NZBERS

New Zealand Built Environment Research Symposium

PROCEEDINGS

4th Annual New Zealand Built Environment Research Symposium
[NZBERS 2014]
14 November 2014
Massey University, Albany, New Zealand

Dr Jasper Mbachu
[Editor-in-Chief]

NZBERS

Industry and academia working together for a productive and sustainmable built environment

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Participating institutions

Sponsors

Winstone Wallboards

Ebert Construction

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4TH NEW ZEALAND BUILT ENVIRONMENT RESEARCH SYMPOSIUM

(NZBERS 2014)

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Prof Didibhuku Wellington Thwala, University of Johannesburg, South Africa.

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- Winstone Wallboards (GIB); this was made possible by Kevin Walls, Manager, Sustainability.
- Ebert Construction Ltd; this was made possible by Ron MacDonald, General Manager, Northern.
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- Professor Robyn Phipps, Programme Director, Construction, School of Engineering and Advanced Technology, Massey University;
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Environmental Engineering, University of Auckland.
- Professor John Tookey, Programme Director, Engineering Project Management, AUT.
- Dr James Rotimi, Programme Coordinator, Master of Engineering Project Management, AUT;
- Associate Professor Linda Kestle, Chair, Research, Faculty of Technology & Built Environment, UNITEC.
- Dr Ricardo Mendoza, Director, Postgraduate Studies, Department of Civil & Natural Resources Engineering, University of Canterbury.
- Dr Fabricio Chicca, Programme Director, Building Science, School of Architecture, Victoria University of Wellington.

Next, the keynote speakers, who sacrificed their precious time to respond to our invitations, and made useful presentations; these are as follows (in no priority order):

- Lt Col (rtd) Warren Parke, Chair, Construction Clients Group (CCG).
- Bruce Rogers, President, Northern Chapter, NZIOB.
- Paul O'Brien, Chair, NZIQS Auckland Branch Board; Commercial Manager, Leighs Construction).
- Regan Solomon, Manager, Research, Investigations and Monitoring Unit (RIMU), Auckland Strategy and Research, Auckland Council.
- Professor Paul McDonald, Pro-Vice Chancellor, College of Health, for delivering the Welcome Address on

behalf of Steve Maharey (CNZM), Vice Chancellor, Massey University.

Our industry patrons deserve special commendation for sacrificing their professional time to respond to our invitations and participated actively as members of the industry workshop during the symposium. The students confirmed that the patrons provided useful and practical advice on how their research could be improved to ensure that expected outcomes would be of value to the industry. They were also satisfied with the industry patrons' feedback on the key challenges they face in their research projects. In no priority order, special thanks go to the following industry patrons:

-   Dr Wayne Sharman (Strategic Business Development Manager, BRANZ)
-   Kevin Golding (Winstone Wallboards);
-   Dr Kevin Walls (Director, Building Code Consultants Ltd).
-   Matthew Ensoll, Director, Quantum Meruit Project Management.
-   Victoria Troake (Director, Troake Group).
-   Gary Caulfield (Director, Construction Cost Consultants)

-   Paul O'Brien (Commercial Manager, Leigh Construction; Chair, NZIQS Auckland Branch Board)
-   Sam Lomax, Vice Chair, Auckland Branch Board, New Zealand Institute of Quantity Surveyors (NZIQS).

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EDITORIAL

E.1) Need for collaborative research in the built environment

The complexity of the 21st Century built environment challenges cuts across professional boundaries. Addressing these challenges requires a multi-disciplinary team working collaboratively and leveraging their multi-disciplinary expertise in joint research undertakings. To make a visible impact on the sector, it is no longer an option for researchers to be working in silos and focusing their research only on their areas of interest without inputs from other collaborators.

The 21st century built environment research is increasingly being underpinned by cross-disciplinary, cross-institutional and multi-national partnerships amongst academics, the industry, policy makers and the government who are on the same boat, talking to each other, sharing ideas, supporting one another and collectively making progress towards a productive and sustainable built environment.

The New Zealand Built Environment Research Symposium (NZBERS) is aimed at providing a platform for multi-stakeholder collaboration on issues relating to the built environment research and the diffusion of innovative ideas and cutting edge knowledge in support of quality education and best practice standards.

The inaugural symposium in 2011 was made possible by the collegial efforts of the built environment research leaders at Massey University, The University of Auckland, Auckland University of Technology (AUT)

and the Unitec. In addition to the participation by these four pioneer universities, the previous and this year's series have attracted participations from the built environment leaders at the Victoria University of Wellington, University of Otago and the University of Canterbury. Participations from the University of Waikato and Lincoln University are still expected in the future series.

E.2) 4th NZBERS 2014: An overview

The 2014 series of the New Zealand Built Environment Research Symposium (NZBERS) was held on 14 November 2014 on the Albany campus of Massey University. The symposium brought together built environment researchers in the New Zealand universities to disseminate their research findings or works-in-progress to the industry and colleagues. It also provided opportunity for the researchers and industry practitioners to exchange ideas and work towards collaborating along areas of mutual research interests and expertise.

The theme of this year's series was "Shaping future directions for collaborative built environment research and practice in New Zealand". The primary aim was to identify existing and future research needs, current research efforts towards addressing the identified needs and hence establish gaps that will underpin future research undertakings.

Seven universities participated in the symposium; these were the University of

Auckland, AUT, Massey University, Unitec, Victoria University, University of Otago and the University of Canterbury.

The one-day symposium included keynote addresses from industry chieftains and decision makers in government departments. Built environment programme leaders in the New Zealand universities also presented on the current and recently completed built environment research by research students and academic staff in their units. Masters and doctoral research students presented findings of their completed research or works-in-progress.

The objective of the Proceedings of this year's series is to document the industry leaders' feedback on the current and future built environment research needs of the key stakeholders in the New Zealand building and construction sector and the efforts of the built environment researchers in the universities towards addressing those needs. The Proceedings and those of earlier series would help to showcase the completed and on-going research in our universities, as well as provide guidance on the research priorities that will shape future research efforts to meet the specific information needs of the industry for reliable decision making process.

The Proceedings comprises 3 sections.

The first section presents the current and future research needs of the industry as highlighted by the industry chieftains and policy-makers in their keynotes.

The second section presents the current and recently completed built environment research by research students and academic staff as summarised by built environment programme leaders of the participating universities.

The third section presents extended abstracts of research works-in-progress and full papers of recently completed research projects undertaken by postgraduate research students and academic staff in the universities.

The last section matches the current research at the universities with the industry research needs and highlights gaps that will underpin future directions for built environment research in the New Zealand universities.

Dr Jasper Mbachu
Editor-In-Chief

SECTION 1

Welcome Address and Keynotes

1.1 Overview on Keynotes

This section comprises a welcome address and four keynotes.

The Welcome Address was by Professor Paul McDonald, Pro-Vice Chancellor, College of Health (Proxy for Hon. Steve Maharey, Vice Chancellor), Massey University at Albany.

The first keynote was on the "*current and future challenges facing New Zealand quantity surveyors – Priority issues and potential solutions*" – by Paul O'Brien, Chair, NZIQS Auckland Branch Board; Commercial Manager, Leighs Construction.

The second keynote was on the "*Priority research needs of the New Zealand building professionals*", by Bruce Rogers, President, Northern Chapter, NZIOB.

The third keynote was on the "*Priority research needs of the New Zealand construction clients*", by Lt Col. (rtd) Warren Parke, Chair, Construction Clients Group (CCG).

The fourth keynote was by Regan Solomon, Manager, Research, Investigations and Monitoring Unit (RIMU), Auckland Strategy and Research, Auckland Council. Regan's presentation was on the "*Built environment research challenges in the Auckland region: Auckland Council's viewpoints and recent research activities*".

The presentations are summarised in the following subsections.

1.2 Paul McDonald's Welcome Address: *NZBERS as a potential vehicle for contributing to the delivery of Massey University's Big Goals*
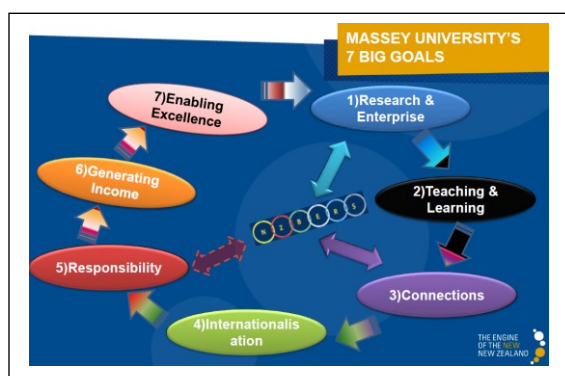
Professor Paul McDonald

Professor Paul McDonald, Pro-Vice Chancellor, College of Health, delivered the Welcome Address on behalf of Steve Maharey (CNZM), Vice Chancellor, Massey University. In his address, Professor McDonald – formerly a Canadian architect – expounded on the NZBERS as a potential vehicle for contributing to the delivery of Massey University's Big Goals, particularly the goals on Research &

Enterprise, Responsibility and Connections. Professor McDonald's presentation highlighted the need for environmentally sustainable buildings, with focus on the impact of the building materials and built environment operations on health through environmental sustainability in key operations:

- Housing design,
- Road design
- Transportation systems (especially active transport)
- Green space, and
- Access to nutritious food and clean water.

Putting on his cap as a health expert, Professor McDonald was particularly concerned with the impact of the built environment processes and outputs on health and social wellbeing of the nation. For instance, unsafe construction processes could lead to accidents and fatal injuries. Leaky buildings and the use of toxic materials and substances could result in health conditions such as cancer and cardiovascular diseases. He urged the built environment professionals to use systems thinking in ensuring that the built environment they create and maintain minimises adverse impact on the environment and the social systems and hence minimise hospital admissions and health bills.

While reflecting on the NZBERS as a potential vehicle for contributing to the delivery of Massey University's Big Goals particularly goals on Research & Enterprise, Responsibility

and Connections, Professor McDonald saw as key pillars for achieving this to be the symposium's focus on collegiality, collaboration, research and result dissemination, and industry connections.
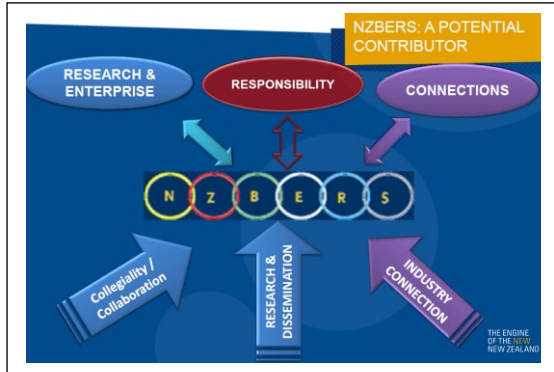
Professor McDonald's Welcome Address is available on the symposium portal: http://construction.massey.ac.nz/NZBERS-2014_McDonald-P_Welcome-address.pdf

1.3 Paul O'Brien's Keynote: *Current and future challenges facing New Zealand quantity surveyors – Priority issues and potential solutions*
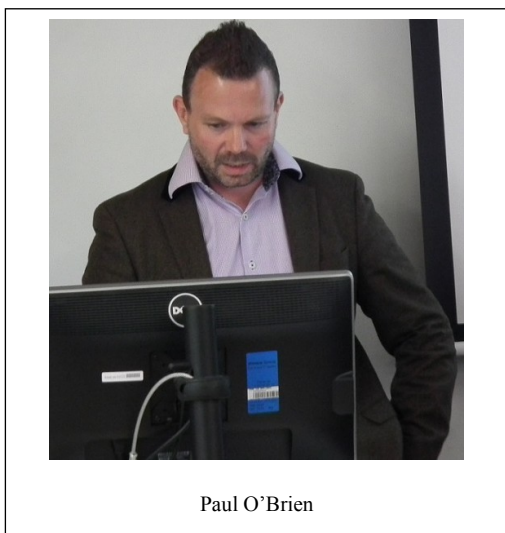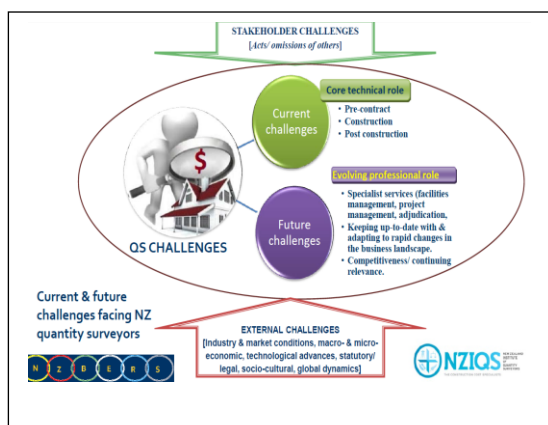
Paul O'Brien

In the first Keynote address, Paul O'Brien, Chair of the Auckland Branch of the New Zealand Institute of Quantity Surveyors (NZQS) presented on the Current and future challenges facing New Zealand quantity surveyors: Priority issues and potential solutions. In his presentation, Paul argued that the current challenges facing quantity surveyors in New Zealand were largely issues in their core professional role at the pre-contract, construction and post-construction stages of the project development process. These comprised the following:

- Preliminary cost advice,
- Procurement and tender management,
- Financial and cost management of the project,
- Contract administration.

The future challenges related more to issues in the quantity surveyors' evolving specialist roles such as:

- Project management,
- Financial due diligence,
- Facilities management,
- Insurance valuation, and
- Dispute resolution and expert witness.

Future challenges also included issues such as keeping up-to-date with and adapting to rapid changes in the business landscape, as well as issues relating to competitiveness/ continuing relevance of the profession.

Both categories of current and future challenges facing the New Zealand quantity surveyors were not only underpinned by the acts and omission of the quantity surveyors themselves; they were a result of the acts/ omissions of other stakeholders that have inputs into the quantity surveyors' role such as the construction clients, councils, designers, contractors and suppliers. Further challenges were introduced by externalities such as industry and market conditions, macro and micro economic dynamics, technological

advances, statutory/ legal environment, and socio-cultural and global dynamics.

Based on analysed results of personal interviews of 110 quantity surveyors across New Zealand from March 2012 to October 2014, Paul highlighted the most critical challenges at the various phases of the project development process as follows:

Pre-contract phase challenges

- For the consultant QS, the most critical challenge was on how to navigate through poor design documentations and the uncertainties around future cost scenarios and provide accurate estimates and reliable cost advice.
- For the contractor QS, the most critical challenge was on how to tender and win jobs sustainable margin potential in a tight and competitive market where clients prefer lowest priced lump sum contracts.

Construction phase challenges

- For the consultant QS, the most critical challenge at this phase was on how to challenge, amidst the prevalence of poor communication and documentation, was on how to carry out proper evaluations and provide impartial cost advice on contractor's contractual entitlements which may be in conflict with client's interests and expectations.
- For the contractor QS, the most critical challenge was on how to make sustainable margins on lump sum fixed price contracts won on lowest cost conforming bids, in situations where the client is quick to dispute claimed amounts within payment schedules, and where taking any formal dispute

resolution steps could result in reputational damage or removal from future tender lists.

Post-construction phase challenges

For the consultant and contractor quantity surveyors, the most critical challenge at this phase was on how to balance ethical, contractual and financial challenges around final accounts settlement and yet maintain enough positive image and confidence to earn the client's invitation for future jobs or positive reference.

