexts relate to both the geological and surrounding characteristics of the environment under which a project is developed. Gidado and Millar (1992) expand more on this in stating that the geographical or geological contexts are characterised by the uncertainty and unpredictability of the location of project development which gives more complexity to the project development process. This is concerning the unforeseen ground conditions, existing services and artefacts that may halt the construction process thus interrupting the productivity of labour (Gidado and Millar, 1992). Xia and Chan (2012) assert that the construction process (especially expended labour productivity to an activity) is irreversible. As a result, lack of thorough and sophisticated geotechnical analysis of an environment has the potential to impact on labour productivity negatively.

4.5 Material Component and Lack of Materials

As per the work-breakdown structure, part of the planning is to ensure the scheduled activities are provided with sufficient time and resources for the activity to be completed to the desired job specification and on time (Enshassi et al., 2007). However, in cases where a disruption occurs resulting in the inability of the material being delivered on site, on time and as per the schedule, labour may find itself idle on site yielding no productive output. This point is further strengthened by Alinaitwe et al. (2007) that if construction material needed for the job are not readily made available for labour, the labourers become unproductive as they, in essence, will not have work to do.
Another intrinsic effect of the shortage of material is that alluded to by Kadir et al. (2005). In their study of the Malaysian construction industry, they found that shortage of material greatly impacts on the productivity of labour. Furthermore, they found that contractors had their operations halted as it sometimes took up to two months for construction material to be delivered onto site due to shortages. It is in this context that labour is found to be unproductive and the project performance declining.

4.6 Rework

Rework of the construction work or sections of works refers to the time taken, and the resources used in repairing a section of the work not meeting the construction specifications (Kaming et al., 1997). Pre-construction, the ideal practice is to avoid construction rework at all cost, and no one project mandates its programme with the possibility of rework. Construction rework may be measured with some level of accuracy as it is the time taken to redo the activity as well as the cost incurred in making good that part of the work. However this impacts on the productivity of labour thus yielding a variance between estimate and actual labour productivity (Baloyi and Bekker, 2011). This is measured by the poor quality of work expended concerning that which is specified in the contract data (Kaming et al., 1997a).

4.7 Lack of Equipment and Tools

Lack of tools and equipment refers to the absence of the adequate provision of equipment and tools essential for the labourers to carry out the specified tasks and activities with optimal efficiency (Kaming et al., 1998). Lack of equipment and tools contribute to the difference in efficient labour productivity and idle time on site (Kaming et al., 1997). Kadir et al. (2005) attribute lack of equipment and tools to breakdowns of tools, shortage of spare parts and poor maintenance. Kaming et al. (1998) also purport that lack of tools is in most cases due to the labourers' attitudes of not taking good care of the tools and regularly maintaining them. These factors impede productivity as labourers cannot continue with the construction work, particularly those activities that require either handheld tools or the aid of plant. Furthermore, without proper tools to do the work, the productivity of labour is compromised, and often, the morale and motivation of workers decline thus impacting negatively on project performance (Kadir et al., 2005).

5 Conclusion and Further Research

This study examines the factors causing the variation between estimated and actual labour productivity observed on construction projects. It is observed through an analysis of literature that the estimate and actual labour productivity expended on a construction project seldom equate. One of the primary arguments is that during the pre-construction phase of the project, varying methods of estimations are employed by different organisations for individual projects. Some of these methods are not limited to an inference of previous experiences to estimate for the new construction project assuming the same complexity. It was further critiqued that utilisation of previous experience ignore the environmental and eminent factors that arise out of the new environment on which a project is being developed. During the planning stage of a project, the estimation process undertaken by construction planners, estimators and construction managers is crucial in defining the core basis of how the labour productivity benchmark is defined. This can be done by establishing the management approach to be used on the project, procurement methods, cost and labour rates and turn-around times in material delivery. In employing this particular approach, a close to accurate estimate of labour productivity can be achieved. It emerged that a series of factors not considered at the pre-construction phase but that originate during the construction phase, have an impact on the actual labour productivity.

Through the analysis of literature, it is found that the determination of labour productivity estimate requires a sophisticated investigation of all probable factors having the potential to affect the estimate to yield actual labour productivity varied to the estimate. It is further evidenced through literature that estimated labour productivity when subjected to the project environment and operating in an environment not fully understood of all critical factors that could arise, more often than not will yield differing labour output.

Based on the findings, the study concludes that labour performance on construction projects operate amidst circumstances that are not always factored in at the pre-construction development stage of a project. The omission thereof gives effect to negative impacts on labour productivity which creates a variation between the estimated labour output set at the onset of a project to that which is achieved on a project. The study recommends that the dynamic nature of a construction project (organisation), environmental context/conditions, material components, lack of materials, rework of the construction work and lack of equipment and tools used should be used in accurately estimating labour output during the project pre-construction stage. Furthermore, this often requires that a new planning schedule that cushion the impact of these factors on project performance be developed and implemented. The study also recommends that future studies that test the proposition that contextual factors impacting negatively on labour productivity using empirical data is key to understanding the variances between estimated and actual labour output.

6 Acknowledgement

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. The opinions expressed, and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF.

7 References


Abstract:
The construction industry in Auckland, New Zealand is currently experiencing an economic boom, which is set to continue due to a forecasted level of unprecedented population growth in Auckland to 2025. The construction industry’s productivity has not improved using traditional methods and has been very slow in adopting new methods such as Lean Construction. This research focuses on a key Lean management tool - the Last Planner System (LPS), and investigates barriers that hinder the NZ construction industry’s adoption and implementation of LPS and the key facilitating factors. LPS participants from two integral groups - the main contractor and the subcontractors, from project managers to site administrators, completed a questionnaire which explored their experiences using the LPS process, and their attitudes towards the tool and the process. The main barrier was a lack of training, which concurred with the literature. None of the subcontractors received any formal training, but the subcontractors’ attitudes towards LPS were more positive than that of the main contractors. Both groups held misconceptions about the other’s knowledge, experience and roles regarding LPS. Shared formal training could be a solution to address the training issue, and for better communication, collaboration and common understanding between the groups.

Keywords:
Lean construction, Last Planner System, collaboration, implementation

1. Introduction

The construction industry in New Zealand is experiencing a significant boom (Rider Levett Bucknall, 2017). The Ministry of Business, Innovation and Employment (MBIE, 2107) identifies multiple drivers for the current and ongoing high level of construction activity. Strong and stable economic growth has been a catalyst for increased net migration, which, in conjunction with a high population growth rate, has resulted in the need for more residential building as well as new commercial developments. A low level of investment in infrastructure in the previous two decades is also contributing to the boom, with the industry now rapidly trying to catch up. Upgrades to existing motorways and highways, and the creation of new motorways, have resulted in high levels of work. In addition to this, the Canterbury earthquake in February 2011, and to a lesser extent, the Kaikoura earthquake in November 2016, resulted in large-scale building damage to residential and commercial structures. This has resulted in ongoing earthquake repair work in the affected areas, with work forecast for at least the next 5 years. Also as a result of the earthquakes, the seismic requirements for both new and existing buildings have become more stringent, creating more work in a market that is
already struggling to keep up with demand (MBIE, 2017). With the industry growing at such a rate, innovative approaches are required to increase efficiency and productivity.

A key element in this innovation is the use of management tools which allow for greater levels of planning, leading to faster delivery times and reduced waste. Although Lean Construction principles are not new in the international context, their application within the New Zealand industry have been limited in the past and are only slowly being taken up by companies seeking better ways of managing the needs of the current construction environment. In particular, Last Planner System (LPS) is increasingly seen as one of the most accessible and readily implemented approaches to improve project performance. As a result, adoption of LPS has been gaining momentum with main contractor companies in New Zealand over the last few years. Overcoming the “not invented here” syndrome is a challenge, however, with many in the industry looking for more evidence of local application before moving to adopt the approach.

In order to help address this need for local substantiation of international practice, this research looked at the experience of two specific stakeholder groups with LPS: main contractor and subcontractor employees. The generic structure of the commercial construction industry in New Zealand is focused around main contractors that act in a construction management role, while subcontractors deliver the labour and trades on the project. This means that the relationship between the main contractor and subcontractor employees is critical to the success of any commercial project delivery, thus the choice to focus on these two stakeholder groups. The perspectives of both groups are necessary to allow analysis of barriers and facilitating factors to the implementation of LPS, particularly through identifying where these views overlap or diverge.

2. Literature Review

The primary function of LPS is to “successfully reduce construction waste” (Song and Liang, 2011, p. 350). Waste in this instance includes unnecessary and unproductive use of any resource, including production, time, transportation and materials. LPS uses 4 main planning tools in order to reduce waste: master plan, pull plan, look ahead plans and weekly work plans (Pheng and Shang, 2013). These tools are all utilised at different stages of the project, targeting specific issues that may arise. According to Aziz and Hafeez (2014), this tool is used to help manage work completed in the construction industry, rework, and the industry itself is only running at 40-60% labour efficiency. The look ahead planning and weekly work plans of LPS seek to combat this inefficiency. The tool identifies tasks that need to be completed in order to allow other critical tasks to be undertaken. Fernandez-Solis et al. (2013) state that this type of planning results in a reduction of non-value adding activities while AlSehaimi et al. (2014) identified increased productivity and greater workflow reliability in their case study as the key benefits of this planning management tool. By forecasting the required tasks for a project, alongside with any critical milestones that they correspond to, the management team of a project are able to best allocate resources on a day-by-day basis to ensure that no trade is being held up by another trade (Song and Liang, 2001) resulting in better work flow dynamics and continuous productivity.