Future challenges

The future challenges facing the New Zealand quantity surveyors were three fold:

1. What new and emerging developments are expected to shape future directions in the field of quantity surveying?
2. What skills and knowledge does the quantity surveyor need to be able to respond more proactively to these developments, maximise the opportunities and minimise inherent threats?
3. What training programmes or CPDs are required to provide the quantity surveyor with the requisite skills and knowledge for growth and continuous relevance?

Paul also highlighted potential solutions for addressing the challenges. His presentation can be accessed at http://construction.massey.ac.nz/NZBERS-2014_OBrien-P_Keynote.pdf while the full research paper can be downloaded at http://construction.massey.ac.nz/NZBERS-2014_proc_fp_OBrien-P_et-al.pdf .

1.4 Bruce Roger's Keynote: *Priority research needs of the New Zealand building professional*

Bruce Rogers

In the second keynote, Bruce Rogers, President of the Northern Chapter of the New Zealand Institute of Building (NZIOB), talked about the priority research needs of the New Zealand building professionals. In his presentation, Bruce hinted that priority research needs of a typical construction professional in New Zealand comprise research on "things that make projects go better, faster, cheaper and safer". He identified the following as important research needs, the relative importance of each need being a matter of the key concerns of the various building professionals:

- Productivity
- New technology integration
- Retrofitting and upgrading existing buildings
- Business Management
- Building user behaviour
- Construction Management
- Building envelope
- Materials durability.

Bruce argued that industry research needs may be at variance with the focus of academic research. He called on researchers to ensure that research results are not only aimed to benefit the academia but must also meet the needs of the industry.

Bruce's presentation can be accessed from the symposium portal at http://construction.massey.ac.nz/NZBERS-2014_Rogers-B_Keynote.pdf

1.5 Warren Parke's Keynote: *Priority research needs of the New Zealand construction clients*

Lt Col. (rtd) Warren Parke

Lt Col. (rtd) Warren Parke, Chair, Construction Clients Group (CCG) presented on the priority research needs of the New Zealand construction clients. Warren's keynote emphasised on the factors that would best ensure positive project outcomes. These comprise new ways of doing things, particularly, the increasing focus on building information modelling (BIM), lean construction, early contractor engagement/ collaboration and cost-effective forms of contracts. Warren argued that for any research to be of value and able to attract the attention of the decision makers, it has to present quantifiable benefits which can persuade the industry to invest in the uptake of the findings, and that can be a game-changer in the sector-wide practice. His concept of the 'Change Flywheel' models an effective approach to undertaking research from the exploration of new/ innovative ways, through setting up the path-finder case studies for confirming the quantifiable benefits, to the industry buy-in and downstream impact assessment.

Change Flywheel
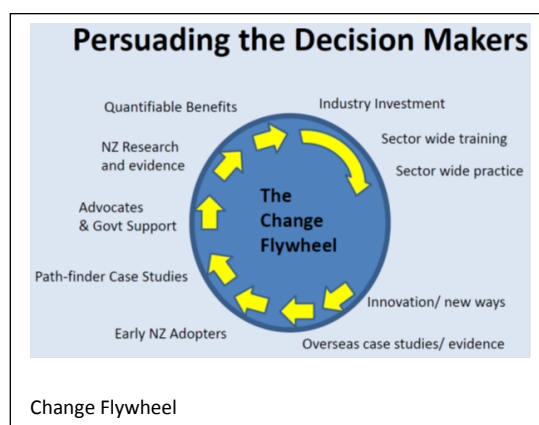
Warren's presentation can be accessed at http://construction.massey.ac.nz/NZBERS-2014_Parke-W_Keynote.pdf

1.6 Regan Solomon's Keynote: *Built environment research challenges in the Auckland region: Auckland Council's viewpoints, and recent research activities*

Regan Solomon

The last keynote was delivered by Regan Solomon, Manager, Research, Investigations and Monitoring Unit (RIMU), Auckland Strategy and Research Department of the Auckland Council. Regan presented on the "Built environment research challenges in the Auckland region: Auckland Council's viewpoints, and recent research activities". His presentation highlighted the four priority sets of built environment challenges facing the Auckland Council as follows:

- Challenge set 1:
    o How might the industry be structured to produce the desired urban form?
    o How and why do developers move between locations, building types and scales?
    o How is the industry responding to the removal of 2nd tier financing?
- Challenge set 2:

    o How do the different spheres interact in practice and what is the role of planning in particular?
    o How does improved granularity change how we think about the built environment?
- Challenge set 3:
    o Will expanding the role of the community sector in housing improve social outcomes for renters?
    o How can the housing stock be made warmer and are different strategies needed for owners and landlords?
    o How is the private rental market structured?
- Challenge set 4:
    o How can we address source issues that are outside of national frameworks?
    o How long does it take to see the removal of pollutants in our environment?
    o What stops sound evidence being key in decision making?

Reagan highlighted the Council's RIMU group's efforts to date in addressing the challenges. Full details of his presentation can be accessed at http://construction.massey.ac.nz/NZBERS-2014_Solomon-R_Keynote.pdf

SECTON2:

CURRENT BUILT ENVIRONMENT RESEARCH AT THE UNIVERSITIES: PRESENTATIONS BY PROGRAMME DIRECTORS

Overview of the built environment research at the universities

Programme directors of built environment programmes in the seven universities that participated in the symposium presented recently completed and ongoing built environment research in their departments. An overview of their presentations is provided as follows.

Current built environment at AUT

Professor John Tookey presented on the construction research at AUT, with a focus on the 'What', 'Who', 'Why' and 'What' research is going on in the Department of Built Environment Engineering (BEE) and the Centre for Urban Built Environment (CUBE). The research relates to the key capabilities in the department, which include the following:

- Productivity and economic evaluation
- Construction economics
- Supply chain management
- Health and Safety
- Disaster response
- Procurement
- Logistics
- Sustainability
- Waste minimisation / waste reduction
- Facilities Management
- Asset Management
- Pedagogy
- BIM / design
- Green design / green building
- Corporate Social Responsibility.

Specific research projects being undertaken are wide ranging, and included funded and unfunded projects such as:

- Innovating towards Zero-Waste Value Chains in the Building Industry
- Building Materials Supply Chains: An Evaluative Study of the New Zealand Residential Construction
- Exploring the potentials for the application of simulation methods in construction projects delivery in New Zealand
- A transportation investment decision support tool for Auckland
- The effectiveness of the newly introduced risk-based building inspection scheme within Councils in New Zealand
- Impact of Procurement System on Transaction Cost Economics: Future Organisational Structure in the construction industry
- Corporate social responsibility agenda for international oil companies (IOC's) - New Perspectives from Stakeholder Engagement in the Niger Delta Region (NDR) of Nigeria
- A rational basis for setting up a monetary retention regime for construction contracts
- Developing World Class Service Quality for the Indonesian Construction Industry
- The potential for Lean and Six Sigma implementation in SMEs operating within the manufacturing industry in New Zealand
- Mapping the economic value of a zero-waste policy for construction materials in New Zealand

In addition, the following research projects are ongoing with partners:

- Continued mapping of Auckland construction logistical flows
- Housing productivity / affordability
- Waste minimisation – designing out waste
- Facilities management / asset management themes.

Current built environment at Massey University

Professor Robyn Phipps presented on the built environment research at Massey University. From her presentations, the following research themes and sub-themes are evident:

Indoor environment quality (IEQ) in homes and schools:

- Low cost solar ventilation system
- Weathertightness
- Air quality.
- Noise.
- Bacterial and mould growth.

Healthy housing design and remediation

- Energy consumption,
- Materials selection,
- Heating & ventilation
- Insulation and sustainable retrofiting.

Smart homes

- Aged care facilities.
- Wireless sensors
- Machine learning algorithms.

Lighting

- Light emitting diode (LED) lighting technology.

- Road and urban lighting assessment.

Energy:

- Solar technologies
- Benchmarking tools for energy performance.
- Intelligent HVAC control systems

Sustainability:

- Construction waste minimisation.

Disaster management:

- Managing earthquake risks,
- Disaster mitigation.
- Disaster preparedness
- Christchurch rebuild: effect of stakeholders' practices on seismic risk mitigation decisions.

Construction law:

- Construction contracts.
- Dispute resolution
- Adjudication.

Construction project management:

- Risk management,
- Cost management.
- Value management.

Productivity:

- Prefabrication/ off-site manufacturing.
- Onsite labour productivity
- Whole life cycle costing for residential building development.
- Productivity measurement and performance improvement.

Organisational study

Strategic facilities management

l research in the Faculty of Engineering at Auckland University. Suzanne's presentation shows that built environment research at The University of Auckland is undertaken by the following research centres/ inter-disciplinary groups:

- Transforming Cities: Innovations for Sustainable Futures
- Institute of Earth Sciences and Engineering
- UoA Centre for Earthquake Research
- Centre for Infrastructure Research
- Transportation Research Centre.

The infrastructure and environmental research projects fall under the following themes:

- Buildings and Structures
- Environment and Sustainability
- Water, Power and Communications
- Transportation.

Specific projects completed or ongoing include:

- Solutions for buildings and bridges subjected to severe earthquake
- Seismic Retrofit Cost Modelling of Existing Structures: Dr. Reza Jafarzadeh.
- Influences of Human Behaviour on Energy Efficiency in Green Buildings: Sakina Mohktar.
- Ensuring better storm water management.
- Low Impact Design Implementation: Towards Sustainable Urban Stormwater Control - by Joshua Olorunkiya.
- Key Practice Indicators of Team Integration in Transport Alliances: Khairil Ibrahim.
- Disaster, Reconstruction, Resourcing – undertaken by the RecRes project team.

- Innovations: IT and BIM research by Garry Miller, Vicente Gonzalez, Robert Amor and others.
- Productivity research.

Current built environment at The University of Canterbury

Dr Ricardo Bello-Mendoza presented on the built environment research in the Department of Civil and Natural Resources Engineering at Canterbury. Main research clusters include:

- Geo-structures Cluster:
  - o Earthquake Engineering (Major contributor to BE research)
  - o Structural Engineering (Major)
  - o Geotechnical Engineering (Moderate)
  - o Fire Engineering (Moderate)
- Transportation Engineering (Moderate)
- Natural Resources Engineering (Moderate)
- Construction Management (Minor)
- Environmental Engineering (Minor)
- Water Resources Engineering (Minor).

Specific projects recently completed or ongoing under the various research clusters are as follows:

Hydro-econ engineering:

- Green roof technology.

Environmental engineering:

- New public sanitation.

Transportation engineering:

- Traffic and safety.
- Transportation planning.
- Pavement material characterisations and asset management.
- Pavement performance and evaluation.

Fire engineering:

- Fire dynamics.
- Fire safety systems.
- Fire performance of materials and structures.
- Probabilistic structural fire engineering.

Seismology:

- Ground motion prediction
- Attenuation relationships
- Site specific seismic hazard analysis
- Vertical acceleration effect.

Geotechnical engineering:

- Slope stability
- Debris flow
- Liquefaction
- Lateral spreading
- Foundation

Materials:

- Fresh concrete
- Corrosion of reinforcing bars.
- High performance concrete.

Seismic performance/ design of buildings:

- Soil/site effect
- Building irregularity
- Soil structure interaction
- Building specific seismic loss assessment
- Performance of non-structural components and contents.

Steel and Composite Structures

- Composite floor slabs under gravity loading
- Slab effects on steel moment frames
- Low damage steel connections (sliding hinge)
- Low damage bases

Lifelines

- Underground pipe network (damage detection and mitigation technique)
- Accelerated bridge construction and design
- Low damage bridge systems.

Reinforced Concrete Buildings

- Improved design of structural walls
- Residual capacity of damaged buildings
- Repair options of damaged RC buildings
- RC frame floor interaction
- Beam elongation effects

Timber Structures

- Post-tensioned timber building systems
- Glulam
- Laminated Veneer Lumber (LVL)
- Timber concrete composites.

Current built environment at Unitec

Associate Professor Linda Kestle presented on the built environment research in the Faculty of Technology and Built Environment at Unitec.

The research projects included:

- Waste management in the construction industry,
- Impact of an innovative construction system on residential internal environments.
- Sustainable design and construction.
- Moisture in buildings.
- BIM.

Current built environment at Victoria University

Dr Fabricio Chicca showcased the built environment research in the School of

Architecture at Victoria University. These fall under nine project clusters:

- Settling our regional landscape.
- Ecologies lab: Urbanism, infrastructure, housing, life.
- Parametric design and digital agency.
- Responsive environments and robotics.
- Housing and public infrastructure.
- Contemporary workplaces/ corporate spheres.

- Reflections of the future.
- Building technologies and materials
- People and designed environments.

Details of the specific research projects recently completed or still ongoing at Victoria University can be accessed in Dr Chicc's presentation.

2.1 Professor John Tookey: *Construction Research at AUT: What, Who, Why, What research and Where next?*

1. THE 'WHAT'

- **AUT developing presence in construction academe in NZ**

- **Based on the Master of Construction Management (MCM)**

- **Steady growth since 2007**

  - **38+ MCM**

  - **36+ Master of Engineering Project Management (MEPM)**

  - **14+ PhD efts (current)**

- **Circa $2.5m funds attracted over 7 years.**

- **CUBE-NZ established as a research entity in 2012. Undertaking funded research with industry**

- **7 Appointed academics, plus adjuncts**

- **10 additional staff expected over next 4years**

- **Dept of Built Environment Engineering (BEE) established November 2014**

- **New BE (Hons) Construction Engineering / Architectural Engineering approved for delivery from 2015.**

2. THE 'WHO' AT AUT

Prof John Tookey
Head of Dept / Director
CUBE-NZ

Dr Jeff Seadon
Snr Research Fellow,
CUBE-NZ

S/L Dr James Rotimi
Programme leader MCM

Dr Fei Ying
Snr Research Fellow,
CUBE-NZ

S/L Dr Dave Moore

S/L Dr Nicola Naismith

Dr Ali

2. THE 'WHO' AT AUT

Key capabilities covered include:-
- **Productivity and economic evaluation**
- **Construction economics**
- **Supply chain management**
- **Health and Safety**
- **Disaster response**
- **Procurement**
- **Logistics**
- **Sustainability**
- **Waste minimisation / waste reduction**
- **Facilities Management**
- **Asset Management**
- **Pedagogy**
- **BIM / design**
- **Green design / green building**
- **Corporate Social Responsibility**
- **etc**

3. THE 'WHY?'

Aspiration for BEE/ CUBE-NZ:-
- **Grow capability**
- **Add value to Industry**
- **Add value for stakeholders**
- **Use research to inform programme development and delivery**

4. WHAT RESEARCH?

Wide range of funded and unfunded research:-

- **Innovating towards Zero-Waste Value Chains in the Building Industry**

- **Building Materials Supply Chains: An Evaluative Study of the New Zealand Residential Construction**

- **Exploring the potentials for the application of simulation methods in construction projects delivery in New Zealand**

- **A transportation investment decision support tool for Auckland**

- **The effectiveness of the newly introduced risk-based building inspection scheme within Councils in New Zealand**

- **Impact of Procurement System on Transaction Cost Economics: Future Organisational Structure in the construction industry**

- **Corporate social responsibility agenda for international oil companies (IOC's) - New Perspectives from Stakeholder Engagement in the Niger Delta Region (NDR) of Nigeria**

- **A rational basis for setting up a monetary retention regime for construction contracts**

- **Developing World Class Service Quality for the Indonesian Construction Industry**

- **The potential for Lean and Six Sigma implementation in SMEs operating within the manufacturing industry in New Zealand**

- **Mapping the economic value of a zero-waste policy for construction materials in New Zealand**

4. WHAT RESEARCH?

In addition ongoing research with partners:-

- **Continued mapping of Auckland construction logistical flows**

- **Housing productivity / affordability**

- **Waste minimisation – designing out waste**

- **Facilities management / asset management themes.**

5. WHERE NEXT?

- **Key themes currently addressed through research will be reinforced.**

- **New staff appointments will grow capacity and research emphasis**

- **Structures**

- **Materials**

- **Building services**

- **Geotech**

- **BIM / Architectural design**

- **Building methods**

- **New investment in infrastructure will grow capacity and output**

- **New city campus engineering facilities**

- **Options for AUT South growth and development**

- **Increased internationalisation options.**

SUMMARY

- **AUT/CUBE-NZ are in a state of flux**

- **Wide range of research capabilities proven and expanding**

- **New programmes create new opportunities in both 'hard' and 'soft' subject matter**

- **New investment in infrastructure will grow capacity – expected to be circa $80+m over the next 3 years**

- **Interesting times.**

2.2 Construction Research in the School of Engineering & Advanced Technology, Massey University

Built Environment Research at Massy University

Prof Robyn Phipps

Director, Construction Programmes

Director, BE Custer

School of Engineering & Advanced Technology

Ventilation

Randomised control trial in 30 Auckland homes with a ceiling cavity mechanical ventilation system installed

Monitored for two winters

Results; homes with ceiling ventilation system;
- Warmer during the day
- 1 hour offset in need to turn on heaters
- Colder overnight

Study completed, publications pending

Contact Robyn Phipps or Mikael Boulic.
- MU contributor to WAVE; (Weathertightness, Air Quality and Ventilation Engineering Program)
- 6-year program, commenced in October 2009
- Airtightness in 60 homes and ventilation in 40 homes (Auckland, Palmerston North, Wellington and Dunedin).
- MU 10 new Palmerston North homes constructed post 1995
- Found new homes can have less 0.25 infiltration. Mechanical ventilation is becoming necessary.

Housing, Heating and Health Study

- 409 children aged 6-12 years with asthma,
- MU and BRANZ: Intensive monitoring in subset of main sample living room and child's bedroom.
- Results; UFGH produced insufficient heat, but exceeded WHO guidelines for NO2
- Replacement heater (heatpump, wood pellet burner or flued gas heater) increased warmth, improved asthma, decreased school absence and drug use,
- Contact Robyn Phipps, Mikael Boulic or Philippa Howden-Chapman.

Schools

- Improving health and air quality in classrooms with a low cost solar ventilation system
- Classrooms can have bacteria levels similar to those found near a wastewater treatment plant and very high CO2 levels
- Need for improved ventilation and indoor air quality
- 10 junior classrooms monitoring 2013/2014
- Contact Robyn Phipps or Mikael Boulic.

Healthy Homes Design

- Development of a Healthy Housing Design and Remediation Decision Support System
- Modelling of tradeoffs between energy consumption, materials selection, heating ventilation, insulation, site factors, user requirements, existing structures, to achieve a healthy home
- Commenced late 2012
- Contact Aizat bin Basir, Robyn Phipps or Hans Guesgen

Smart Homes

- Smart homes for monitoring elderly living alone.
- Wireless sensors that can be retrofitted into peoples' houses, that provide sufficient information for machine learning algorithms to identify behaviours (and deviations from expected behaviours) without intruding upon the inhabitant's privacy (no cameras, microphones, etc.). We have developed algorithms that are capable of learning about behaviours based on sensor activations alone, and are now investigating how contextual information (such as time, temperature, previous behaviours) can help to detect normal and abnormal behaviours.
- Ongoing. Contact Stephen Marsland

Lighting

- Ongoing lighting research into three areas:
- LED technology, performance
- Energy efficient lighting systems, and the
- Photometry of lamps and luminaires.

LED'S

- Investigation of MR16 Light Emitting Diode (LED) Lighting Technology.
- Low voltage MR16 LED lamps have been designed as direct one-for-one replacements for older halogen MR16 technology. The project considers whether these new lamps can live up to their marketing hype. Parameters include:
- equivalency with halogen lamps
- lighting quality over time
- effect of heat build-up in downlights
- Study began in 2011, experimentation ongoing
- Contact Susan Mander, Roy Speed or Robyn Phipps

Road Lighting

- Development of a Road and Urban Lighting Holistic Assessment Model
- The development of a computer based assessment model to calculate the economic and environmental performance of road and urban lighting systems to assess and compare holistic performance over whole-of-life.
- The model is currently running and is being trialed in New Zealand and internationally.
- Contact Roy Speed or Brian King

Energy

Stakeholder Perceived Barriers to the Use of Solar Energy in Thailand's Tourism Buildings
- Design decisions based on past projects
- Solar technologies seen as risky and expensive by developers.
- Consultants don't consider their fee structure allows them to incorporate new technologies.
- Masters thesis completed 2012
- Contact Manda Trevarthen, Robyn Phipps or John Holland

Energy

Development of a Benchmarking Tool for Assessing the Energy Performance of University Infrastructure
- Statistical analysis of energy use by factors including building use, student numbers, external contracts, weather, building's resilience to weather, age of building
- Informs energy retrofit and investment decision making
- Masters thesis completed 2012, further research ongoing
- Contact Paul Compton or Robyn Phipps

Energy

Intelligent HVAC Control to Minimize Building Energy Use in a Lecture Theatre
- Assessment of HVAC system use, thermal comfort, energy balance and actual HVAC energy consumption
- Optimize the HVAC control using the Riccati equation in order to minimize energy use while maintaining thermal comfort in occupied rooms.
- Research in the early stages
- Contact Claire Flemmer or Rory Flemmer

Sustainability

Reducing Construction Waste in Healthcare Sector

- A Healthcare Construction Waste Minimisation Framework Self-Assessment Tool has been developed to address comprised six waste minimisation strategies namely project documents management, stakeholders" waste awareness, communication and coordination, buildability, materials selection and procurement, and change management.
- Contact Niluka Domingo

Disaster Management

Systematic Information Flow: A Prerequisite for Managing Earthquake Risks and Disaster Mitigation Activities

- Information flow within the earthquake risk management sector affects building owners' risk mitigation decision.
- Qualitative and quantitative approach.
- Need to develop a unified earthquake safety assessment information system to provide information to all stakeholders involved in reducing the community's vulnerability to earthquake risks.
- Contact Temitope Egbelakin or Suzanne Wilkinson
- Recently completed, stage 2 in planning.

Rebuilding Christchurch: Framework for Enhancing Property Owner's Motivational Potential for Earthquake Disaster Preparedness

- A framework developed in the study shows that the process of motivating property owner's motivational potential is made up of three sequential phases: intention formation, decision formation and adoption and implementation of seismic mitigation measures, where the first and second phases are influenced by a specific set of motivational interventions.
- Contact Temitope Egbelakin
- Recently completed

Disaster Management

Effect of Stakeholders' Practices on Seismic Risk Mitigation Decisions
- Investigation of property market practices affect on building owners' decision to adopt mitigation measures.
- Multiple case studies provided new insights on how practices such as non-assessment of seismic risks in property valuation, high earthquake insurance premiums and deductibles, and lack of trust in risk management professionals impeded building owners' risk mitigation decisions.
- Contact Temitope Egbelakin or Suzanne Wilkinson
- Recently completed

Dispute Resolution

The Ideal Construction Dispute Resolver – Professional Viewpoint On Users' Expectations
- Examination of qualifications, skills, and characteristics expected of a dispute resolver, (mediators, arbitrators, and adjudicators)
- Results; more comprehensive training required in adjudicator and other dispute resolver training courses, and the appointment of a dispute resolver should match the skills of the dispute resolver with the type of dispute .
- Contact Naseem Ameer Ali
- Recently completed

Financial Risks

Sources of contractor's payment risks and cash flow problems in the New Zealand construction industry
- Investigate contractor's payment risks and cash flow problems and mitigation measures via interviews with contractors, subcontractors, project managers, designers and quantity surveyors
- Results; employers contributed 24% financial problems; contractors and subcontractors 19% and 17%,
- Valid payment and variation claims supported with well-documented evidence was a key mitigation measure Contact Jasper Mbachu

Productivity

Prefabrication/ Off-site Manufacture
- Develop a model to measure and compare productivity for prefab and construct in situ construction systems.
- 1) develop and test a model for measuring onsite productivity
- 2) apply model to Auckland case studies
- 3) establish the marginal productivity of prefab system and in situ to determine optimised applications for prefabrication
- Work-in-progress.
- Contact Wajiha Shahzad, Jasper Mbachu or Niluka Domingo.

Productivity

Onsite labour productivity
- Pareto analysis of on-site productivity constraints and improvement techniques in New Zealand building industry
- key constraints to on-site productivity in NZ construction industry
- risk levels of constraints-impact and occurrence frequencies
- innovative solutions for improving productivity in the industry
- Completed 2012
- Contact Serdar Durdyev or Jasper Mbachu.

Residential building life cycle
- Productivity increase leverage points in the residential building life cycle.
- Results; technical, managerial and generic knowledge and skills required to support high productivity and performance construction project delivery.
- 20 out of the 24 identified skills and knowledge were found to have moderate to high impact on contractors' productivity and performance.
- Completed in 2012
- Contact Dr Jasper Mbachu or Dr Jeff Seadon.

Productivity measurement
- Holistic understanding of the concept and measurement of productivity in the construction industry
- Interview contractors and building owners of 16 recent medium to large industrial / retail projects in Auckland,
- Results; productivity resource efficiency (measured as the ratio of the value of the completed project to the total resource inputs), and goal effectiveness (measured as the extent to which the set project objectives were achieved, namely, budget, schedule and quality performance, as well as client satisfaction level).
- Contact Jasper Mbachu or Wajiha Shahzad
- Completed in 2012

Professional Practice

Organisational Strategic Health Diagnostics

- Diagnosing the strategic health of the Australasian quantity surveying organisations: a SWOT-based analytical model
- Develop Strategic Health Index (SHI) as a conceptual tool for diagnosing the strategic health of an organisation based on analysis of its strengths, weaknesses, opportunities and threats. The SHI is being applied to the Australasian quantity surveying profession to ascertain its strategic health and the key areas requiring corrective action.
- Contact Marcel Frei, Jasper Mbachu or Robyn Phipps Work-in-progress

Strategic facilities management

- Challenges facing Australasian University Facilities managers
- Qualitative interviews, quantitative surveys and case studies (model-testing).
- Preliminary results; emergency management/business continuity planning, inadequate funding, statutory compliance, sustainability and environmental stewardship, technology changes. Poor funding root of all other issues.
- Contact Myzatul Kamarazaly, Jasper Mbachu or Robyn Phipps
- Work-in-progress

Contracts

Modernising Construction Contracts Drafting – A Plea for Good Sense

- Critical examination of drafting styles of construction contracts from several commonwealth jurisdictions and compared them against plain language drafting styles. Also some 'before and after' examples were compared to establish the potential benefits of plain legal drafting.
- Recommendation for a model set of plain language drafting guidelines for developing and adopting construction contracts.
- Contact Naseem Ameer Ali
- Recently completed.

Adjudication

Statutory Adjudication – The Need for a Pre-legislation Model Framework

- CA pre-legislation model framework was developed for determining industry needs and the concepts required in statutory adjudication processes. Adopting the model framework will help jurisdictions develop the most appropriate response model including a consideration of adjudication beyond the construction industry and one that avoids anomalies in legislation.
- Contact Naseem Ameer Ali
- Recently completed

Noise

Identify existing noise management interventions & relative effectiveness

- Results; conformance to noise management standards was poor;
- Elimination and isolation strategies to reduce noise exposure not generally utilised. Hearing protection tended to be employed as the key control strategy.
- Safety climate: little perceptions of safety as a workplace priority. After decades of effort in trying to improve safety management, this is disappointing.
- Contact Ian Laird.

2.3 Professor Suzanne Wilkinson: *Infrastructure and environment research in the Faculty of Engineering, University of Auckland*

Infrastructure and Environment Research at The University of Auckland, Faculty of Engineering

Professor Suzanne Wilkinson
Faculty of Engineering: Theme Leader

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Stats ...

- University : ~40,000 students total, ~10,000 postgraduates
- Faculties (Engineering): ~4000 students total, ~1000 postgraduates
- Departments (C&E) : ~1000 students total, ~ 250 postgraduates of which 120 PhD students, 40 staff
- Groups: 6

Where is the Built Env. Research?
Univ. Inter-disciplinary Groups
- Transforming Cities: Innovations for Sustainable Futures
- Institute of Earth Sciences and Engineering
- UoA Centre for Earthquake Research
- Centre for Infrastructure Research
- Transportation Research Centre

Where is the Built Env. Research?
Faculties

- Engineering,
- NICAI,
- Business,
- Law,
- Science

Faculty: Infr. & Env. Research Theme

- Buildings and Structures
- Environment and Sustainability
- Water, Power and Communications
- Transportation

Better Buildings & Structures

- Tools and systems for life cycle costing/ whole life value
- The effects of climate change, extreme natural events and fire on buildings and infrastructure.
- Procurement/Project Delivery
- ***Solutions for buildings and bridges subjected to severe earthquake***

Seismic Retrofit Cost Modelling of Existing Structures: Dr. Reza Jafarzadeh

- Variables for predicting seismic retrofit cost were identified
- Variables that made a statistically significant contribution to the prediction of this cost were identified.
- Parametric regression models for predicting the seismic retrofit construction cost were developed.

Improving the Environment and increasing Sustainability
- Improving sustainability assessment and technology
- minimising waste from infrastructure development
- improving use of natural resources in infrastructure development
- ***Understanding green buildings***

Influences of Human Behaviour on Energy Efficiency in Green Buildings: Sakina Mohktar

Show how human behaviour can assist with optimum energy efficient performance in buildings

- Current management measures
- taken to engage occupants in
- energy conservation goals
- are not effective
- and not widely implemented.

	Green Building		Conventional Buildings	Total
	Certified	**Non-certified**		
New Zealand	1	1	1	3
Malaysia	1	1	1	3

Water, Power and Communications
- improved water quality
- improving telecommunications design, delivery and management;
- improving power transmission.
- **Ensuring better storm water management**.

Portland South Waterfront

Low Impact Design Implementation: Towards Sustainable Urban Stormwater Control: JOSHUA OLORUNKIYA

- Gap between knowledge and hands-on experience among construction professionals which impacts upon LID adoption decisions.
- Collaboration required to:
    - speed up rate of LID uptake,
    - help shorten LID adoption learning curve;
    - facilitate effective and practical changes on the ground

Key Practice Indicators of Team Integration in Transport Alliances: Khairil Ibrahim
Key indicators of team integration:

Department of Civil and Environmental Engineering
- Structures
- Water
- Environment
- Transportation
- Geotechnical
- Construction management

Construction Management Staffing

Suzanne Wilkinson

Vicente Gonzalez

Kepa Morgan

Garry Miller

Kenneth Yiu

Suzanne Wilkinson

Challenges
- How can we make infrastructure and communities more RESILIENT?
- How can we improve CONSTRUCTION PRODUCTIVITY?
- What are the NEW INNOVATIONS and how will they change the industry?