One of the key benefits of LPS as a whole is the greater level of collaboration between onsite workers and management staff (Alarcon et al., 2008). Onsite workers, known as the ‘last planners’, are given the responsibility of updating the weekly work plan, which is forecasted for a period of up to 6 weeks in advance. In the traditional context, this planning was previously left to onsite management to initiate, the required tasks were ‘pushed’ onto the workers and the workers simply performed the task as and when they were told. LPS aims to change this by using the pull method instead, where the workers pull the essential tasks along for the progression of the whole job. This concept also allows for better overall planning of the project as the workers have the most knowledge regarding how long a particular task will take as well as knowing what is required prior to that task taking place. Placing a greater level of responsibility in the hands of the workers allows for a more personal connection to the project and goes on to foster a greater sense of commitment to the project from the workers, increasing labour productivity and thus allowing for more favourable delivery timeframes (Kalsaa, 2012). When management encourages this connection, onsite workers are likely to respond in a positive way, leading to other positive impacts such as workers contributing to problem solving discussions regarding issues on site and contributing a greater variety of solutions (Alarcon et al., 2008).

This strength of a culture change is also one of the key challenges of LPS implementation. The two main implementation challenges of LPS implementation are organisational inertia and resistance to change (Fernandez-Solis et al., 2010). The initial implementation is down to the project management team, but LPS relies heavily on the knowledge of the onsite workers to succeed, so both parties need to be engaged for successful use of LPS. If the management team is shown to be reluctant to change and unwilling to implement new tools for improvement, the onsite workers will feed off of this energy and will also determine that tools like this are of no benefit to them (Kalsaa, 2012). Kalsaa (2012) identifies that the culture needs to evolve from “this is how we have always done it” to “how can we become better”. This shift in attitude is forecasted for a period of up to 6 weeks in advance. In the traditional context, this means that the ‘last planners’ are given the responsibility of updating the weekly work plan, which is forecasted for a period of up to 6 weeks in advance. In the traditional context, this planning was previously left to onsite management to initiate, the required tasks were ‘pushed’ onto the workers and the workers simply performed the task as and when they were told. LPS aims to change this by using the pull method instead, where the workers pull the essential tasks along for the progression of the whole job. This concept also allows for better overall planning of the project as the workers have the most knowledge regarding how long a particular task will take as well as knowing what is required prior to that task taking place. Placing a greater level of responsibility in the hands of the workers allows for a more personal connection to the project and goes on to foster a greater sense of commitment to the project from the workers, increasing labour productivity and thus allowing for more favourable delivery timeframes (Kalsaa, 2012). When management encourages this connection, onsite workers are likely to respond in a positive way, leading to other positive impacts such as workers contributing to problem solving discussions regarding issues on site and contributing a greater variety of solutions (Alarcon et al., 2008).

Another significant challenge in implementing LPS is its relative newness within the construction industry. According to Fernandez-Solis et al. (2010), the whole lean concept is new to construction, and a lack of education surrounding the topic means that employees can be wary and reluctant to implement the changes. Lack of training and education can also lead to partial or late implementation of LPS where its contribution to a project might not be fully appreciated (Fernandez-Solis et al., 2010). Alarcon et al., (2008) argues that while a lack of education surrounding LPS is an issue in adoption, a lower level of knowledge also results in a lack of self-critiquing, which is a bigger barrier in implementation. Implementers of the tool are not willing to accept criticisms regarding their systems and often take the criticism in a negative light. The review process in this case becomes redundant, which causes a certain level of stagnation in the improvement of the system.

Perhaps the greatest barrier to LPS identified in the literature is the relationship between sub-contractors and main contractors. Fernandez-Solis et al. (2010) argues that bad chemistry has often developed because parties have previously worked on projects together with difficulty. This preconceived negative attitude can translate from one project to another, meaning that collaboration is difficult to achieve. Hamzeh (2011) also argues that incompatibilities between different personnel on site are at the core of this barrier to achieving a collaborative relationship. Kalsaa (2012) suggests that a shift from fixed work identities needs to occur, especially regarding management teams. Hierarchical identities create a divide between the parties where the onsite workers do not feel comfortable to initiate the conversations that LPS requires. LPS relies on a cultural shift from the traditional “management versus workers” culture to one where the parties function as a collaborative unit with a common goal.
3. Research Methodology

The research was carried out using a qualitative survey, based on questionnaires with multi-choice and short answer questions. A qualitative approach was appropriate for this research as it was focused on the opinions and experiences of the different participants (Denscombe, 2010). The aim of the questionnaire was to collect data that would allow identification of trends and patterns between individual participants, and also between the two different stakeholder groups.

Two separate stakeholder groups were surveyed: main contractor and subcontractor employees. LPS calls for a collaborative relationship between these two stakeholder groups to be implemented; therefore, obtaining data from representatives of both these groups was essential. There were 24 participants in total, 12 from the main contractor group and 12 from the subcontractor. Participants were selected from a range of commercial construction sites, within Auckland, that actively use LPS as their primary management tool. The participants varied in their levels of experience, ranging from one year in the construction industry to 20+ years of experience. There was also a variety of roles across the participants, including project managers, quantity surveyors, package managers, cadets and on-site trade workers. The range of roles ensured that a variety of perspectives were obtained, instead of focusing on subgroups of workers in the two stakeholder groups.

The questionnaire comprised two different sets of questions. The first set established the participant’s level of experience in the construction industry and their level of involvement in LPS. This was used to ensure that there was a range of participants from each group with different levels of experience and involvement. The second set of questions (see Appendix A) was focused on LPS as a whole, and included a set of statements using a rating scale for the participant to identify how they felt about the statement. This was followed by four short-answer questions which allowed the participants to further expand on their opinions and ideas surrounding LPS. The questions were designed to only allow positive or negative responses from the participants regarding their attitudes and perspectives surrounding LPS as a whole and its implementation on their sites. Removing a neutral option from the questionnaire meant that not only could conclusions be drawn from the responses but particular barriers could be identified, allowing for actions to be implemented in the future to combat these.

The choice to use a questionnaire with multi-choice options over structured interviews stemmed from the fact that LPS is a very young management tool in New Zealand. While all the participants that were chosen for the research do have some experience using LPS, this experience is varied. Utilizing an interview approach may have introduced concepts that the participants were not familiar with, and a potential lack of understanding around this may have resulted in dishonest answers, particularly in a face-to-face situation where participants may not have wanted to appear ignorant of the concepts (Denscombe, 2010). The questionnaire focuses on basic concepts and opinions of LPS and while the data collected may not be as in-depth as that gained through a structured interview, it provides sufficient basis for an exploratory view of LPS adoption.

4. Findings and Discussion

4.1 Contractor involvement

The Main Contractor (MC) group considered that there is not enough ‘buy-in’ to LPS from the subcontractors. Their response to the statement ‘I feel that LPS could be implemented more effectively’ indicated that all the MC participants felt that there was room for improvement – no participant disagreed or strongly disagreed with this statement. Which led to identify the biggest fault with LPS. 7 out of 12 MC participants identified a lack of subcontractor involvement and participation. Previous studies have emphasised the need for subcontractor participation. Fernandez-Solís et al. (2013) state that external resistance from subcontractors results in ineffective implementation of the tool. Similarly, AlSehaimi et al. (2014) state that in order for LPS to be implemented effectively, the involvement of the subcontractors needs to be the norm, and part of the ingrained culture within a project.

In the questionnaire statements ‘LPS takes too much time to implement on site’ and ‘Sites are already busy enough, there is no time for the additional administrative work required for LPS’, the response from both groups was predominantly negative, suggesting that they were provided with sufficient time to undertake the LPS process. Alarcon et al. (2008) found the opposite in their study, which identified that the last planners on site (subcontractor workers conducting the onsite work) were resistant to using LPS due to the time it took to implement any new processes. This idea was further reiterated by Fernandez-Solís et al., (2013) who found that external resistance from clients and subcontractors rose from perceived time implication issues. The Auckland commercial construction participants did not answer as the literature would indicate in this regard. However, when asked to list negative aspects of LPS, several participants stated that they felt there was too much administration involved in the system. From this it would appear that although participants had sufficient time to undertake the processes, they still considered that the processes themselves were unnecessarily time-consuming.