Resilience: Christchurch

Structures/management/ geotechnics
- Resilient Infrastructure and Buildings
- Resilient Organisations

RecRes Project

Disaster, Reconstruction, Resourcing
www.recres.org.nz
- Long- term study for Canterbury Recovery
- Evaluate *real-time* resource availability and resourcing issues
- Provide advice on resourcing availability, efficiency and improvements for rebuilding
- Respond to anticipated problems, monitor for best practice

Disaster, Reconstruction, Resourcing

- Are there shortages in human resources/ materials/ plant/ equipment
- Impact(s)
- Arrangements
- Changes.

CCH: Factors construction productivity

- Waiting for council approvals
- Delays in main contractor providing information
- Excessive head contractor/client oversight or (New) procedures
- Inadequate work specification & changed specification after work began
- Waiting for EQC inspections/ approvals.

INNOVATIONS: IT and BIM Research at UoA for the AEC Industry (Garry Miller, Vicente Gonzalez, Robert Amor and others)

- Collaboration between Civil and Environmental Engineering (Construction Management Team), Computer Science and the Architecture and Planning Departments.
- 8 Postgraduate students (4 PhDs and 4 MEs) and 4 staff members are involved covering:
- BIM+Lean+Sustainability
- Integrated Project Delivery/Procurement
- Interoperability Issues in Construction
- Augmented Reality
- Real Time Data Collection Devices
- BIM+Education in the AEC Industry

Productivity
- Improving project delivery methods
- Recommendations for using PPPs for school development; Tingting Liu
- Programme approach, bundle projects to increase the viability of PPPs.
- School board consulted and engaged
- Streamlined tendering process
- Involve local private sector partner.

AUBEA 2013

The 38th Australasian University Building Educators Association Conference

20 – 22 November 2013 | www.aubea2013.org.nz

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2.4 Dr Ricardo Mendoza: *Current built environment research at the University of Canterbury*

Current Built Environment Research at Canterbury

Dr. Ricardo Bello-Mendoza

Deputy Director of Postgraduate Studies
Department of Civil and Natural Resources Engineering
University of Canterbury

Built Environment Research at Canterbury

- Several Engineering (Mechanical, Electrical, Chemical & Process, etc.) and non-Engineering (Geological Science, Geography, etc.) Departments are involved in BE research, but the majority of BE research comes from Civil and Natural Resources Engineering (CNRE).

Civil and Natural Resources Engineering

- **CNRE main research disciplines:**

Geo-structures Cluster:

      Earthquake Engineering (Major contributor to BE research)

      Structural Engineering (Major)

      Geotechnical Engineering (Moderate)

      Fire Engineering (Moderate)

Transportation Engineering (Moderate)

Natural Resources Engineering (Moderate)

Construction Management (Minor)

Environmental Engineering (Minor)

Water Resources Engineering (Minor)

Built Environment Research from outside the Geo-Structures Cluster

- From the ground Up (Susan Krumdieck, Mechanical Engineering)
- Hydro-Eco Group (Tom Cochrane, Tonny de Vries, Brian Caruso, Aisling O'Sullivan)
- Transportation Group (Alan Nicholson, Glen Koorey, Mofreh Saleh, Tony Sze)
- Environmental Group (David Wareham, Mark Milke, Ian Mason, Ricardo Bello-Mendoza)
- Fire Group (Charles Fleischmann, Michael Spearpoint, Tony Abu)
- Fluid Group (Mark Davidson, Roger Nokes, Pedro Lee)

From the Ground Up

From the Ground Up

250 Year Design Perspective

It doesn't matter what your city's buildings look like if the city's infrastructure and activity systems cannot adapt to the future conditions:

- oil supply and resource limits
- contraction of consumer coal & gas
- limitations of alternative technologies
- the challenges of climate change

Decisions made today about infrastructure and locations and types of personal and social assets will determine the opportunities for prosperity from this point forward.

Sustainability

Today we have a perspective based on our history and experience. It is possible to engineer infrastructure and systems at all levels that can manage the delivery of essential goods, activities and services into the future. People today have profited from unsustainable practices. From the Ground Up takes responsibility for re-design and re-development to secure wellbeing and prosperity for posterity.

Transition Engineering

It doesn't matter if we have vision or good intentions if we can't achieve the changes we and our future city needs for prosperity. Transition Engineering designs the change projects with profitable developments and organisations that can carry out the re-developments and manage the new businesses, services and enterprises.

- Cooperative development model
- Synergies across scales
- Integrated complex systems approach
- Coherent stakeholder involvement

Performance

Access

Structures

Connections

Foundations

Needs & Drivers

Aesthetics

Built Environment

Passive Building	HVAC Design
Cultural Expression	Fenestration
Waste Water Management	
Building Materials	Building Design
Playgrounds	Fountains

Travel and Goods Movements

Population Density	Proximities
META Score	Infrastructure
Walking Distance	Travel Comfort
Travel Time to Destinations	
Energy & Technology	

Work, Education and Services

Employment	Retail
Entertainment	Schools, Training
Outdoor Activities	Religious Activities
Social Activities	Waste Management
Multiple Purpose Places	

Environment and Trade

Water	Ports, National Rail
Food	Productive Industry
Fuel	National Markets
Sun	Government
Shade	Services
Breeze/Wind	

Safety and Security

Seismic Stability	Flood Risk
Sea Level	Rock Fall
Fire Protection	Biosecurity

Cost Management, Benefit Multiplication, Cooperative Development

From the Ground Up (cont'd)
Designing the long term transition
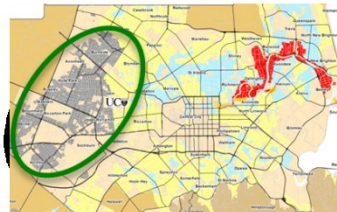
From the Ground Up (cont'd)

High Street Development

Plan for an optimal balance of housing, commerce, incomes and services
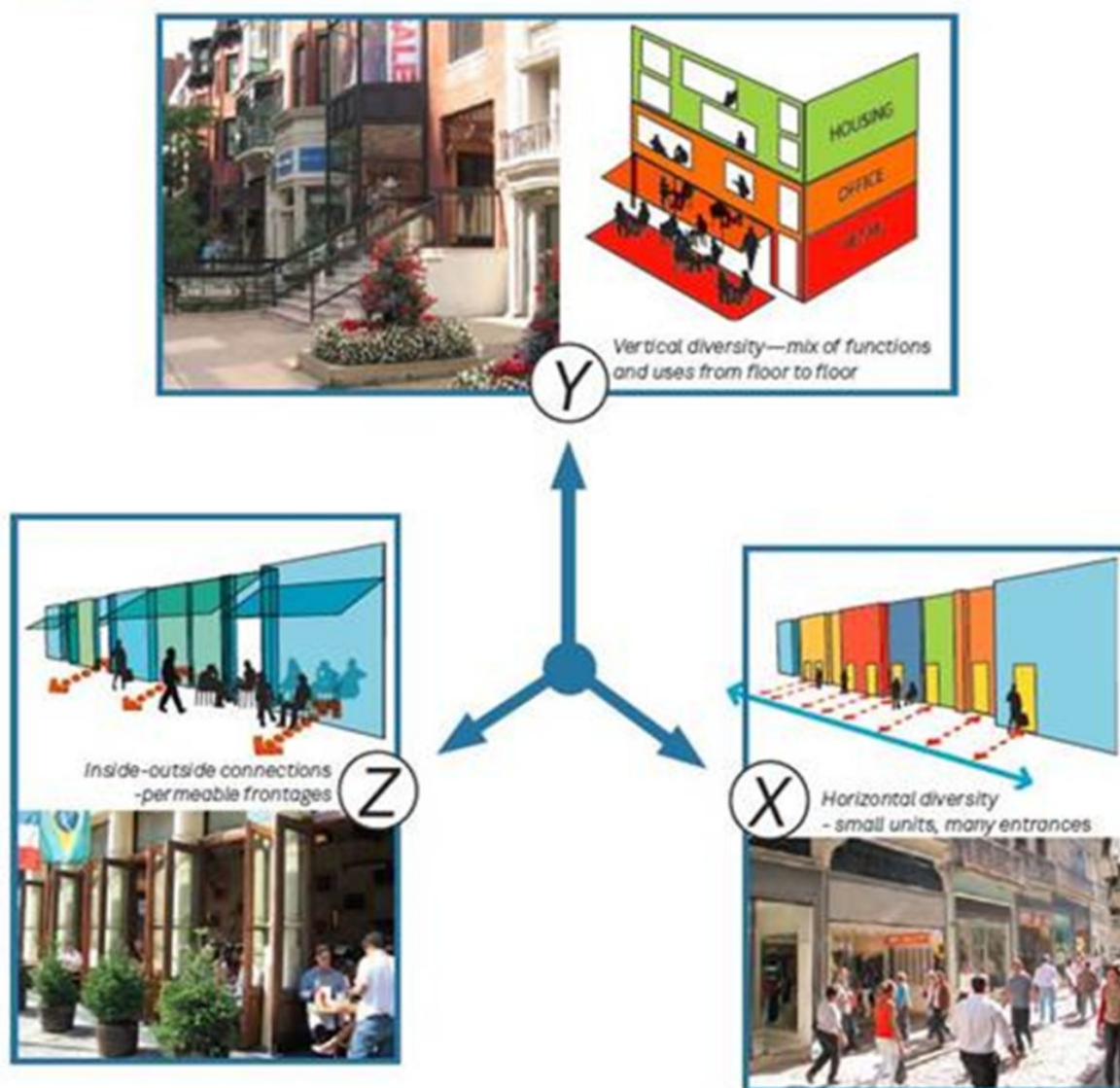
Hydro-Econ Engineering

Green roof technology – Impact on:

- Roof lifespan
- Building energy use
- Air filtration
- Aesthetics and amenity
- Green Roof future in Christchurch rebuild?

For Information contact Dr. Tonny de Vries tonny.devries@canterbury.ac.nz

Environmental Engineering

New Public Sanitation

- Analysis of different sanitations concepts:
  (1) centralised treatment,
  (2) source separation and on-site treatment of black water only, and
  (3) complete source-separation and on-site treatment of all waste streams.
- Objectives:
  a) to identify critical influencing factors, and
  b) to make a preliminary materials and energy analysis.
  Overall, the project will examine the feasibility of using source-separation decentralised sanitation in Christchurch.

For Information contact Dr. Ricardo Bello-Mendoza
ricardo.bellomendoza@canterbury.ac.nz

Transportation Engineering

Traffic and Safety:
- Traffic behaviour observations (including before/after implementation of treatments)
- Analysis of road, traffic and accident data using various computer software tools, to measure network performance

Transportation Planning:
- Estimate future travel demand (people and freight) using behavioural transport planning models
- Predicting the effects (social, economic, environmental, etc.) of transport policy, land use and transport network changes
- Transport infrastructure resilience

For Information contact Dr. Glen Koorey glen.koorey@canterbury.ac.nz

Transportation Engineering (cont'd)

Pavement Material Characterisations and Asset Management:
- UC utilises a world-class Transportation Laboratory equipped with top notch equipment to characterise bitumen, hot-mix asphalts, unbound granular materials

The research at UC covers different aspects of pavement performance and evaluation
- Fatigue behaviour evaluation & modelling
- Permanent deformation modelling of visco-elastic materials
- Sustainable pavement design techniques including recycling, foam bitumen stabilisation, and warm mix asphalt technology

For Information contact Dr. Mofreh Saleh
mofreh.saleh@canterbury.ac.nz

Fire Engineering

Fire Dynamics
- Modelling of compartment fire behaviour
- Application of zone and computational fluid dynamic models in building fires
- Combustion behaviour of different materials using TGA/DSC
- Measurement of wildfire severity
- Tunnel fire dynamics
- Smoke explosions and backdraft
- Performance-based fire codes

For Information contact Prof Charley Fleischmann
charley.fleischmann@canterbury.ac.nz

Fire Engineering (cont'd)

Fire Safety Systems
- Fire prevention and control measures in buildings and tunnels (sprinklers and ventilation, etc.)
- Fire and smoke detection
- Building evacuation modelling and human behaviour
- Uncertainty in fire safety system effectiveness
- Database management systems for storing and processing fire test data
- Fire risk analysis
- Building information modelling

For Information contact A/Prof Mike Spearpoint
michael.spearpoint@canterbury.ac.nz

Fire Engineering (cont'd)

Fire performance of materials and structures
- Fire performance of precast pre-stressed concrete floor systems
- Charring rate of timber
- Fire performance of post–tensioned timber structures
- Fire performance of timber-concrete composites structures
- Fire performance of steel-concrete composite structures

Probabilistic Structural Fire Engineering
- Quantification of fire hazard
- Incremental fire analysis

For Information contact Dr. Tony Abu tony.abu@canterbury.ac.nz

Geo-Structures Cluster at UC

Expertise
- **Engineering seismology**: Bradley
- **Geotechnical engineering**: Cubrinovski, Haskell
- **Engineering materials**: Scott
- **Structural control**: Chase, MacRae
- **Advanced structural analysis**: Lee, Dhakal
- **Retrofit options**: Pampanin, Bull
- **Low damage building systems**: Pampanin, Dhakal, MacRae
- **Risk/loss assessment**: Dhakal, MacRae, Bradley, Giovinazzi

Research Questions

- **What are the likely hazards our built environment is likely to be subjected to? How can they be quantified reliably? (Demand assessment)**
- **How vulnerable are our built environment to these hazards? (Capacity/performance assessment)**
- **How can we use what we have learnt to improve our engineering practice? (Research-practice nexus)**
- **How can we improve resilience of our existing built environment? (Retrofit)**
- **How can we design and build more resilient/sustainable structures in future? (Low damage/loss systems)**

Areas of Current Research

Seismology
- Ground motion prediction
- Attenuation relationships
- Site specific seismic hazard analysis
- Vertical acceleration effect

Geotechnical Engineering

- Slope stability
- Debris flow
- Liquefaction
- Lateral spreading
- Foundation

Areas of Current Research (cont'd)

Materials
- Fresh concrete
- Corrosion of reinforcing bars
- High performance concrete (HSC, SCC, FRC)

Seismic Performance/ Design of Buildings
- Soil/site effect
- Building irregularity
- Soil structure interaction
- Building specific seismic loss assessment
- Performance of non-structural components and contents.

Areas of Current Research (cont'd)

Steel and Composite Structures
- Composite floor slabs under gravity loading
- Slab effects on steel moment frames
- Low damage steel connections (sliding hinge)
- Low damage bases

Lifelines
- Underground pipe network (damage detection and mitigation technique)
- Accelerated bridge construction and design
- Low damage bridge systems.

Reinforced Concrete Buildings
- Improved design of structural walls
- Residual capacity of damaged buildings
- Repair options of damaged RC buildings
- RC frame floor interaction
- Beam elongation effects

Timber Structures
- Post-tensioned timber building systems
- Glulam
- Laminated Veneer Lumber (LVL)
- Timber concrete composites.

Earthquake Engineering

- Improved seismic hazard modelling
- Mitigation measures for soil liquefaction and lateral spreading
- Innovative building materials
- Low damage building systems for future
- Retrofit technologies for existing buildings
- Residual capacity and repair techniques of damaged RC buildings
- Damage resistant non-structural systems
- Assessment of contents damage in earthquakes
- Loss based design (Loss Optimisation Seismic Design, LOSD)

For Information contact Dr. Brendon Bradley
brendon.bradley@canterbury.ac.nz

Recently completed research projects

- 2008-2013 (UC/UA/UTS Consortia)
- Vision: Earthquake resistant multi-storey timber building systems
- Precast RC building concept to be used
- Use of LVL (Laminated Veneer Lumber)
- A company has been established for this: STIC (Structural Timber Innovation Company)
- Buchanan, Pampanin.
- Energy and Comfort Design Tool for Concrete Homes (CCANZ)
  01 September 2007 to 31 December 2011, $100,000 (Carr)
- Geotechnical & Engineering Geological Characterisation of Christchurch Soils (ECAN)
  1 June 2009 to 31 October 2012, $75,000 (Cubrinovski)
- Seismic Behaviour of Structural Connections with Post-Installed Rebars
  1 October 2009 to 31 December 2013, $77,000 (Pampanin)
- Pile-Group Effects in Liquefying Soils 10/590 (Earthquake Commission)
  1 April 2010 to 31 March 2012, $40000 (Cubrinovski)
- Assessment & Mitigation of South Island Geological Hazards (Earthquake Commission)
  1 April 2010 to 31 March 2013, $75000 (Cubrinovski).
- Energy and Comfort Design Tool for Concrete Homes (CCANZ)
  01 September 2007 to 31 December 2011, $100,000 (Carr)
- Geotechnical & Engineering Geological Characterisation of Christchurch Soils (ECAN)
  1 June 2009 to 31 October 2012, $75,000 (Cubrinovski)
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- Pile-Group Effects in Liquefying Soils 10/590 (Earthquake Commission)
  1 April 2010 to 31 March 2012, $40000 (Cubrinovski)
- Assessment & Mitigation of South Island Geological Hazards (Earthquake Commission)
  1 April 2010 to 31 March 2013, $75000 (Cubrinovski).

Recently completed research projects (cont'd)

- To Determine the Cost of Construction of Commercial Multi-Storey
  1 March 2010 to 30 June 2011, $150,000 (Buchanan)
- Seismic Behaviour of High Strength Self-Compacting Concrete Beam
  1 July 2010 to 28 February 2014, $60,000 (Dhakal)
- Non-Structural Elements in Building Seismic Performance
  1 April 2010 to 30 September 2011, $325,000 (McRae)
- Liquefaction Hazard Investigations in Residential Areas of Greater Christchurch, 1 March 2011 to 28 February 2014, $45,000 (Cubrinovski).
- Short Term Recovery Projects for the Canterbury Earthquakes (GNS Science), 1 March 2011 to 30 November 2011, $780,000 (Pampanin and others.
- Seismic Site Response Analysis of Soil Sites During the Christchurch Earthquakes 12/631 (Earthquake Commission)
  1 April 2012 to 30 Sept 2013, $42,000 (Bradley)
- Strong Motion Analysis of the Canterbury Earthquakes in the Near Source Region
  1 April 2012 to 30 Sept 2013, $35,000 (Bradley)
- Residual Capacity and Repairing Options (GNS Science)
  1 April 2012 to 31 December 2014, $450,000 (Pampanin)

Ongoing Research Projects

SAFER (Significant Advances for Earthquake Resistance) Concrete Technology:
- Design of structural walls
- Design of floor diaphragms
- Catering for beam elongation
- Safer Staircases
- Residual capacity of damaged RC structures
- Repair options for damaged RC buildings

[For Information contact Prof Stefano Pampanin
stefano.pampanin@canterbury.ac.nz]

Earthquake resistant non-structural building elements and contents
- Design of suspended ceilings
- Earthquake resistant ceiling systems
- Low-damage partition walls
- Earthquake resistant facades
- Vulnerability assessment of contents damage
- Seismic loss assessment

 [For Information contact Prof Rajesh Dhakal rajesh.dhakal@canterbury.ac.nz
]

- Retrofit Solutions for NZ's Earthquake Risk Multi-storey Buildings
  July 2004 to June 2015, $2.9m (Pampanin)
- Advanced Bridge Construction and Design for NZ (GNS Science)
  1 October 2011 to 30 September 2015, $617,000 (Palermo)
- Composite Solutions (GNS Science)
  1 July 2011 to 30 June 2015, $617,000 (McRae)
- Improved Seismic Performance of Non-Structural Elements & Contents (GNS Science)
  1 July 2011 to 30 June 2015, $617,500 (Dhakal)
- Lessons Learned from Christchurch (GNS Science - Natural Hazards Platform)
  1 October 2012 to 30 September 2015, $256,000 (Bradley)

Ongoing Research Projects (cont'd)

- The Impacts of Soil Liquefaction - Geotechnical Evaluations & Design (GNS Science - Natural Hazards Platform)
  1 July 2012 to 30 June 2015, $726,000 (Cubrinovski)
- Examining the Role of 3D NonLinear Local Site Effects in the Canterbury Earthquake (Earthquake Commission EQC)
  1 May 2013 to 30 April 2015, $60,000 (Bradley)
- SAFER Structures: Safer Reinforced Concrete Structures In
  1 July 2012 to 30 September 2015, $480,000 (Pampanin)
- Implementation Pathway for Performance Based Design in New Zealand
  1 July 2012 to 30 June 2105, $180,000 (Dhakal).
- Development of Optimal Performance Based Passive Control Strategies
  1 October 2013 to 30 September 2016, $63,000 (Dhakal)
- Earth-Shattering Detective Work: Uncovering the Mysteries of Unresolved Ground Motion
  1 January 2014 to 31 December 2018, $800,000 (Bradley)
- Hybrid Broadband Simulation of Ground Motions from the Canterbury
  1 March 2014 to 30 September 2015, $43,000 (Bradley)
- 3-Dimensional and Non-linear Local Site Effects in the Canterbury
  1 March 2014 to 30 September 2015, $43,000 (Bradley)
- A Liquefiable Bowl of Jelly: Understanding the Seismic Response
  1 March 2014 to 28 February 2017, $300,000 (Bradley)

Postgraduate Studies at UC

- Certificate of Proficiency (COP): Single courses
- Post Graduate Certificate in Engineering (PGCertEng) : Courses only (60 points)
- Master of Engineering Studies (MEngSt): 1 year of coursework providing expertise in your area of choice. May be endorsed in "Civil", "Construction Management", "Earthquake Engineering" and "Transportation".
- Master of Engineering (ME): 45 points (0.375 EFTS) coursework and 1.0 EFTS thesis. See endorsements above.
  Specialist masters degrees: Fire: MEFE, Transportation: MET, Management: MEM.
- PhD in Civil Engineering

2.5 Current built environment research at the University of Otago

Unfortunately, the representative from the University of Otago could not make the symposium. However, Professor Robyn Phipps was able to provide an overview of the current built environment at Otago. Being part of the Wellington-based Healthy Housing Research team, Professor Phipp's overview focused on the recently completed and on-going research that formed part of the group's work.

Details of the research projects could be viewed in Dr Michael Keall's presentation at the 2nd NZBERS held on 15 November 2012 (see *Health and Safety Implications of Improved Housing Quality*).

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2.6 Current built environment research at Unitec

BUILT ENVIRONMENT RESEARCH AT THE UNITEC FACULTY OF TECHNOLOGY & BUILT ENVIRONMENT

Associate Professor Linda Kestle

Chair, Faculty Research Committee
Faculty of Technology and Built Environment

Built Environment Research Team
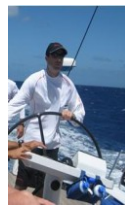
Dr Linda Kestle and Dr Regan Potangaroa
 4th International Conference on Building Resilience. Sept 8-11.UK. 2014 . Paper 151

Are we listening? Are we learning?

The objective of the paper was to review the potential short-comings of the Auckland and Unitary Plan for Auckland with respect to 'disaster preparedness and response', based on lessons from the Christchurch earthquake experiences, but also in response to the key points on the 'Resilient Cities Framework'(RCF) checklist.

So, the question posed was "whether we are really listening or learning, or not, as the 30 year Auckland Plan, and Auckland's Unitary Plan are rolled out? "

Conclusions

- The Unitary Plan for Auckland is sadly lacking as a tool to ensure Auckland's business and residential sectors can be relocated, and/or accommodated seamlessly when large scale natural disasters strike Auckland.
- No mention is made of a budgeted disaster plan, or a hazard data-base being updated and maintained, nor are realistic or pertinent risk compliant building regulations included.
- No mention or recognition of how and where rebuilds, relocations of businesses will/could be addressed and catered for in a disaster recovery plan, nor is there any sense in the 30 year plan of the need for the involvement of the relevant community organisations in the planning and implementation process.
- This despite the fact that almost half of NZs population live and work in Auckland city, and Auckland is where a very significant proportion of New Zealand's GDP is created.

Prepared by: Jonathan Leaver
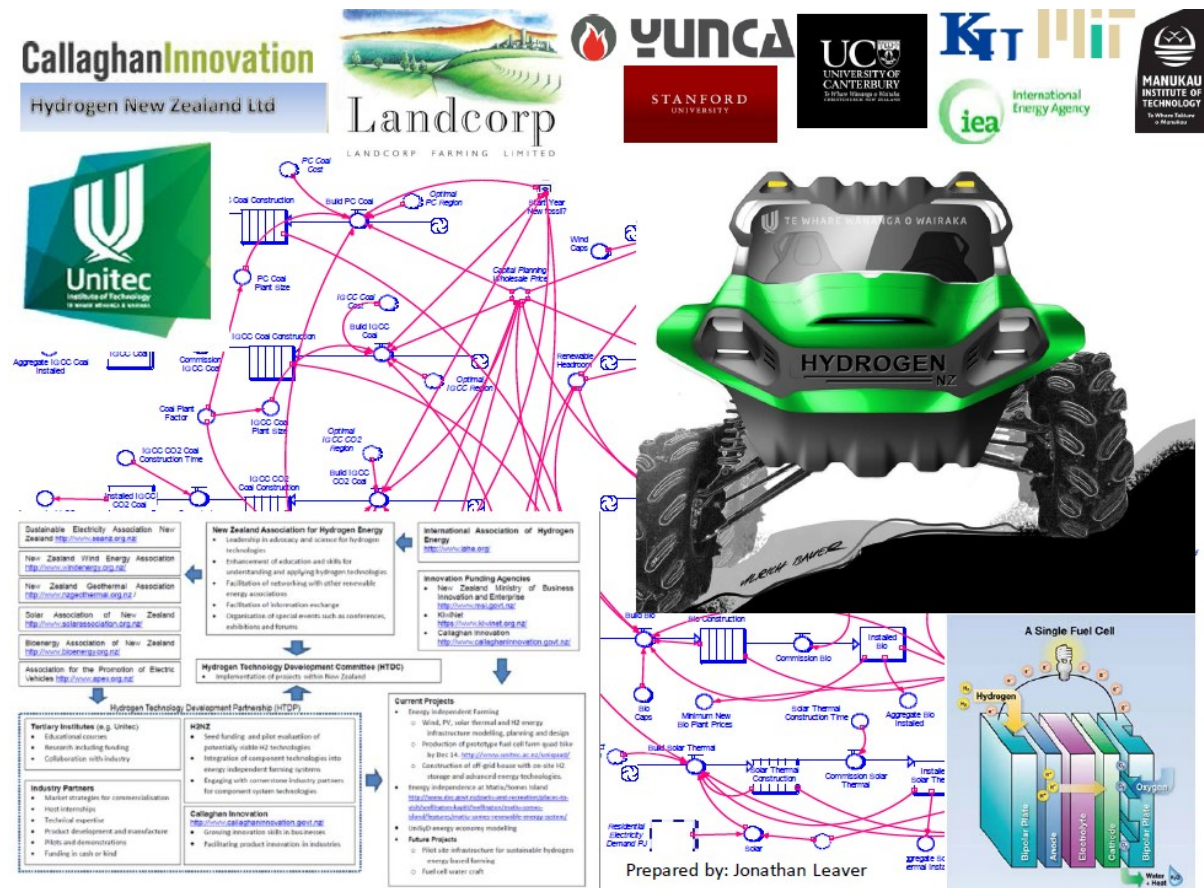
Facts about water

Water boils at:

- o **100o C at sea level**
- o **69oC on Mt Everest**
- o **107oC at a 3.0m head of water (under pressure**

Latent ('hidden') heat

- o **When water reaches boiling point a lot of additional energy is required to turn it to steam (change state). This additional energy does not contribute to a rise in temperature.**

Thermosiphon

Passive heat exchange based on natural convection

- **Gravity acts on dense (cool) water drawing it downwards and displacing less dense (warmer) water effectively pushing it upwards**

- **The '*hot air rises*' affect**

Wetback Project

Tests were done with multiple configurations, and the data was able to be compared

Typical direct system configuration
- Garry Cruickshank/Don Mardle

Indirect system – conventional Wetback plumbing

Indirect system – 'counterflow' Wetback plumbing.

We were then able to directly compare the performances under a wide variety of configurations.
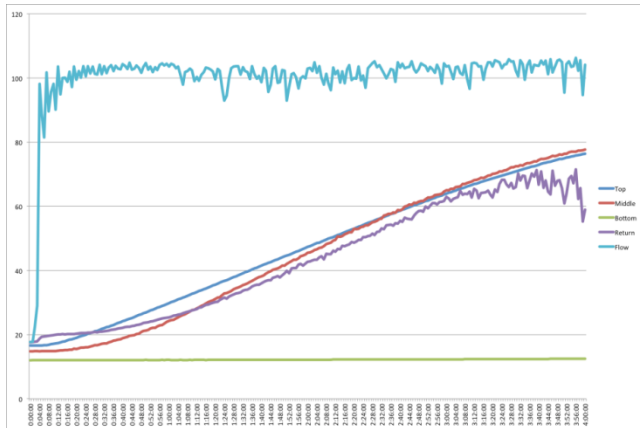
Indirect mid-coil; return pipe falling
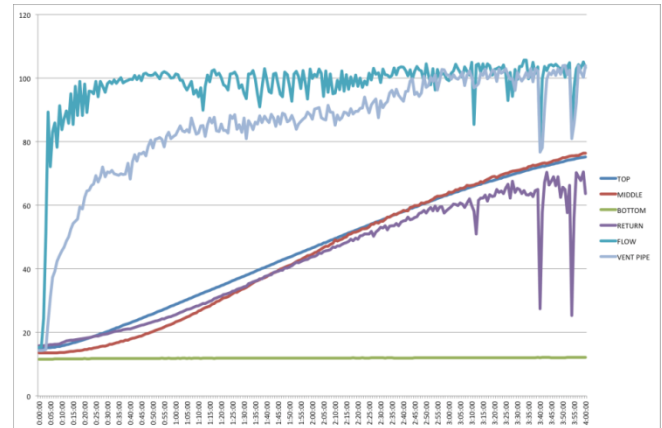
Indirect mid-coil; return pipe rising

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Waste Not, Want Not: Education for Sustainability in the Construction Industry - BBNZ Conference Sept 2014.
Daniel Fuemana - Head of Department Building Technology

Employment growth in the Auckland C&I sector

Auckland has the largest share of forecast levels of growth for the C&I in NZ. Auckland's construction sector is predicted to grow from 8.2 billion dollars in 2013/2014 to 11.8 billion dollars in 2018/19 and 12.2 billion by 2023 (48% higher than 2013/14).