4.2 Formal training

Both stakeholder groups identified a lack of formal training as a barrier to better use of LPS. While some of the participants identified that training and information is lacking for all parties involved in using the system, 4 of the 12 MC participants considered that there is not enough training provided to subcontractor workers specifically, resulting in workers not being engaged in the process. This again reflects what was seen in the literature; for example, Alarcon et al. (2008) found that a lack of training and understanding of key processes of LPS was one of the major barriers to successful adoption. In this case, only half of the MC participants had received formal training in the use of LPS, and half of the participants also stated that they would be more likely to use LPS if they had completed some form of training around the topic. This compared with the SC stakeholder group, where none of the participants had received any formal training in the key components of the tool or LPS as a system. Every participant in the SC group stated that to a certain degree, they would be more willing to use LPS onsite if they had been provided with training. The lack of education provided to subcontractors indicates that within Auckland, main contractors are the driving force behind the implementation of the tool but the drive is predominately to members of their own company, instead of facilitating any training to their subcontractors. Main contractors are now commonly requiring subcontractors to attend a pre-programme workshop (a key aspect of LPS) as part of implementing LPS on a project. However, if the subcontractor involved does not have a clear overview or training in the tool, these pre-programme workshops may have less impact than desired.
This opens up the issue of who should be responsible for administering the training to LPS users. One argument is that if the main contractor requires the subcontractors to use the tool, it becomes their responsibility to ensure that the subcontractors then receive appropriate training. Another view is that formal training should be undertaken by the subcontractors themselves, as this is a skill set that will be used for future jobs and projects. The lack of education around the topic of LPS, and lean construction as a whole ideology, was the most common barrier indicated in the literature (Aziz and Hafez, 2013; Fernadez-Solis et al., 2013).

4.3 Attitudes towards implementation

The construction industry is very conservative and inherently resistant to change (Song and Liang, 2013). Traditionally, the roles of main contractor and subcontractor workers have been segregated. LPS requires a collaborative effort from both main and subcontractor, so this is a barrier that needs to be addressed in order to ensure that LPS can be effectively implemented. Kalsaas (2012) states that it will take time for everyone to break out of this mentality, for everyone to “find it natural and desirable to participate...where they have to be more involved” (p. 96). The perceived view is that subcontractors are wary of main contractors and their motives on site, so calls for collaboration are treated as potentially not genuine (Akintan and Moreledge, 2013). Based on the literature, the expected result of this study was that the use of LPS, imposed on subcontractors by the main contractor, would be undertaken with some trepidation. On the contrary, however, the majority of responses from the subcontractor group were in support of the use of LPS on sites. The questionnaire statement ‘I feel that using LPS has made a positive difference on projects that have utilized it’ received a more strongly positive response from the SC participants compared to the MC participants. This encouraging attitude is further demonstrated in the responses of the SC group to other questionnaire statements. ‘I feel like LPS has been used to its fullest potential on my projects’ elicited a more positive response from the SC participants than from the MC participants (9 SC and 3 MC participants), which indicates that the SC group has a more positive outlook on the LPS process as a whole.

The responses of the SC group to other questionnaire statements were similarly positive, and none of the barriers that they identified were related to perceived negative connotations. However, this may be related to the SC participants’ lower level of formal training. Because the MC participants have more formal knowledge surrounding the tool, they may thus have a more realistic expectation of what LPS has the potential to achieve. The SC group, on the other hand, may feel that LPS is being used to its fullest potential but may have less knowledge and lower expectations of what it should achieve.

The MC responses also indicated a positive view of the use of LPS; however, their views seemed to centre more around how it could be beneficial if appropriately implemented in the future, rather than its use in the current market. The MC participants identified that a major barrier for implementation from their perspective was a lack of subcontractor buy-in. When considering this view alongside the attitude of the subcontractor group, there seems to be a disconnect between what each group perceives as the attitudes of the other group.

4.4 Conflicting Findings

Participants were asked about their familiarity with all aspects of the LPS system, and how comfortable they were with using the corresponding tools. The expected result of these two questions would be a correlation between the two, that is, a positive reaction in the familiarity question should yield a positive response in the following question. However, only 7 of the SC participants indicated that they were familiar using all aspects of the tool (7 agree, 0 strongly agree). When answering how comfortable they were using all tools in the system, the response was significantly more positive (8 agree, 1 strongly agree). The current research did not investigate participants’ level of knowledge on the possible tools. Therefore, the expected conclusion would be that the MC participants would have a more positive response to whether LPS is being used to its fullest potential. However, the research indicated that SC participants have a more positive perception of this statement (3 participants strongly agree, 6 agree) than MC (0 participants strongly agree, 3 agree). These findings could be again explained by the low level of training received by the two stakeholder groups. In the MC group, 6 participants had experienced some form of formal training of LPS, but none of the SC group had received any. The lack of formal knowledge on the part of the SC participants may have resulted in a false level of confidence regarding their understanding of the system. Furthermore, the survey did not examine how LPS was being used by the different participants. It is possible that only some of the tools are being used within a project, instead of exercising a full implementation of the LPS. If this is the case, the SC participants may feel they have a good understanding of the system, when in reality they only understand some of the concepts. As a result, they may be satisfied that LPS is delivering benefit to their projects and remain unaware that there are further activities and resulting benefits that they could be making use of. Fernadez-Solis et al. (2010) identified partial application of the LPS system as one of the key barriers to successful implementation. This, combined with a lack of formal training, could explain the conflicting findings.

5. Conclusions

The New Zealand construction industry is currently experiencing an increase of work combined with a shortage of skilled labour. Inherent pressures to perform under these conditions has meant that it is more important now than ever to look at new and innovative methods of ensuring that work is being conducted to a high standard with as little construction waste as possible. This study has provided some answers and insights with regard to the barriers and facilitators to effective implementation of LPS in the commercial construction sector in Auckland, and indicated that experiences in the New Zealand situation are broadly in line with international research. One key difference appears to the willingness of subcontractors to participate in LPS adoption. Internationally, subcontractors’ negative attitudes to LPS were a barrier to adoption, whereas the responses in this study found that subcontractors were often more positive than the main contractors.

Two main recommendations can be made in order to ensure that management tools such as LPS are effectively and seamlessly integrated into everyday projects within commercial construction in Auckland. The use of such management tools is mutually
beneficial to both main contractor and subcontractor workers in the long term, but without proper education and training, the system is likely to be implemented incorrectly and therefore ineffectively. Therefore, a greater emphasis on knowledge and education is needed, prior to implementing any new systems. One central question that needs to be resolved before this can be achieved is whose responsibility it is to provide this training. Main contractors are currently providing training for their own employees, but considering it is becoming increasingly common for main contractors to request LPS involvement from their subcontractors, it may be argued that the main contractor has a responsibility to train subcontractor workers to allow them to work effectively within this system. However, LPS is a skill that will be beneficial to subcontractors for future project use, so another perspective is that the responsibility should lie with the subcontractor to train their staff. Conversation between the two parties should focus on establishing the best way to deliver training to everyone involved, to ensure that projects get as much benefit from the tool as possible.

The second recommendation is focused around strengthening the collaborative relationships between main contractor and subcontractor workers. LPS requires the two groups to work together in order to effectively plan, programme and share knowledge surrounding task duration and requirements. The study has indicated that the two stakeholder groups appear to have skewed views of the other groups’ attitude. The main contractor participants feel that the subcontractor workers will not be willing to use tools such as LPS, while in fact the subcontractor group appears to have taken on board the idea of implementing new techniques. More participants in the subcontractor group felt that LPS has already made a difference on the projects they have been involved with, and all the participants involved in the study believed that LPS would make a positive impact on projects in the future. More open communication between the two stakeholder groups would ensure that the expectations regarding the use of such management tools are understood by all the parties involved in using them, as well as contributing to the formation of better collaborative relationships on site.

Research surrounding management tools such as LPS is limited in New Zealand, despite the fact that these are prevalent overseas and are becoming increasingly common in the New Zealand market. In order to ensure effective use, further research is necessary to identify the level of knowledge that participants have in regards to key aspects and their individual uses. Connected to this is the question of partial implementation. If projects are utilising only some of the tools and processes, then those involved may have the perception that they are successfully using LPS, while missing out on some of the potential benefits. A survey of current practice would allow any additional improvements to be identified.

6. References


Appendix A Sample questionnaire (LPS-specific questions)

For each statement below, please state to what degree you agree or disagree with the statement:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>disagree</th>
<th>agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. I am familiar with all aspects of the LPS tool</td>
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<tr>
<td>7. I am comfortable using all the tools in the LPS</td>
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<tr>
<td>8. I feel like LPS has been used to its fullest potential on my projects</td>
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</tr>
<tr>
<td>9. I feel that LPS could be implemented more effectively</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>10. When LPS is used on projects, I feel like everyone is committed to using it</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. LPS takes too much time to implement on site</td>
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<td></td>
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<tr>
<td>12. I would be more willing to use LPS if I had more formal training surrounding it</td>
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<tr>
<td>13. By using tools like LPS, we are trying to fix something that isn’t broken</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14. Sites are already busy enough, there is no time for the additional administrative work required for LPS</td>
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<td></td>
<td></td>
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<tr>
<td>15. I feel that using LPS has made a positive difference on projects that have utilised it</td>
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<td></td>
<td></td>
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<tr>
<td>16. LPS will have a positive impact in the future if people are willing to implement it</td>
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</table>

For the remaining questions, please finish the statement:

17. I enjoy using LPS because:

18. The biggest fault with LPS is:

19. I would use LPS more if:

20. Any final comments regarding LPS?

‘Pacing’ Delays: The Essentials

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Abstract:

Concurrent delays have generally followed that where apportionment is not possible the contractor gets a time extension but no delay damages; in turn, the owner grants time extension and gives up liquidated damages. However, an exception to this can be found when either party tries to get rid from own liability asserting its concurrent delay is a result of a conscious decision for ‘pacing’, just to keep pace with the other party’s delay. Thus, the purpose of a ‘pacing’ delay is to claim compensation which may otherwise not be possible in a typical concurrent delay situation. Yet, the concept often involves in controversy as its success depends on the presence of certain essential circumstances. Without these essentials being factored into claims analysis, an arbitrary approach could potentially generate major disputes. However, currently there is only a limited amount of literature on the subject and the related case law is also scarce; this vacuum also appears to have contributed to the fact that contractors and employers often find themselves at odds over the ‘pacing’ delay claims. This paper aims to bridging this ‘gap’ to some extent through identifying essential pre-requisites for distinguishing, validating and quantifying ‘pacing’ delays. Here, ‘Case study’ and ‘Archival Analysis’ have been used as the research methodology while the ensuing discussion is based on related academic works and case law; it is believed that employers and contractors alike would be benefitted from the research findings to make informed decisions when dealing with ‘pacing’ delay situations.

Keywords: claims, compensation, delays, concurrency, pacing.

1 Introduction

Legally, at least under US jurisdiction, the right of a party to a construction contract to ‘pace’ its performance to another party’s critical path delay is acknowledged. Zack (1999) points out that as a legitimate business management decision the issue has been addressed by the courts, and it is clear that a contractor has a legal right to a ‘pacing’ delay. A working definition suggested for ‘pacing’ delay is a ‘deceleration of the work of the project, by one of the parties to the contract, due to a delay to the end date of the project caused by the other party, so as to maintain steady progress with the revised overall project schedule’ (Zack, 1999). Notwithstanding, the ‘pacing’ concept still remains a controversial issue in construction delay claims. Typically, ‘pacing delays’ occur in a period of concurrent delays; hence, the controversies normally inherent in concurrent delays may also be common to ‘pacing’ delays. Also, such controversies can be possible due to that the forensic application of pacing theory is often inconsistent with the actual performance of the parties at the time of the delay (Livengood and Peters, 2008). Further, there is only a limited amount of literature on ‘pacing’ delay and
the related case law is also scarce; this vacuum has also contributed to the contractors and employers being often found at odds with one another over the practical effect of ‘pacing’ delay in a claims situation (Spinelli and Zack, 2014). Existence of all these ‘gaps’ often leads to escalation of claims and disputes between the parties. Therefore, the main objective of this paper is bridging this ‘gap’ to some extent through defining essential pre-requisites for distinguishing, validating and quantifying ‘pacing’ delays. It is believed that employers and contractors as well as claims analysts, project managers, lawyers alike would be benefitted from the research findings to make informed decisions when dealing with ‘pacing’ delay situations.

2 Literature Review

It’s not infrequent in construction claims that the concept of ‘pacing’ delay is used in a rather impulsive manner. The complexity inherent in the concept itself is mainly responsible for this situation; however, only a few recent publications have made some valuable contribution to curing this shortcoming; for its objectives, this paper has mainly relied on such literature.

Typically, ‘pacing’ delays have to occur in a period of concurrent delays. According to AACE International RP 29R-03 (2011, p.112) ‘if there have been no potential concurrent delays identified, then pacing is irrelevant’. Considering that concurrent delays are also irrelevant where ‘compensability’ is not in issue (Bramble and Callahan, 2000), it can be firmly deduced that the sole objective of the pacing party claiming a ‘pacing’ delay is to convert otherwise non-compensable concurrent ‘parent’ delay into a compensable one.

Another essential issue to be considered in dealing with ‘pacing’ delay claims is the position taken by the contracting parties as to ‘float ownership’. The sole relationship of a ‘paced’ activity to the ‘parent’ delay is the fact that the latter creates additional, relative total float available for consumption by the ‘paced’ activity. Thus, this is consistent with the view that float (being a shared commodity) is available for consumption on a ‘first come first served’ basis (AACE International RP 29R-03, 2011). However, if the contract language attributes the float ownership to a specific party’s consumption only, then ‘pacing’ delay concept will effectively be irrelevant.

Though ‘pacing’ concept is not considered in depth in many jurisdictions, in the US there have been several judgments upholding the concept. For example, in John Driggs Company, Inc., END BCA No. 4926, 87-I BCA 19833 [1987], the US Army Corps of Engineers Board of Contract Appeals stated:

‘When a significant owner-caused construction delay occurs, the contractor is not necessarily required to conduct all of his or her other construction activities exactly according to the pre-delay schedule, and without regard to the changed circumstances resulting from the delay…’.

Likewise, in Uiley-James Inc., GSBCA No. 5370, 85-I BCA 17,816, aff’d, Uiley-James Inc., v United States, 14 CL. Ct.804 [1988], the General Services Agency Board of Contract Appeals decided:

‘Where the government causes delays to the critical path, it is permissible for the contractor to relax his or her performance of the work to the extent that it does not affect project completion’.

Wickwire et al (2003) agreed with this legal position and argued that when project delays occur and create additional float in the schedule, the contractor is not required to ‘hurry up and wait’ and slavishly follow the original plan for performance. Zack (1999, p.CDR.01.3) observed that this acknowledgement of the US legal system of the contractor’s right to slow-down when faced with owner-caused delays is not illogical and the ‘…courts appear to be simply acknowledging the fact that a contractor has the right to manage the project as he or she sees fit, in order to maximize his or her profit’.

It is also noted that the term ‘pacing’ is applied as ‘direct pacing’ and ‘indirect pacing’. ‘Direct pacing’ occurs where the duration of a scheduled-Activity in a Critical Path Method (CPM) Programme is extended due to its direct dependency or logical relationship on a predecessor delay. For example, the Activity of employer-supplied permanent power may have to be suspended and delayed due to a preceding delay in completion of the Activity of electrical works which is the responsibility of the contractor; here, due to the dependency on the preceding delay, the duration of the successor Activity(ies) automatically increases and that ‘creates’ a float to be consumed by the ‘pacing’ party for slowing down or suspension of the related Activity(ies) without affecting or reducing his entitlement to compensation for the preceding delay (See Figure 1 below). However, this type of pacing is not considered a ‘pacing’ delay per se ‘because the two Activities are sequential and not concurrent’, and without ‘concurrency’ pacing is irrelevant (AACE International RP 29R-03, 2011). As for the second type of ‘pacing’ it is distinguished mainly due to that the ‘pacing’ delay has no such dependency on the ‘parent’ (or predecessor) delay but occurs concurrently on a separate, independent (critical) path. Here, as already stated above, the only relationship the ‘parent’ delay has with the ‘pacing’ delay is that the former creates additional relative total float in the Programme (this is an additional negative float in a constrained CPM Programme) which is available for the consumption of the latter (i.e. by slowing down or even suspending the progress of works). This ‘indirect’ type is considered the actual ‘pacing’ delay which is the main focus of this paper. (See Figure 2 below).

However, notwithstanding its intimate relationship with concurrent delays, a ‘pacing’ delay is characteristically distinguished from a typical concurrent delay by some major aspects. One of those aspects is that ‘pacing’ is a conscious decision taken by its performing party to pace the work, in the latter case, work is involuntarily delayed by factors independent of any problems arising from the subject delay (AACE International RP-29R-03, 2011).
The effect of any delay occurring on Path B after end of AX delay period is sequential; not concurrent;
Total effect of AX delay is excusable and compensable; it creates a relative ‘float’ for consumption by Path B delays without culpability/liability.

DIRECT ‘PACING’:
AX ‘parent’ delay on Path A has already started 2 days earlier when BX ‘pacing’ delay on Path B occurs; however, AX and BX delay periods are overlapping only for 8 days and BX delay continues for further 2 days exceeding the AX delay period;
Including the first 2 days (non-overlapping) the whole of AX delay effect is excusable and compensable; BX delay ‘pacing’ effect is limited to its extent of overlapping with AX delay effect; accordingly, the non-overlapping 02 days effect of BX delay is the contractor’s culpable delay and subject to LAD.

Another aspect of difference is their respective purposes related to ‘compensability’. When a party raises a claim for concurrent delays it is for the main purpose of offsetting the other party’s claims for financial compensation. Thus, the concurrent delay claim generally acts as a shield to protect from the other party’s claims for delay-damages. However, that shield can become a sword for a party trying to claim a ‘pacing’ delay in a potentially non-compensable concurrent delay situation; here, it may not only be excused from liability for delay damages during the period of paced performance, but also be entitled to delay damages from the party responsible for the ‘parent’ delay (Livengood and Peters, 2008).

Though a concurrent delay situation is a pre-condition for a ‘pacing’ delay claim, it has an important caveat. It arises from the current lack of industry-consensus as to defining ‘concurrent delays’. At present, the ‘concurrent delays’ are generally defined by two theories: (a) the ‘Literal Theory’ which upholds that delays have to be literally concurrent as in happening at the same time (i.e. start and end during the same period); and (b) the ‘Functional Theory’ which advocates that the delays need only occur within the same analysis or measurement period, not necessarily at the same time. Based on which theory is followed, the outcome of determining each party’s entitlement or liability may radically be different; for the same reasons this situation could similarly apply to ‘pacing’ delay claims as well. However, it appears that many academics and practitioners are reluctant to support the ‘Literal Theory’ only. Thus, it has been submitted ‘if concurrent delay is only acknowledged when impacts occur at the same time, the analyst must acknowledge that truly simultaneous performance may be difficult to achieve’ (Livengood and Peters, 2008). Also, AACE International RP-29R-03 (2011) maintains a clear position in this regard; it has taken the view that ‘pacing’ almost never occurs in the context of a literal method of concurrency analysis. Thus, it may be safely inferred that ‘parent’ and ‘pacing’ delays need not occur starting and ending at the same time as required under ‘Literal Theory’.