 The workforce in the Auckland construction sector is anticipated to increase at an annual rate of 4.8% per year between 2013-2018, higher than national growth forecasts for employment in this sector.

It is therefore essential that the future students (the participants) join the profession with a deep awareness of the importance of sustainability already embedded as part of their psyche.

Methodology of the case study

- investigate the various categories of waste the participants identified, and investigate options available to re- or up-cycling for all of the products
- participate in a questionnaire that was designed to discover to what, if any, extent the participants' understanding of waste management had been transformed by this process.
- this process in turn would encourage transformational thinking. Their critical analysis via the online forum, in conjunction with the results of the questionnaire.

Findings

Four main themes emerged from the questionnaire evaluation and their responses were examined in parallel with the forum responses made by the different groups after their exposure to the waste. These were:

1. Real World Waste
2. Waste management in industry
3. Money matters
4. Students' perceptions of the activity's value

disappointment seeing waste not properly grouped
   "waste material sorting method wasn't appropriate or correctly sorted" and
   "people did not classify waste material very well"
… students starting to critically evaluate waste recycling
   *"students are mixing all the waste together which is very hazards'[sic]
   because most of the waste are flammable and easy to catch the fire.
   Moreover the containers are uncovered and not made for collect most of
the waste. In addition the safety topics are not covered in this area."*
… saw the importance of planning to reduce waste
   "planning ahead of project saves material wastage
… educating the community to be aware of recycle
   "educating people"

The impact of an innovative construction system on residential internal environments

Collaborative Research in the FTBE with Robert Tait, Andy Pivac, Roger Birchmore & Kathryn Davies

What are we doing?

Using 'control' and 'test' houses to monitor the seasonal performance. (Air temp, Dew Point, RH)

Monitoring the actual seasonal performance of particular components (The innovative wall construction)

Trying to get a computer simulation to replicate the actual results

Use the ratified simulation to try out other improvements

Test the best ones on complete houses

1. What changes can be made to a conventional NZ house design to improve:
   a. energy efficiency
   b. thermal comfort
   c. and eventually sustainability?
2. Identify impacts on the construction process
3. Produce learning resource material
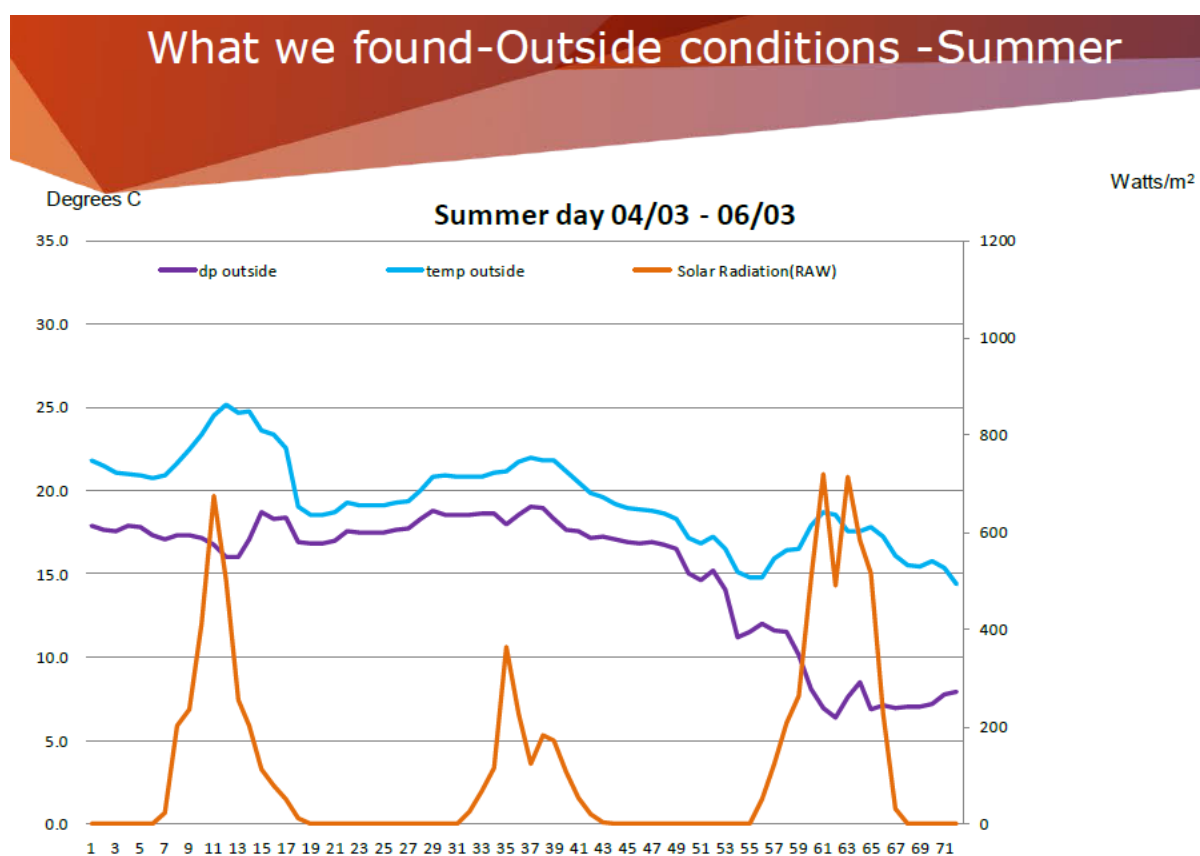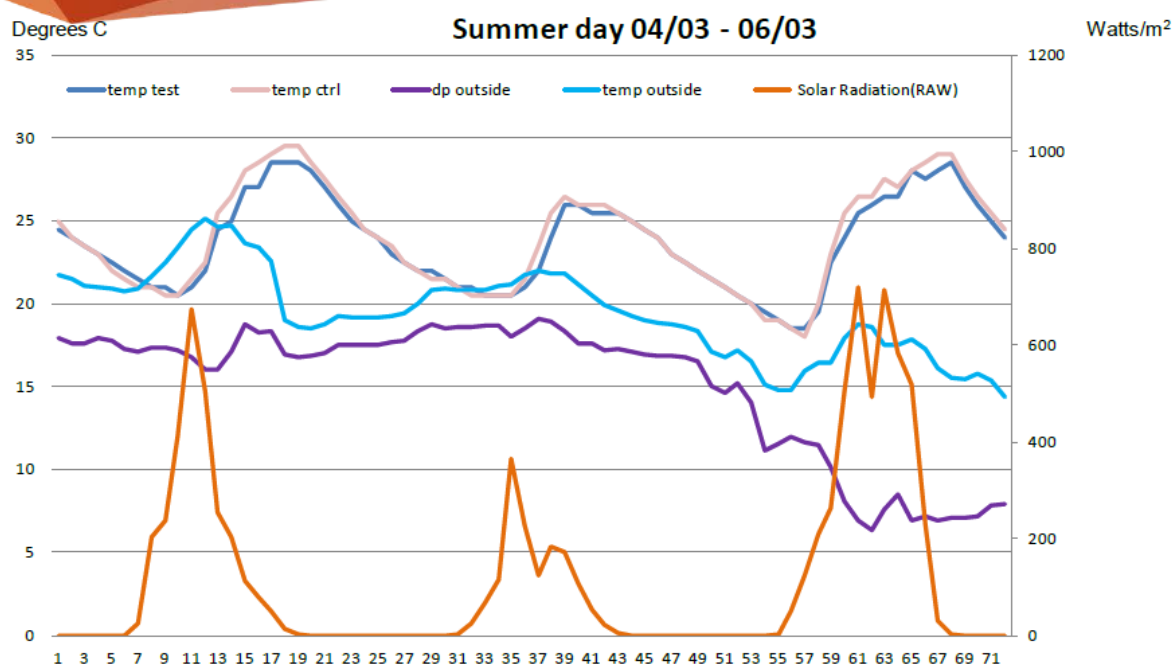
Results summary

The Wrap appears to be performing as expected
By keeping moisture out of the structure in winter
(higher internal moisture levels)
By allowing moisture though the structure in summer
(higher internal moisture levels)

The internal dew points seem to follow the internal air
temperatures, not the external dew point.

The daily variation in dew point equates to about 0.5 litre of water evaporating then being re-absorbed.

Questions still to be answered

Where is the moisture coming from and going to ?

Will internal generation of moisture increase the differences between Control and Test Houses?

What is happening interstitially in the wall?

Why is there not a larger difference of internal temperature difference between Control and Test Houses in winter?

Robert Shaw
Shaw 12 metre Blink
1st on line Brothers race
Cook Strait NZ
October 2014
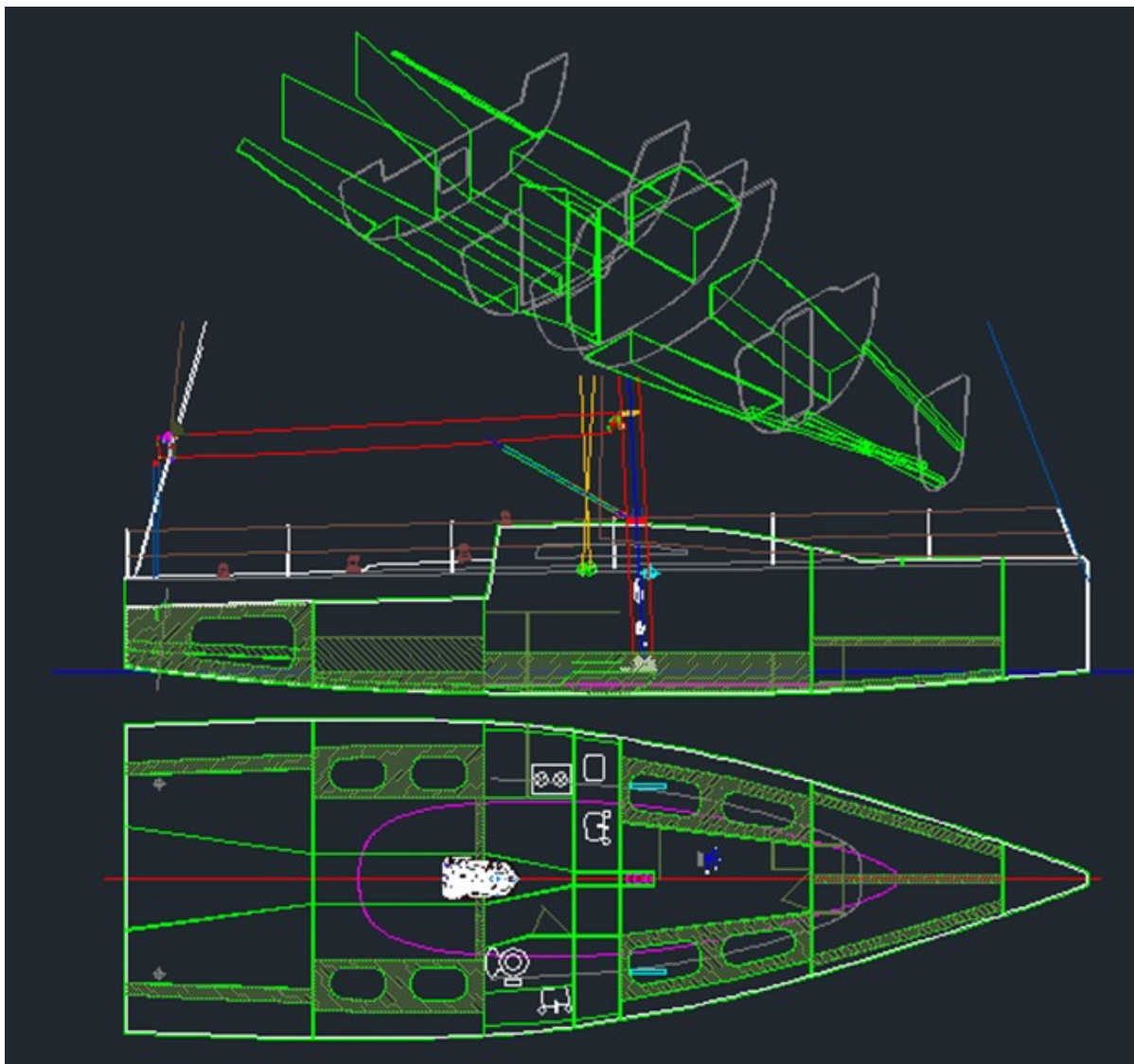
Robert Shaw

Shaw 12 Metre performance yacht

Construction overview

Features, full carbon construction, 50 degree canting keel, twin asymmetric dagger boards, twin rudders, High modulus carbon mast with carbon rod rigging

2013

BIM et al

BIM research publications this year have, for example, been in the area of 5D BIMQS by Harrisson, Stanley and Thurnell (2014) and currently in the areas of BIM education at the undergrad level

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2.7 Dr Fabricio Chicca: *Current built environment research at Victoria University*

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

VICTORIA
UNIVERSITY OF WELLINGTON

PRESENTATION

BY

DR FABRICIO CHICCA

DIRECTOR

BUILDING SCIENCE PROGRAMME

VICTORIA UNIVERSITY

School of Architecture Research Stream s

Settling Our Regional Landscape	**Ecologies Lab: Urbanism, Infrastructure, Housing, Life**	**Parametric Design and Digital Agency**
Responsive Environments and Robotics	**Housing and Public Infrastructure**	**Contemporary Workplaces/ Corporate Spheres**
Reflections of the Future	**Building Technologies and Materials**	**People and Designed Environments**
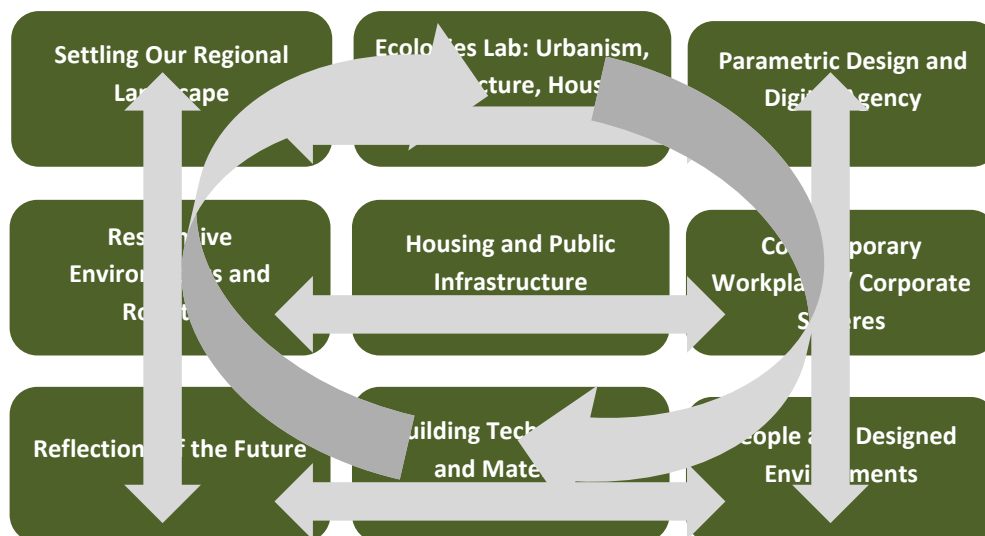
Reflections of the future

- Re-appropriating waste materials
- Re-working project management techniques to foster self-build and incremental build.
- Changing work processes to suite resources.
- Using BIM as an interactive community tool.
- Communal energy production.
- New forms of communal food production and distribution.
- Regenerative urban design.
- Ecosystem services and urban design.
- Biomimicry and ecology.
- Climate change and biodiversity loss in relation to the built environment.
- Biophillia and wellbeing.
- Social justice issues in relation to architectural design.