A further factor that can influence the quantification of either party’s entitlement/liability is the application of theory of ‘Criticality’ to measure the ‘critical effect’ of ‘parent’ or ‘pacing’ delay. These theories could potentially generate completely opposite outcomes for the same delay events (Perera and Sutrisna, 2013). Unless both ‘parent’ and ‘pacing’ delays are on ‘critical path’ at their occurrence a ‘pacing’ claim merits no further consideration. However, determining a delay is on critical path or non-critical path solely depends on whether the ‘criticality’ is measured against the ultimate (projected) completion date (based on Longest Path approach) or the contractually agreed date for completion (based on Total Float approach). Interestingly, this factor is closely connected with the issue of theories of ‘Literal’ and ‘Functional’ concurrency.

Thus, if Longest Path theory is followed, in order to be considered ‘critical’, both ‘parent’ and ‘pacing’ delay events should, theoretically, start and end at the same time (‘Literal Theory’) having equal potency of delaying effect (in terms of negative float value); if ‘pacing’ is on a subordinate path having a lesser negative float value than the Longest Path’s negative float value it will not be considered on ‘critical’ path (since it falls short of critically affecting the ultimate completion date). In other words, in strict application of Longest Path theory there is no room for a ‘pacing’ delay claim unless and at least it has equal potency of delaying effect with the longest path affecting the ultimate completion date.

On the other hand, if Total Float theory is followed, even though a ‘pacing’ delay on a subordinate path has a lesser negative float value than the Longest Path, its concurrent effect is still considered critically affecting the Contract Completion Date, and therefore, treated as both excusable and compensable; in other words, ‘Total Float’ theory takes more flexible stand to determine ‘criticality’ of a ‘pacing’ delay than the ‘Longest Path’ theory which has ‘all or nothing’ approach towards determining ‘criticality’ and hence entitlement.

However, it is important to note that even under ‘Total Float’ theory such subordinate effects can retain ‘pacing’ character only if the ‘pacing’ has occurred during the occurrence of ‘parent’ delay (though not necessarily starting and ending at the same time); without such overlapping with ‘parent’ delay period the ‘pacing’ delay argument may not sustain. Accordingly, when quantifying the effect of a ‘pacing’ delay, the relevant ‘window’ period for schedule-analysis is to be this overlapping period.

When relying on ‘pacing’ argument with hindsight the claiming party may be at risk if it cannot support the ‘pacing’ claim with contemporaneous records. For example, in another US case where the contractor attempted to use ‘pacing’ delay argument, but could not prove with contemporaneous records that he could have completed the work but for the employer delay, had to do so at his own peril (John Murphy Construction Co., AGBCA, No. 418 79-1 BCA 13,836 [1979]). According to this case, an alleged ‘pacing’ delay is not a compensable delay when the result was merely to consume float. Thus, attempting to use that argument (without the ability to prove it) may be construed as a self-admission of an own delay and counterproductive. In order to mitigate this risk, Livengood and Peters (2008) insisted that the party claiming ‘pacing’ should notify the party responsible for ‘parent’ delay his intention to pace performance. Otherwise, with no such contemporaneously given notice, the party responsible for ‘parent’ delay would be deprived of a chance to mitigate its delay assuming that the ‘pacing’ party’s concurrent delays would offset any potential claim for compensation. For the party claiming ‘pacing’, existence of a contemporaneously given notice would be substantive evidence to defend that the claim for ‘pacing’ is not a forensically used excuse to get out of the liability for its culpable delay.

Another Similarly important issue along with contemporaneously giving notice prior to commence ‘pacing’ is the evidence showing of contemporaneous ability to resume progress at normal pace if the pre-existing ‘parent’ delay was mitigated or avoided (Keane and Caletka, 2008). Pacing is not realistic unless the party claiming it was pacing can show that it had the ability to resume progress at a normal, un-paced rate. Implicit in that party’s ability to show that it could have completed the schedule activity...
on time if necessary is the fact that the party was able to reasonably determine or reliably approximate when the 'parent' delay would end.

As for determining compensation related to 'pacing' claims, Zack (1999) argues, inter alia, that considering the contractor’s obligation to mitigate his damages, if he opts to decelerate he would have experienced some cost savings (i.e. lower production cost or decreased labor costs); in such event, to demand full compensation for the pacing period would be a demand of ‘over compensation’. Thus, if a ‘pacing’ delay is proved to have incurred cost savings, not extra costs, the contractor’s entitlement would most likely be limited to extension of time only.

3 Research Methodology

The research methodology in this paper has used ‘case study’ and ‘archival analysis’ which are among the five common research strategies in the social sciences as considered by Yin (1994). For both methods, the focus on events is ‘contemporary or past’ and no control over independent variables is required (Fellows and Liu, 2015). Thus, these methods have ideally fitted into this type of research, particularly using descriptive case study research which does not directly aim at testing a theory or hypothesis but at ‘systematically identifying and recording a phenomenon or process’ (Fellows and Liu, 2015: p 116) like ‘pacing delay’.

4 Case Study- Background

The current case study pertains to a Superstructure Concrete Package (SCP) with certain mechanical & electrical (MEP) works; the package formed part of a recently completed major infrastructure project in the United Arab Emirates. The necessary facts for the case study have been extracted from the archival records of this project. However, in view of the strict confidentiality involved, ‘sensitive’ information of this project has to be withheld in this paper.

The project concerned had tight time targets. Accordingly, the timely completion of SCP Works was essentially dependent on both the contractor’s and his MEP nominated subcontractor’s performance strictly as scheduled. The bespoke Form of Contract used for this package was generally based on the FIDIC ‘Red-book’ of 1987 4th edition. The MEP works were scheduled to commence only after certain elements of SCP works were completed. The completion of these elements was a pre-requisite to enable commencement of MEP works though it was not a contractual milestone per se. Nevertheless, the said elements of works were on the critical path from the beginning to the completion of same. The ‘consented’ Baseline Programme had specific dates for the completion of the said elements of works and for the commencement of the MEP works. The Programme used ‘Primavera’ version 6 as the planning software. Notably, the contract language acknowledged that float was available to either party on ‘first come first served’ basis; therefore, float ownership was a ‘shared commodity’ freely available for both parties to rely on ‘pacing’ delay claims as suggested by AACÉ International RP-29R-03 (2011).

From very early stages, the contractor ran into a major delay in his SCP works due to reasons of his own. Consequently, the necessary elements of the SCP works for commencing the MEP works could not be completed as scheduled. Meanwhile, when the employer called for tenders for the MEP works to select and nominate a MEP subcontractor it was almost nine months after the scheduled date for the commencement of the MEP subcontract works. The contractor’s said delays in SCP works resulted in having critically delayed the Contract Completion Date. Thus, he was exposed to delay damages under the Contract, and the employer promptly deducted the same from the amounts due to the contractor as and when certified by the engineer.

As the deductions for delay damages had taken a heavy toll on his cash-flow the contractor challenged the grounds for such deduction. The contractor claimed his was a ‘pacing’ delay; accordingly, since the employer himself had been in an excusable critical delay for almost nine-months for nominating the MEP subcontractor he did not want to hurry up and wait until the employer’s delay came to an end; thus, he decided to slow down the related SCP works; he could have ably completed and made available the related SCP works for the commencement of MEP works but for the employer’s own delay to nominate the MEP subcontractor; therefore, his delay should be considered as a typical ‘pacing’ delay allowing recovery of delay damages from the employer to him, not the other way around.

The employer’s counter argument was almost of similar logic; accordingly, he could have appointed the MEP subcontractor as planned but for the contractor’s own delay to SCP works required for commencing the MEP works; moreover, when MEP works could not be commenced, the appointment of subcontractor could have resulted in additional cost/time claims from it; accordingly, the employer had the right to mitigate such losses by intentionally delaying the nomination of the MEP subcontractor while the contractor was unable to allow MEP works to commence as scheduled.

Thus, as for both parties, one can see a typical argument of a ‘pacing’ party thinking: ‘why should I hurry up and wait when the other party’s critical delay is ongoing’. Therefore, the purpose of relying on ‘pacing delay’ is clearly for using it as a ‘forensic excuse’ in order to gain financial compensation for own delays which wouldn’t otherwise be possible in a typical situation of concurrent delays.

5 Findings and Discussion

Figure-3 below illustrates the stand-alone effect of ‘critical delay’ to the Contract Completion Date arising from either party’s delay to the commencement of MEP works. This illustration is based on ‘Functional’ theory of concurrency and ‘Total Float’ approach as for measuring ‘criticality’ of delay effects. Accordingly, both delaying events had been on separate critical paths at the time of occurrence and therefore were carrying the ‘effect’ equal to the number of months of delaying ‘period’. The facts stated above have indicated the employer’s delay to the appointment of MEP subcontractor started one month before the planned date for Commencement of MEP works and continued one month after the end of contractor’s delay to SCP works related to MEP works.

As stated above, the contractor was in a major delay in his SCP works from the very early stages. This resulted in that he was continuously warned by the engineer of the substantially slow-rate of progress of the works and the lack of labour resources relative to planned resources-deployment allowed in the ‘consented’ Programme; but he was never able to recover, and the gap between the scheduled and the actual progress rates was continuously widening. Consequently, he was in a substantial critical delay to the Contract Completion Date affecting all the Activities in general, including those work items required to be completed prior to commencement of MEP subcontractor’s work. These particular work items were completed only after seven months from the originally planned date. As stated above, the employer was also in a parallel delay, taking nine months after the scheduled date for commencement of MEP works to formerly appoint

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the MEP subcontractor. Thus, concurrent with the contractor’s delay effects, the effect of the employer’s delay was also critically affecting the Contract Completion Date.

While these delays were independent of each other, each party asserted ‘pacing’ occurred during a pre-existing critical delay by the other party. This was a classic case where either party was competing to fit into the ‘working definition’ for ‘pacing’ delay as suggested by Zack (1999) as described in the Literature Review above. Taken the contractor’s argument at face value, first it appeared the employer’s delay was pre-existing at the time of occurrence of contractor’s delay to completion of MEP related SCP works; however, that argument did not hold water observing that this delay could also be regarded as a logical extension of the contractor’s already existing critical delay caused by its slow rate of progress and lack of deployment of resources from the beginning of the project. However, in any event, for both cases no evidence of contemporary intent was found considering that ‘pacing’ must be a conscious, express and deliberate decision made at the time of ‘pacing’ in order to be distinguished from a typical concurrent delay where work is involuntarily delayed by factors independent of any problems arising from the subject delay (AACE International RP-29R-03, 2011); thus, there were no records of notification from either of the parties that their respective performance would be paced so as not to cause further delay and or disruption to the works; nor did either party demonstrate the ability to reinstate normal pace and output if the asserted pre-existing delay was mitigated or avoided.

Based on the foregoing findings, in summary, the following can be identified as the essential pre-requisites for distinguishing, validating and quantifying ‘pacing’ delays:

- If no potential concurrent delays exist, ‘pacing’ is irrelevant; also, when compensability is no issue ‘pacing’ is irrelevant. Further, ‘pacing’ almost never occurs in the context of a literal method of concurrency analysis (AACE International RP 29R-03,2011; Bramble and Callahan, 2000);
- Presence of a ‘parent’ delay as a pre-existing critical delay is a must and a prerequisite (a ‘pacing’ delay cannot exist without a ‘parent’ delay); a ‘parent’ delay event should not start later than the ‘pacing’ delay event; it may start earlier or simultaneously;
- A ‘pacing’ delay cannot exist when occurring sequential to a ‘parent’ delay; therefore, ‘pacing’ delay must start and end during the occurrence of ‘parent’ delay though not necessarily at the same time as in a true concurrency situation (‘literal’ concurrency); thus, compensation for ‘pacing’ is limited to the extent the occurrences are overlapping each other. This is because if ‘pacing’ delay period occurs sequentially or extends beyond the end of ‘parent’ delay period the reasons for claimant’s argument for ‘pacing’ would not be valid any longer;
- Such overlapping ‘parent’ and ‘pacing’ delays should occur on unrelated, independent and different critical paths only, having their effects felt concurrently at the same time;
- The ownership of ‘float’ must be on ‘first come first served’ basis (AACE International RP 29R-03, 2011) without attributing that ownership to any particular party; if the contract language attributes the float ownership to a specific party’s consumption then ‘pacing’ delay concept becomes irrelevant;
- Whether delay-effects are considered ‘critical’ or not is based on which theory of criticality is followed (AACE International RP 29R-03,2011; Perera and Sutrisna, 2015), subject to contract language. In other words, the criticality of a ‘parent’ or a ‘pacing’ delay depends on whether it is measured against the ultimate (projected) completion date of the project (as under Longest Path theory) or the prevailing contract date for Time for Completion (as under Total Float theory). For quantifying entitlement this is a decisive factor;
- The party claiming ‘pacing’ shall prove it had the ability to resume progress at a normal, un-paced rate if the pre-existing concurrent delay of the other party was mitigated or avoided (Keane and Calekta, 2008); unlike a typical ‘concurrent’ delay, ‘pacing’ delay is a result of voluntary, conscious decision taken by the performing party to pace the work (AACE International RP-29R-03, 2011); thus, evidence of contemporary intent is essential that ‘pacing’ is a conscious and deliberate decision made at the time of ‘pacing’. Otherwise a claimant can use ‘pacing’ as a hindsight-excuse for concurrent delay by offering after the event testimony;
- ‘Pacing’ delay’, if proven, should be considered against the respondent; it is applicable whether delay analysis is done prospectively (e.g. using Time Impact Analysis method) or retrospectively (e.g. using Collapsed-As-Built method);
- Any claim for compensation should be based on proof of ‘actual’ costs to avoid ‘overcompensation’ (Zack,1999); thus, if there is a cost saving from slowing down

From the foregoing findings it is evident that ‘pacing’ assertions of both parties were unsupported by contemporaneous records. Accordingly, in the final delay analysis, it has been concluded none of these claims was to be reckoned as a ‘pacing’ delay giving entitlement to compensation; thus, these asserted delays were required to be considered as typical ‘concurrent’ delays only.

With no evidence to establish that (i) the asserted ‘pacing’ was a conscious, express and deliberate decision made at the time of ‘pacing’ (AACE International RP-29R-03, 2011), and (ii) the ability to resume progress at a normal, un-paced rate if the pre-existing ‘parent’ delay was mitigated or avoided (Keane and Calekta, 2008), both parties’ ‘pacing’ delay claims failed; consequently, they were treated no better than a forensically used excuse to get out of the liability for their respective culpable delays; thus, neither party was able to use the purported ‘pacing’ delay as a sword for claiming delay damages from the party responsible for the ‘parent’ delay (Livengood and Peters, 2008).
or deceleration resulting from ‘pacing’ such claim would not only be futile but also counterproductive as it would be a self-acknowledgement and evidence against the claimant himself that he incurred a culpable delay.

6 Conclusion and Further Research

This paper has strived to delineate the essential prerequisites for distinguishing, validating and quantifying ‘pacing’ delays. Accordingly, in the preceding sections, it has managed to identify the most essential of such prerequisites following a discussion of the findings of a case study from the perspective of related academic works and case law.

As reckoned earlier the contractors and employers are often found at odds with one another over ‘pacing’ delay claims and to an extent the scarcity of literature on ‘pacing’ delay and the related case law has been a contributory factor for creating such ‘gap’. Therefore, this paper expects as its main objective that it would aid, even to a limited extent, to bridge this ‘gap’, and employers and contractors alike would be benefitted from its research findings to make informed decisions when dealing with ‘pacing’ delays related situations.

It may be noted that due to the space availability this paper had to be limited to a single case study and archival analysis; thus, the need for investigating how this specific form of delay being addressed across the board in contemporary practices still remains to be fulfilled by further and broader research.

7 References


Abstract:

Construction industry is a universal driver of an economy but it is largely affected by its reluctance to innovate. This paper aims to identify the drivers of innovation adoption in Ghanaian Quantity surveying firms by looking at related previous literatures. The study adopted Quantitative research approach with census sampling technique, where questionnaires were sent to and retrieved from the top management of Quantity Surveying firms in Ghana. The study then adopted the use of mean score ranking, and hypothesis (H) was tested to check the significance level of all the push factors using One Sample Wilcoxon Signed rank test. 29 out of 43 questionnaires were retrieved from the quantity surveying firms (QSFs) at a response rate of 67.44%. Mean score ranking analysis clearly display that technological capability has the power to drive innovations in Quantity surveying (QS) firms. One Sample Wilcoxon Signed rank test concluded that effective information gathering is not important to the Quantity Surveying firms because it had a significant level of 0.384, which is greater than 0.05. Therefore, this research study has discovered that, programmes promoting access to technology is the main driver of technological capability towards innovations in professional service firms. The finding of this study is valuable to the Quantity Surveying firms as well as the other professionals in the construction industry as well as innovation policy makers and stakeholders, as it will help invest in technological capabilities including programmes promoting access to technology with the aim of driving innovations in the professional service firms.