People and Designed Environments/ Housing and Public Infrastructure

- Retrofitting thermal mass into New Zealand houses:
  - What are the potential benefits?
    - Aiming to understand the benefit to cost characteristics of thermal mass introduced into timber framed houses.
- Life cycle cost comparisons:
  - Precast concrete claddings and lightweight cladding systems:
    - Aiming to understand the benefit to cost characteristics of precast cladding systems in New Zealand.

History and Theory

- History of the technology of NZ house:
  - Exploring origins from subfloor to roof:
    - Hollow concrete blocks 1904 – 1910 & beyond.
    - Changes in construction & structure.
  - Thermal performance of buildings (historic & current):
    - Building science & building warrant of fitness.
  - Common failures in NZ houses.
  - Building pathology based on 70 house inspections.
  - Hempcrete (visiting Czech student).
  - Water & energy use in offices (HEEP & BEES).
    - Improving understanding of end-uses.
    - Developing tools to assist occupants/ owners.

Reflections of the Future/ People and Designed Environments

- Performance of Wellington's Green Star Rated Buildings:
    o Research projects regarding performance, following previous summer research 2012/2013.
    o Nine selected Green Star Office Design rated buildings in the Wellington region; names are confidential.
    o Focus on energy and water consumption.

Comparison of Green Star Base Building Energy Consumption Predictions and Actual Energy Consumption of Wellington Green Star Rated Buildings
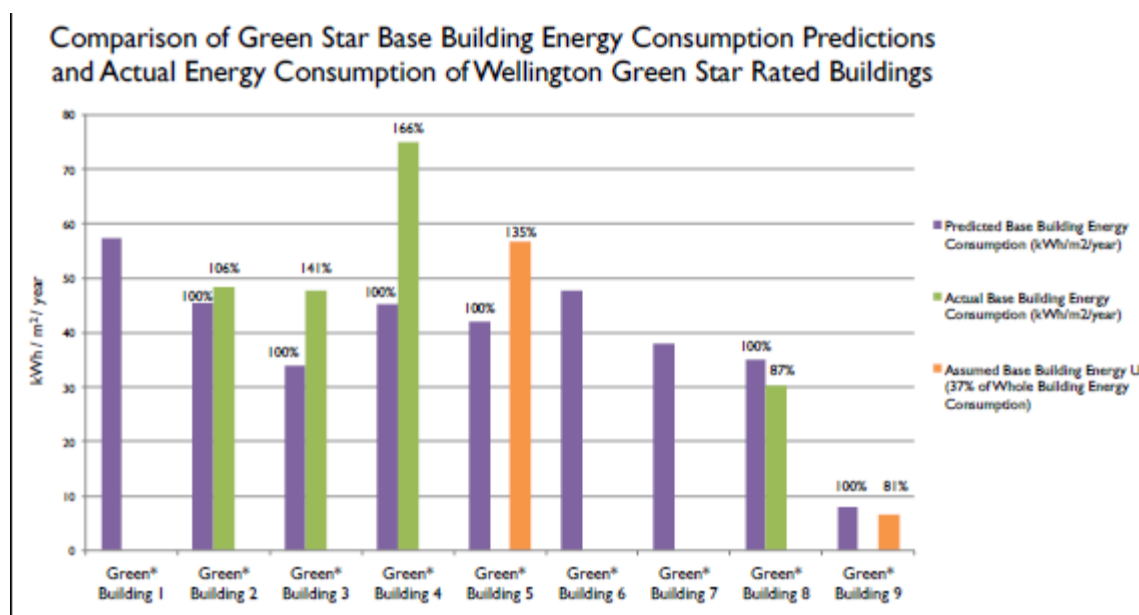
- Energy Efficiency vs Energy Conservation:
  o Energy efficiency and Rebound effects.
  o Does energy efficiency save energy?
  o Life cycle analysis.
  o Embodied energy of new buildings versus retrofitting.

Comparision of Wellington Green Star Base Building Energy Consumption Predictions with Actual Energy Consumption and the Existing Building Stock
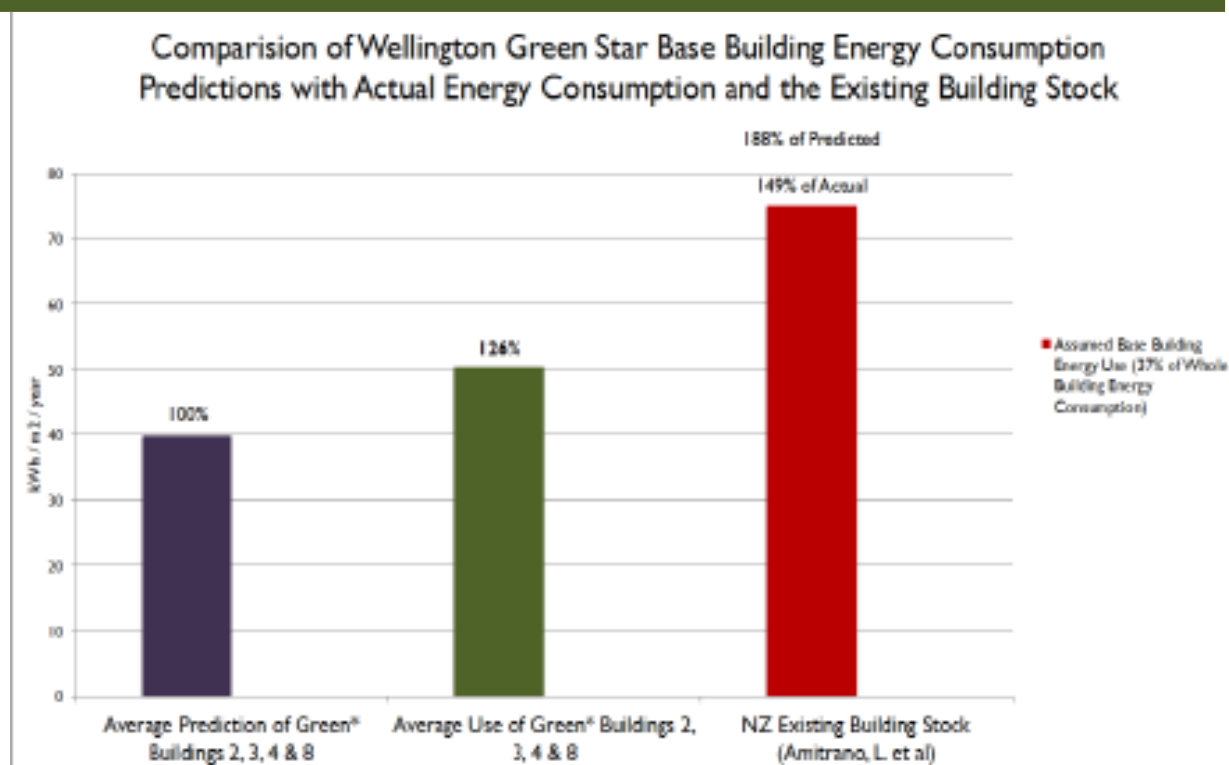
- Designing sustainable regions
  o Food production in urban areas.
  o Public transportation and food production in urban areas
    - share use.

For further details, visit http://www.victoria.ac.nz/architecture/design-research

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SECTION III

EXTENDED ABSTRACTS OF RESEARCH WORKS-IN-PROGRESS AT THE UNIVERSITIES

3.1 AUCKLAND UNIVERSITY OF TECHNOLOGY (AUT)

DANANJOYO, R.

Developing World Class Service Quality for the Indonesian Construction Supply Chain Industry

DEVELOPING WORLD CLASS SERVICE QUALITY FOR THE INDONESIAN CONSTRUCTION SUPPLY CHAIN INDUSTRY

Radyan Dananjoyo
Engineering Project Management, School of Engineering, AUT

ABSTRACT

Key Question / Hypothesis / Problem or Issue(s) to be Investigated:

The critical problem to be addressed is the current poor level of performance in the Indonesian construction sector in terms of materials delivery. Excessive cost and waste is incorporated into the Indonesian construction industry as a result of the systemic wastage created by its supply system. Construction projects are significantly delayed as a result of poor predictability and deliverability, all of which originate in the capability of the supply chain in Indonesia. In order to improve the overall performance of the Indonesian construction sector, and thus to achieve 'world class' performance levels, the construction materials supply chain similarly needs to achieve world class performance levels. Without a high performance supply chain, the Indonesian construction industry will never be able to deliver on the expectations of society. In order to address this problem it will be necessary to answer the following questions:

1. What constitutes high quality service for the construction sector?

2. What constitutes current customer expectations in the Indonesian construction market?

3. What are the key metrics defining effective supply performance in Indonesia?

4. What are the critical areas that need to be improved in the construction materials supply sector in order to increase overall performance in the Indonesian construction industry to 'world class' standard?

5. What does the implementation framework look like that would be necessary to transition the current Indonesian construction materials supply sector to achieve a world class level of performance?

Rationale and Significance of the Study (with references):

Construction and house building is an essential component of any developed society. Property and real estate is essential in order to provide places to live in and spaces in which to work. Construction is therefore a key social and economic facilitator of society development. As a developing country, the economic and social importance of the construction sector is even greater. The construction sector has to provide the infrastructure for housing a growing population that has increasing expectations in terms of quality of life. At the

same time the Indonesian economy is rapidly growing and in need of new infrastructure. According to Chief of Indonesian Central Statistics Bureau, the total Indonesian citizenry reached 240 million people with 61 million households. Around 78 percent of Indonesian population is in 'liveable' property, however the remainder of the population (approximately 22%) are living in illegal, temporary and/or informal developments (Central Statistics Bureau, 2012). Teguh Satria, Chairman of Real Estate Indonesia, said that Indonesia needs to build 2.6 million houses each year to cover all society (Detik Finance, 16-02-2012). In essence the construction and property industry, particularly in the housing sector, has a huge level of expectations on its shoulders. Demand for housing is constrained by low and insecure incomes, a weak financial sector, high interest rates, the elimination of housing subsidies and high neighborhood risks which hinder investments in housing. These circumstances make it very difficult for the construction industry to be funded sufficiently to be able to deliver on societal expectations in terms of housing and other property.

There are numerous bottlenecks in the supply systems for housing, particularly the supply of serviced land and a lack of private housing finance. These could be alleviated by well-designed and targeted government policies and programmes. Accessibility of affordable housing for low income families is the critical housing problems in Indonesia. This is a problem recognized by both the researcher and the Indonesian government. Consequently it is the principle requirement of this study to address the particular needs of the house building sector – although it is recognized that the Indonesian construction industry as a whole has significant opportunities to improve.

As a principle stakeholder in the Indonesian house building industry, the building material supply sector has a major contribution to make

in the fulfillment of the housing needs for Indonesian citizens. Usually building material suppliers are strong product focused – particularly in terms of unit price. As a result of this myopic view, service orientation is poor. Thus such measures as 'on time in full' delivery, reliability, traceability and other quality measures are largely downplayed or ignored.   In short price to customer is everything; other non-price attributes are ignored.   However elsewhere in the world, whilst price to customer is import, the concept of non-price, service driven attributes are gaining ground rapidly in the construction sector.   This is a key area in which the Indonesian construction material supply sector can develop in terms of its performance.

Quality is an important and growing feature of all industry, and is rapidly developing in construction supplier performance metrics. (Zahari et al., 2008). It is the extent to which a service meets or exceeds customer needs and expectations (Lewise and Mitchell, 1990; Dotchin and Oakland, 1994a; Asubonteng et al., 1996: Wisniewiski and Donnelly, 1996; Seilier, 2004; Zahari et al., 2008). Indonesia now stands at the cusp of a period of dramatic growth in the construction sector that will be facilitated by the establishment of a customer centric culture.   In order to achieve this transformation in the Indonesia construction materials supply sector, it is essential to establish mechanisms for companies to measure and evaluate the quality of service encounters (Brown and Bitner, 2007) and thus to improve overall service performance in the Indonesian construction sector.

Design of the Study:

It is anticipated that the research project will undertake a triangulation approach.   The primary data source is anticipated to consist of a combination of both a questionnaire administered in Indonesia alongside a series of

interviews conducted with leading members of the Indonesian construction industry. It is further expected that interviews will be conducted with both client bodies and contractors in order to establish the operational requirements and expectations that a 'world class' materials supply industry for the construction sector would consist of. Quantitative research will be used to measure the gap between retailer's perspective of service and customer's perception. In general the research process adopted by the study could be seen as:

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┌────────────────────┐   ┌────────────────────┐   ┌────────────────────┐   ┌────────────────────┐
│ Exploratory study  │   │ Use questionnaire  │   │ Undertake          │   │ Quantitative       │
│ to gain specific   │──▶│ template for       │──▶│ interviews to      │──▶│ Analysis           │
│ information of      │   │ SERVQUAL           │   │ develop            │   │                    │
│ building material   │   │ Analysis           │   │ qualitative data   │   │ Qualitative        │
│ supplier            │   │                    │   │                    │   │ analysis           │
│                     │   │                    │   │ Test variable of   │   │                    │
│                     │   │                    │   │ questionnaire.     │   │                    │
└────────────────────┘   └────────────────────┘   └────────────────────┘   └────────────────────┘
                                                                                     │
                         ┌────────────────────┐   ┌────────────────────┐            ▼
                         │ Development of      │   │ Development advice │
                         │ framework for       │◀──│ to government and  │
                         │ industry transition │   │ educational        │
                         │ to 'world class'    │   │ suppliers          │
                         └────────────────────┘   └────────────────────┘
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According to Parasuraman, Berry, Zeitham, there are five dimensions to characterize customer perception of service quality, consist of: tangibles, responsiveness, assurance, and empathy (Van Ree, 2009:47). This position is anticipated to inform the research questions developed. However at this stage, the work cited is only a starting position and this is anticipated to evolve as the student's understanding of the general conception of 'world class' performance meets the development of an understanding of current Indonesian experience and expectation. For the principle quantitative aspect of this study it is expected that the work of Zahari et al (2008) will be informative in the creation and analysis of the dimension of service performance for construction materials suppliers in Indonesia. There is also an anticipation of the need for a qualitative research instrument to be developed as a means of developing more contextual information regarding the current behavior of both purchaser, contractors and suppliers. It is expected that the fundamental work of Zsidisin, Panelli and Upton (2000) and Sitkins and Weingart (1995) will be helpful in the development of appropriate qualitative tools for the investigation of the behaviours of stakeholders in the supply chian process.