Keywords:

Adoption, Drivers, Innovation, Ghanaian Quantity Surveying, Professional Services Firms

1 Introduction

Innovation adoption is a process that brings about assimilation of a product, process or a practice that is new to the adopting organization (Kimberly and Evanisko, 1981; Walker, 2008). Many researches on innovation have come out with the fact that innovation has the ability to create value, achieve incremental improvement to systems or products and ultimately reduce costs (Radjou, 2006). Construction industry consultants generally referred as knowledge-based professionals are persons or organizations employed to: provide expert analysis and advice that will enhance decision-making; provide specialized and one-of-service(s); and perform task(s) that are not ordinarily available within the departments or agencies of the Clients (Ijigah et al., 2012). The construction
industry operates in an environment which is occasionally undergoing transformation, causing the materials, technologies and other inputs implemented in construction to also experience changes at a very fast rate; making it essential for the QS firm to intermittently keep their practices up to date (Ofori, 2012). Furthermore, the object of Ghana Institute of Surveyors (GHiS) is among all things is to secure the adoption of innovation in the advancement of the profession of surveying and its members (Ghana Institute of Surveyors, 2015). However, the advancement of an industry can be achieved by enhancing or adopting new approaches to delivery of projects (Kissi et al., 2012). Agolla et al. (2016) did a study on the empirical investigation into the drivers and barriers of innovation in public sector organizations regarding developing countries to identify some available factor that can push innovation adoption in the public sector, as well as the challenges that are capable of limiting innovation adoption. Torku et al. (2017) also identified the impedance to innovation practices in the Ghanaian Construction Industry, particularly the Quantity surveying firms. Torku et al. (2017) furthered his research activity to find out the measures to enhance the innovation adoption in Ghanaian Quantity Surveying Firms, with less focus on the drivers of innovation. In Ghana, less focus has been on the push of innovation adoption regarding professional service firms, especially Quantity Surveying firms. This paper resolves the problem by aiming to address the available push factors of innovations in Ghanaian Quantity surveying firms. The outcome of the paper is expected to elucidate understanding of these push factors for policy discussion in order to help comprehend how innovation occurs in practice. The study uses 5-point Likert Scale with the help of Mean Score Rank Analysis and One Sample Wilcoxon Signed Rank Test to measure the responses from the population. Ghanaian Quantity Surveying Firms and Policy makers will benefit from the outcome of this study by investing in the drivers of innovations especially programmes promoting access to technology, so as to enhance innovation adoption in the professional services firms.

2 Literature Review

2.1 Innovation by Quantity Surveying Firms (QSFs)

Innovation is the ability of Quantity Surveyors to use different ways to approach client needs without causing excessive problems. Barrett et al. (1998) supported by explaining innovation in construction as the act of introducing and using new ideas, technologies, products and processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living. Consultancy services in construction are executed by highly educated professionals who are expert in solving problem, judgment and giving advice to people (Sandberg, 2003). Construction industry consultants are usually approached and commissioned by clients to provide services relating to the conceptualization, planning as well as the execution of the construction projects (Ibironke, 2004). This implies that the higher the level of innovation practices inputted into the services rendered by the QS consultancy firms the greater the probability that it will increase its contributing to the growth of the economy (Blayse and Manley, 2004).

2.2 Conceptualizing the Push factors of Innovation Adoption in QSFs

This paper made use of four main factors that are capable of driving innovation adoption in Ghanaian Quantity Surveying Firms. These include environmental pressures, Technological capability, knowledge exchange and boundary spanning.

2.2.1 Environmental Pressures

The environmental pressure constitutes the influences that force and stimulate organizations to innovate (Gann and Salter, 2000). Miozzo and Dewick (2002) did a research and found the development of strategic innovations and the operational capabilities of the largest contractors in Germany, Sweden, Denmark, France and the United Kingdom. Bossink (2004) also did research on environmental pressures that include innovation stimulating regulation, market pull, governmental client with innovative demand, subsidies for innovative application and material and governmental guarantee for markets for innovative firms. According to Arditi et al. (1997), market forces have made the innovation rate in construction equipment in the United States over a period of 30 years and found that the innovation rate increased. This then displays that environmental pressure has the capability to drive innovation adoption in Quantity surveying firms, as it helps to draw strategies to change from traditional way of executing project to new ways.

2.2.2 Technological Capability

Technological capability consists of factors that enable organizations to make and develop innovative products and processes (Gann and Salter 2000). This supports that, technological capability deals with the factors that can help to enhance the innovative development of product and processes. Seaden and Manseau (2001) named the evaluation of new process, technology and product before market launch, as an instrument to guarantee the innovation quality. According to Bossink (2004), technological capability includes Technology leadership strategy, Technology push, Programmes promoting access to technology, Finance for pilot projects, Technology fusion, and product evaluating institutions. Seaden and Manseau (2001) and Goverse et al. (2001) stressed the necessity of programs and bridging institutions facilitating access for organizations to the technology needed mostly to innovate. Contributions from Miozzo and Dewick (2002) stated that, long-term relations between external knowledge centres and firms in the construction industry facilitated access to, and adoption of, new technologies.

2.2.3 Knowledge Exchange

Knowledge exchange consists of the arrangements that facilitate the sharing of information and knowledge needed to innovate in and between organizations (Kangari and Miyatake, 1997; Gann and Salter 2000; Goverse et al., 2001). Bossink (2004) said, development of new knowledge that can be used to innovate is facilitated by exchange of knowledge. Seaden and Manseau (2001) listed programs promoting collaborative arrangements between organizations as an innovation stimulator and driver. Bossink (2004) said, another way of becoming an innovative firm in the field of sustainability, an organization had, or developed, a broad view of risk. Sharing of knowledge and information is an effective mean of encouraging innovation in Quantity surveying firms as it helps to create, stabilize and upgrade knowledge network.

2.2.4 Boundary spanning

Boundary Spanning deals with the initiatives to co-innovate across the boundaries of partnerships, organizations and departments (Gann and Salter, 2000). According to Bossink (2004), boundary spanning is the capability of institutions and organizations to co-innovate with other institutions and organizations. According to Barlow (2000), he stated that the establishment of financial mechanisms for sharing project risks and benefits is needed to ensure that innovations are defined and it is clear how costs and revenues are shared between project participants. Bossink (2004) contributed that, sharing
of the risks and benefits of the innovation trajectories were according to fixed price contract. Boundary spanning is also an effective way to push innovation as it helps to co-innovate across boundaries of Quantity surveying firms in the construction industry.

3 Research Methodology

Literature was extensively reviewed to increase understanding of the topic and to accurately determine the data to be collected for the research (Walliman, 2011). Quantitative research technique was used and questionnaires were sent out to Ghanaian Registered Quantity Surveying firms to check if actually innovation management is bringing good impact or bad impact. A five-point Likert scale was adopted in this study to measure the response of each respondent. The five-point Likert Scale helps to give better understanding on what options the respondents should choose for his or her answer. Scaling style was adopted because the data was primarily ordinal where 1= Not High, 2 = Less High, 3 = Moderately High, 4 = High and 5= Very High. The type of questions used involves the use of close ended questions. According to Copper and Schindle (2008), the nature of the aim of the research determines the type of research methodology to adopt, thus from the stated aim the exploratory research design will be employed. Census Sampling was adopted due to the small number of data collected. The population sample constituted the Ghanaian Registered Quantity Surveying firms because they are the target group. The research study targeted the 43 registered Quantity Surveying Firms in the two major regions of Ghana: Greater Accra region and Ashanti region as a pilot study for all Quantity Surveying firms in Ghana. Out of 43 total questionnaires sent out to the population, 29 were retrieved. The collected data were coded and analysed using the Statistical Package for Social Sciences (SPSS) version 20 or current version. Tables were used for Interpretation of data to get valid meaning to the responses. Means score Ranking Analysis was used to rank the dependent variables obtained to establish how they are prioritized by the Ghanaian Registered Quantity Surveying (QS) Firms. One sample Wilcoxon Signed Rank Test was then used to test the relationship of the dependent variables according to the level of importance using hypothetical median of four (4).

3.1 Hypothetical test

Wilcoxon signed rank test was used to check the level of importance or significance.

Therefore, each group of the items was subjected to One sample Wilcoxon signed rank test and the result is shown in Table 2. The testing posited the null hypothesis that these variables were not important. A summary of the test results is shown in Table 2. For each factor identified, the null hypothesis was that the factor was unimportant (H0: η = η0) and the alternative hypothesis was that the attribute was important (Ha: η > η0), where η0 is the population median (η0 was fixed at 4.0). The significance level was place at 95% in accordance with conventional risk levels.

4 Findings and Discussion

This section of the paper establishes statistical evidence base on the result shown on Table 1, using Mean score ranking. This was done with the help of SPSS tool. One sample Wilcoxon Signed Rank Test was then used to test the relationship of the dependent variables according to the level of importance using hypothetical median of four (4). This is shown clearly on Table 2.

### Table 1. Ranking of push factors of Innovation Adoption base on mean score
(Source: Field Survey, 2017)

<table>
<thead>
<tr>
<th>PUSH FACTORS</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNOLOGICAL CAPABILITIES</td>
<td>3.496</td>
<td>0.864</td>
<td>1*</td>
</tr>
<tr>
<td>Programs promoting access to technology</td>
<td>3.66</td>
<td>0.814</td>
<td>1*</td>
</tr>
<tr>
<td>Technology fusion</td>
<td>3.62</td>
<td>0.942</td>
<td>2**</td>
</tr>
<tr>
<td>Technology push</td>
<td>3.52</td>
<td>0.986</td>
<td>3**</td>
</tr>
<tr>
<td>Technology leadership strategy</td>
<td>3.52</td>
<td>0.738</td>
<td>3**</td>
</tr>
<tr>
<td>Product evaluating design</td>
<td>3.38</td>
<td>0.677</td>
<td>5**</td>
</tr>
<tr>
<td>Finance for pilot project</td>
<td>3.28</td>
<td>1.032</td>
<td>6**</td>
</tr>
<tr>
<td>KNOWLEDGE-EXCHANGE</td>
<td>3.495</td>
<td>0.870</td>
<td>2*</td>
</tr>
<tr>
<td>Effective information gathering</td>
<td>3.86</td>
<td>0.875</td>
<td>1*</td>
</tr>
<tr>
<td>Creation of knowledge network</td>
<td>3.66</td>
<td>0.769</td>
<td>2**</td>
</tr>
<tr>
<td>Training of workers on the site</td>
<td>3.55</td>
<td>1.212</td>
<td>3**</td>
</tr>
<tr>
<td>Broad view of risk</td>
<td>3.52</td>
<td>0.738</td>
<td>4**</td>
</tr>
<tr>
<td>Stimulation of research</td>
<td>3.45</td>
<td>0.910</td>
<td>5**</td>
</tr>
<tr>
<td>Lateral communication structures</td>
<td>3.34</td>
<td>1.045</td>
<td>6**</td>
</tr>
<tr>
<td>Integrated and informal R &amp; D function</td>
<td>3.34</td>
<td>0.814</td>
<td>6**</td>
</tr>
<tr>
<td>Programme promoting collaboration</td>
<td>3.24</td>
<td>0.689</td>
<td>8**</td>
</tr>
<tr>
<td>BOUNDARY SPANNING</td>
<td>3.388</td>
<td>0.981</td>
<td>3**</td>
</tr>
<tr>
<td>Involvement of the client</td>
<td>3.59</td>
<td>0.946</td>
<td>1*</td>
</tr>
<tr>
<td>Innovation from suppliers</td>
<td>3.45</td>
<td>0.948</td>
<td>2**</td>
</tr>
<tr>
<td>Strategic alliances and long-term relationships</td>
<td>3.41</td>
<td>1.150</td>
<td>3**</td>
</tr>
<tr>
<td>Integration of design and build</td>
<td>3.41</td>
<td>1.086</td>
<td>3**</td>
</tr>
<tr>
<td>Explicit coordination of the innovation process</td>
<td>3.38</td>
<td>1.013</td>
<td>5**</td>
</tr>
<tr>
<td>Mechanism for sharing financial risk and benefits</td>
<td>3.38</td>
<td>0.942</td>
<td>5**</td>
</tr>
<tr>
<td>Coordination of participation groups</td>
<td>3.38</td>
<td>0.862</td>
<td>5**</td>
</tr>
<tr>
<td>Empowerment of innovation leaders and innovation champions</td>
<td>3.10</td>
<td>0.900</td>
<td>8**</td>
</tr>
<tr>
<td>ENVIRONMENTAL PRESSURES</td>
<td>3.248</td>
<td>1.030</td>
<td>4**</td>
</tr>
<tr>
<td>Subsidies for innovative application and material</td>
<td>3.48</td>
<td>1.271</td>
<td>1*</td>
</tr>
<tr>
<td>Innovation stimulating regulation</td>
<td>3.34</td>
<td>0.974</td>
<td>2**</td>
</tr>
<tr>
<td>Market pull</td>
<td>3.28</td>
<td>1.032</td>
<td>3**</td>
</tr>
<tr>
<td>Government client with innovative demand</td>
<td>3.14</td>
<td>1.026</td>
<td>4**</td>
</tr>
<tr>
<td>Government Guarantee for market for innovative firms</td>
<td>3.00</td>
<td>0.845</td>
<td>5**</td>
</tr>
</tbody>
</table>

Technological capability (3.496) was indicated as the highest driver or push factors of innovation adoption in Ghanaian Quantity Surveying firms with a mean of 3.496 among the drivers’ categories or divisions because technology has the capability of bringing an idea into existence. This concludes that technological capability is an important factor that drives an innovation adoption. Seaden and Manseau (2001) and Goverse et al. (2001)
stressed on the necessity of programs and bridging institutions facilitating access for organizations to the technology needed mostly to innovate. This agrees to the fact that the activities of the world are now driven by technology.

Furthermore, the variables under technological capability (3.496) were also ranked. Programmes promoting access to technology (1st) evolved as the highest ranked variable under technological capability and finance for pilot project (6th) being the least ranked. This concludes that programmes promoting access to technology is the most important factor chosen by the respondents in the Quantity Surveying firms. Programmes promoting access to technology will pave a way to get in touch with technologies that can transfer an idea into a reality. This is consistent with Seaden and Manseau (2001) and Goverse et al. (2001) stressing that the necessity of programs and bridging institutions facilitating access for organizations to the technology needed mostly to innovate.

Knowledge exchange (3.495) was emerged as the second push factor division of innovation adoption. Effective information gathering (1st) emerged was the highest ranked variable under the knowledge exchange category, and programme promoting collaboration (8th) became the least ranked. This concludes that effective information gathering was considered as the most important factor among the others by the respondents because it will seek to provide validity and reliability on information gathered that will help to satisfy the client. This agrees to the fact that Kangari and Miyatake (1997) and Veshosky (1998) included effective information gathering as an important innovation driver.

Boundary spanning (3.388) also evolved as the third under the divisions that push innovation in Ghanaian Quantity Surveying Firms. Involvement of the client (1st) was emerged the highest rank variable under the boundary spanning division and the empowerment of innovation leaders and innovation champions (8th) as the least rank. This then concludes that involvement of the client is the most significant variable under boundary spanning because involving the clients on innovation decision making will help him to get what he will be satisfied with. This also supports the fact when Bossink (2004) said specific wishes and demands of clients can help stimulate architects to come up with innovative solutions and ideas.

Environmental pressure (3.248) emerged as the last ranked division among the four divisions that push innovation adoption in Ghanaian Quantity Surveying Firms. Subsidies for innovative application and material were also very critical driver of innovation, and can be used as a regulatory measure.
hypothesis (Ha) that all the factors under environmental pressure are important or significant.

Factors underneath the technological capabilities including product evaluating design (0.000), programme promoting access to technology (0.032), finance for pilot project (0.002), technology fusion (0.040), and technology leadership strategy (0.003) and technology push (0.015) are all also important. They also had significance level below 0.05. Therefore, retaining the hypothesis (Ha) that all the factor making up the technological capabilities are significant.

In Knowledge exchange, stimulation of research (0.004), creation of knowledge network (0.025), programme promoting collaboration (0.000), broad view of risk (0.003), integrated and informal R & D function (0.000), training of workers on the site (0.041) and lateral communication structures (0.003) are all less than 0.05, except effective information gathering (0.384), which had more than 0.05. This concludes that, excluding effective information gathering, all the factors under the knowledge exchange are important because they had significance level to be less than 0.05. Therefore, rejecting their null hypothesis. Effective information gathering was not proved enough to reject its null hypothesis (Ho) because it had significance level to be 0.384, therefore retaining its null hypothesis.

Finally, factors under boundary spanning: integration of design and build (0.009), involvement of the client (0.027), mechanisms for sharing financial risk and benefits (0.002), coordination of participating groups (0.002), empowerment of innovation leaders and innovation champions (0.000), innovation from suppliers (0.006), explicit coordination of the innovation process (0.004), and strategic alliances and long term relationships (0.013) are all having significance level being less than 0.05 (Sig. <0.05). This then concludes that all the factors are significant thereby rejecting the null hypothesis (Ho) that they are not important.

4.1 Practical Implication

The importance of this study can also be extended to the other sectors apart from the construction sector in Ghana including innovation policy makers. Firstly, push factors of innovation adoption have been clearly identified as a research gap to be catered for in the professional service firms, especially Ghanaian Quantity Surveying firms. It has been revealed that technological capability is an important factor that can drive innovations in both public and private sectors. The outcome of the study will be beneficial to stakeholders as it will help them invest in programmes promoting access to technology with the aim of driving innovations in the professional service firms. The study continuously discloses that programmes promoting technology adoption is a critical factor that can help to drive innovations in professional service firms in Ghana. There is a need for government and leaders to consider investing in programmes that can help workers to access technology in order to make their innovative ideas real and attainable. This paper has contributed to the research gap by making it known to both public and private sector the push factors to help adopt innovation in the firms.

4.2 Theoretical Implication

The study will further seek to enhance the understanding of innovation adoption in the professional service firms, especially the Quantity Surveying firms by making it available the push factors of innovation adoption. This is an important theoretical gap the study has contributed to, and it is reliable for further studies of innovations in both the public and the private sector.

5 Conclusion and Further Research

The results as seen throughout this research have pointed the definition of innovation, which has provided integrating focus to categorize the drivers of innovation adoption in Ghanaian Quantity firms. It was concluded that technological capability has the most ability to drive innovation adoptions in firms. The paper further established clearly that programmes promoting access to technology is the most important push of innovation by the Ghanaian Quantity Surveying Firms. The paper therefore makes a strong case to back the drivers of innovation in Ghanaian Quantity Surveying Firms.

The list of registered Ghanaian Quantity Surveying firms collected from the Ghana Institute of Surveyors covered the two major regions in Ghana namely Accra and Kumasi. Meanwhile there are other eight (8) regions left, in so doing, may affect the generalization of the results. The study was steered with a sample size of 29 out 43 registered Quantity Surveying firms purposively collected from Ghana Institute of Surveyors, thereby the extent to which the results can be comprehensive may be in distrust. Relying alone on the significance level to drive conclusion is quite simplistic, and can there affect the trust of the study. Lastly, the study was purely quantitative, henceforth, there is a need to have incorporate the qualitative method, which could have reduced the weaknesses found in the use of only quantitative method. It is recommended that further research work is undertaken to identify: factors that will enhance implementation of innovation adoption in Ghanaian Quantity Surveying firms, and the process of innovation management in professional service firm in the construction industry: the perceptive of Ghanaian Quantity Surveying Firms.

6 References