Research Benefits

The intention of the study is to ultimately develop a model for world class service provision in the construction materials supply chain in Indonesia. The creation of this model will facilitate the development of a transition plan to develop current Indonesian construction material supplier performance up to the point of achieving 'world class' performance. It is anticipated that this transition plan will

incorporate policy advisory material for construction industry decision makers in Indonesia as well as recommendations for training and educational metrics for educational providers in the Indonesian context. It is also expected that procurement, supplier selection criteria and supply chain management best practice advice for Indonesian government, clients, contractors and subcontractors will also be critical outcomes. The combination of these outcomes is expected to be highly significant for the Indonesian construction industry as a whole and the materials supply industry in particular since at present such research has not been conducted. Also at the time of writing the level of scholarship and understanding within the construction management arena in Indonesia is of a low order. As such this study will have significant impact for both the student and academic organization.

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GHAFFARIANHOSEINI1, A; TOOKEY, J. and GHAFFARIANHOSEINI, A.H

Application of nD BIM Integrated Knowledge-based Building Management System (BIM-IKBMS) for Inspecting the Post-Construction Energy Efficiency

APPLICATION OF ND BIM INTEGRATED KNOWLEDGE-BASED BUILDING MANAGEMENT SYSTEM (BIM-IKBMS) FOR INSPECTING THE POST-CONSTRUCTION ENERGY EFFICIENCY

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ABSTRACT

The evolution of construction industry towards sustainability highlighted the absolute necessity to inspect sustainable performances throughout the post-construction building lifecycle. Correspondingly, application of relevant building management systems (BMS) to achieve this goal is mandatory (Ippolito, Riva Sanseverino, & Zizzo, 2014). In addition, conventional post-construction building inspection methods are outdated and less effective. Therefore; this research aims to propose specific utilization of BIM during building maintenance for the consequential post-construction energy efficiency.

Contemporarily, Building Information Modelling (BIM) is considered as a leading technology capable of being utilized in Architecture, Engineering, Construction (AEC) practices highlighting its critical role in enhancing the effectiveness of project delivery from conceptual initiation to eventualization and even post-construction maintenance (Ding, Zhou, & Akinci, 2014; Volk, Stengel, & Schultmann, 2014). Alternatively, despite the

recent presentation of BIM to the AEC industry, it has widely emerged to an undisputedly contributive technology towards advancement of AEC implementations. Furthermore, BIM's capability of nD project integrations has prominently highlighted its potential effectiveness while being accurately incorporated with sustainable performances (Farr, Piroozfar, & Robinson, 2014). Moreover, researchers have highlighted that information gathering and modelling through BIM can reduce respective building energy consumptions (Lawrence et al., 2012).

The remarkable proportion of global energy consumption by the construction industry has fundamentally driven the concentration on decreasing the building energy consumption via amplified sensor data and improved computational support for building controls (Klein et al., 2012). Subsequently, it is vital to balance the maximization of building energy efficiency and users' desired level of comfort while employing an efficient BMS for sustainable maintenance of facility operations overstressing the implication of post-construction building inspection.

Researchers have overstressed that application of an efficient Facility Maintenance and Management systems (FMM) enables executives to detect problems primarily and sustain the facility more effectively (Chen, Hou, & Wang, 2013). On the other hand, the conventional inspection method of progress tracking practice would solely rely on manual visual assessments and periodical respective reports. This progress consisted of logs and checklists manually prepared to indicate the project's level of adaptability with the required milestones and specifications (Bosché, Ahmed, Turkan, Haas, & Haas, 2014). Effectiveness and accuracy of the corresponding inspection progress would have been affected based on the individual's personal judgment and observational skills. Additionally, high probability of inaccurate manual building inspections plus the lack of real-time input of dynamic factors urges development of automated BMS. Therefore, Building Information Modelling (BIM) plays a key role towards automation in construction and corresponding management systems. However, adequate skills; competence and enthusiasm of construction role-players and contractors is a significantly important issue towards future success of such propositions (Miettinen & Paavola, 2014).

Additionally, the progression of AEC building delivery includes design, construction, contracting and maintenance. This complex process, engaging multi-layer and multi-domain information storage and exchange, necessitates integrative contributions from versatile and incorporative professional teams thus; competent information sharing among players is a critical factor towards success therefore; a proposed BIM system capable of resolving AEC interoperability complications would remarkably enhance the overall project output and respectively the building energy

efficiency throughout its lifecycle (Dong, O'Neill, & Li, 2014).

Despite the nD capability of BIM enabling its potential practice during versatile building lifecycle phases, designers-contractors focused primarily on the application of BIM during design-construction management stages. Furthermore, positive prospects of BIM's potential to be applied throughout the post-construction energy efficiency enhancements can be augmented while highlighting the conceivable successful utilization of BIM during corrective building maintenance management concerns compared to preventive concerns (Motawa & Almarshad, 2013).

Moreover, integration of knowledge management systems empowering handling and sharing of respective building maintenance information over the building lifecycle is an inevitable essential during post-construction sustainable performances. Harmoniously, contemporary sustainable developments incorporate advancement of exploiting the aforementioned practices. Congruently, focusing on the building energy efficiency, this article suggests engagement of an Integrated Knowledge-based Building Management System using nD BIM applications (BIM-IKBMS) during the post-construction building lifecycle to advance the implementation of sustainable building performances.

Keywords: *Building Information Modelling; Building Management System; Post-construction Lifecycle; Energy Efficiency*; *n Dimensional Implementations*

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STAAL, A; TOOKEY, J; SEADON, J; MOBACH, M. and WALHOF, G.

Procurement of non-incremental sustainable technology innovations - the case of small entrepreneurial firms supplying New Zealand construction & building industry

PROCUREMENT OF NON-INCREMENTAL SUSTAINABLE TECHNOLOGY INNOVATIONS - THE CASE OF SMALL ENTREPRENEURIAL FIRMS SUPPLYING NEW ZEALAND CONSTRUCTION & BUILDING INDUSTRY

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ABSTRACT

Motivation

Traditionally, the construction industry in New Zealand and in other countries has seen a low productivity and a low track record for successful innovations (Fairweather, 2010). The industry also lags in sustainability (e.g. Nemry, 2008) when seen from a broader or lifecycle perspective. This has a negative impact on private and government spending, on quality and health/wellbeing, and on the environment.

This paper posits that the construction industry needs non-incremental (disruptive or discontinuous, i.e. modular, architectural, system or radical) sustainable technology innovations to make drastic improvements in sustainability. Such innovations are often procured (acquired) and (co-) developed by small entrepreneurial firms thus introducing such innovations into the construction and building industry. *However it is unclear exactly how entrepreneurial small firms procure non-incremental sustainable technology innovations.*

Knowledge gap from extant research

Often entrepreneurial small firms from outside the industry or at the beginning of supply chains play an important role in procuring innovations (e.g. Baumol, 2002; Johnsen 2011; Gambatese, 2011, Pries, 1995, 2005). There is a wealth of literature on how *large* organisations procure their goods and services but it often remains unclear how *small* firms procure these (e.g. Hagelaar, 2014). There is Australian literature (e.g. Hardie, 2006; Hardie 2013) on small firms successfully introducing sustainable innovations in the construction industry. Likewise, there is a growing body of literature (e.g. Johnsen, 2011; Philips 2004) on how large organisations procure non-incremental innovations.

There is some literature on non-incremental sustainable innovations in the construction industry (e.g. Hardie, 2013; Sheffer, 2010, 2013). There is research on innovation types in the construction industry (Slaughter, 2000, Hardie, 2006). Literature also suggests (e.g. Hardie, 2011) several barriers to adoption of innovations on a meso (industry) level and on a macro (systemic) level in the construction industry. Utterback (1994) suggested that such (infrequent) non-incremental innovations would trigger more frequent process and incremental innovations, and would hence deliver large benefits to stakeholders. Manley (2008) concluded that despite the importance of product innovation there is not much research within the construction industry.

Small firms are not miniature versions of large firms (e.g. Torres & Julien, 2005) and small firm innovation and procurement processes will

differ from those of larger firms. Processes are likely to be more informal, holistic, and centred round the firm owner although Meijaard (2004) suggested a wide variety of organisational structures within small firms including formal and complex structures. Entrepreneurial small firms are a small subset of small firms but realize growth and renewal (OECD, 2010). In general there is a research gap on *how entrepreneurial small construction firms procure non-incremental sustainable technology innovations.*

Key words: construction & building industry; entrepreneurs / small firms; New Zealand; non-incremental sustainable technology innovations; strategic procurement.

AIMS AND OBJECTIVES

The research question is: *How do entrepreneurial small New Zealand construction firms procure non-incremental sustainable technology innovations?* The related research aims are:

1. Determine how current procurement activities (i.e. acquisition practices and strategies) interact with innovation activities (i.e. related to non-incremental sustainable technology innovations) within small entrepreneurial New Zealand construction firms.
2. Determine the effect of dominant variables.
3. Determine value-adding procurement activities in economic, social and environmental terms within small entrepreneurial New Zealand construction firms when interacting with innovation activities.
4. Operationalize such value-adding procurement activities into best practices (or even into management instruments).
5. Develop and communicate these new insights to firms and other participants involved in this research, and via academic journals and conferences.

6. Provide recommendations on further research, and on generalisations of insights.

RESEARCH METHOD

The focus of this research is the New Zealand construction industry and this paper is explorative by nature. It is based on a literature review and expert interviews. The paper develops a conceptual framework on strategic procurement and innovation activities of entrepreneurial construction firms in the New Zealand context and identifies clusters of dominant variables. It describes hypotheses from the dominant variables. The hypotheses and related research questions will be tested in three rounds of focus studies (e.g. Hoffmann, 2011; Schiele 2010) alternating with two rounds of multiple case studies (e.g. Eisenhardt, 1989).

This research starts with introducing a conceptual framework. The framework shows two independent concepts of *strategic procurement activities* and (internal and external) *innovation activities* of the small entrepreneurial New Zealand construction firm. These procurement activities must be aligned with innovation activities for an optimal firm performance. The resulting *small firm performance* is the dependant concept. The independent and dependant concepts are affected by four concepts which describe the *firm's meso and macro environment*, the *characteristics of the innovation*, the *characteristics of the owner and the small firm*, and the *firm's strategy and business model*. For classifying the strategic procurement activities this research proposes the procurement process framework of Van Weele (2010). For classifying the innovation activities this research proposes the framework of Cooper (1995). Both validated frameworks are on a sufficient high level to account for *informal and iterating* procurement (acquisition) and innovation processes within small firms.
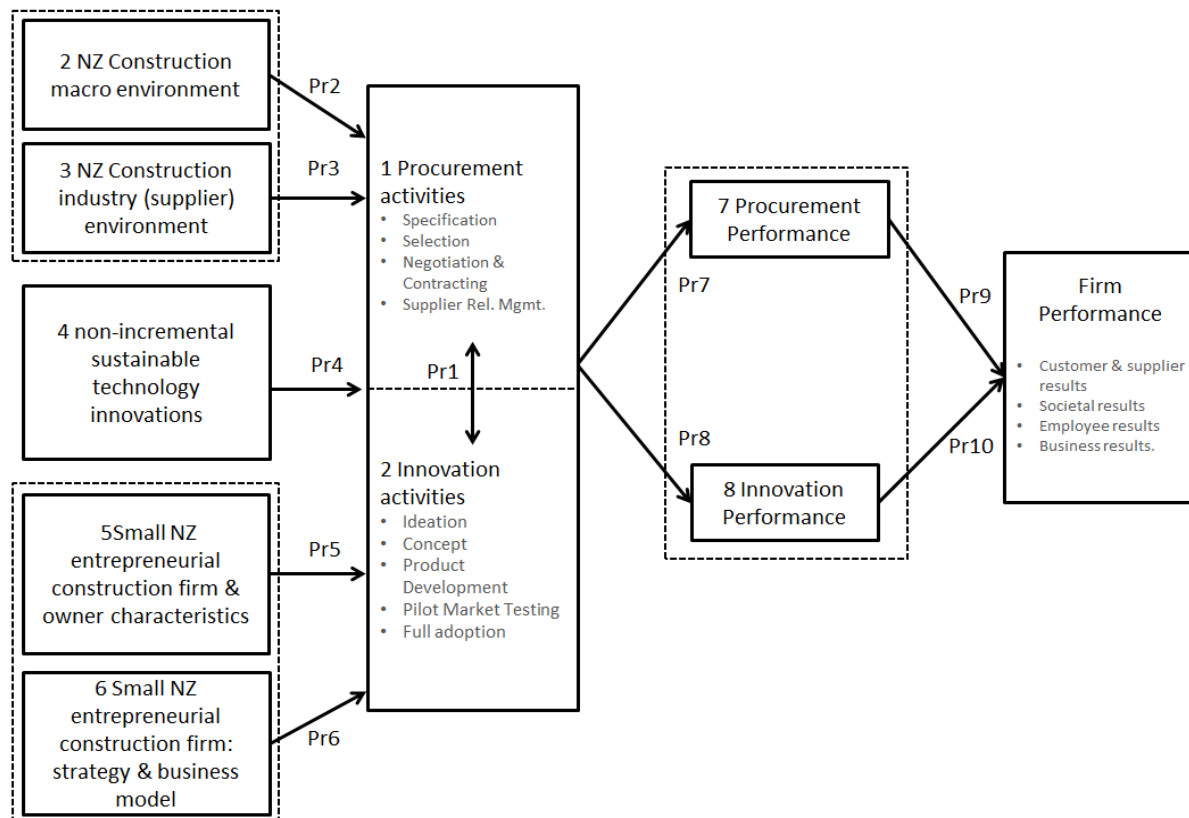
Figure 1: Conceptual framework for this research

The paper discusses the Resource-Based View (RBV) in combination with the Resource-Dependency Theory (RDT) perspective and has the small firm with its (external and internal) procurement and innovation activities as a unit of analysis. When using this perspective and unit of analysis, extant literature provided a number of dominant variables of each of the four moderating concepts. These variables have been used to describe clusters of hypotheses related to the strategic procurement and innovation activities. The paper ends with questions for further research.

RESEARCH SIGNIFICANCE

This research wants to learn what the role is of procurement in successful disruptive waste-reducing technology innovations in small entrepreneurial New Zealand construction firms. This will be beneficial to innovating construction firms and their business partners, to owners and occupants of buildings, and to the wider environment. Hence this research has

a scientific and business relevance, and a social and environmental relevance.

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A SYSTEMATIC REVIEW OF CONSTRUCTION AND DEMOLITION (C&D) WASTE MANAGEMENT

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ABSTRACT

Waste is present in all industrial production processes, including construction. Waste generated by the construction industry is collectively referred to as construction and demolition (C&D) waste. C&D waste is generated throughout the life of a structure, from construction to maintenance and renovation, and finally demolition. Due to the physical size, scopes and complexity of construction projects, waste generated in construction is often highly visible. Worldwide, C&D waste represents a significant amount of total waste generated (between 10% and 36% of all landfill waste).

C&D waste consists of many waste streams including timber, brick, concrete, plasterboard, insulation, paper, glass, and steel; much of which is avoidable. There are a number of factors that have significant effects on the generation of C&D waste. They can be broadly divided into 2 main categories: technical factors and human factors. In the technical category, such factors include:

1) inadequate/unrealistic considerations for planning and scheduling,
2) inadequate design
3) overstock/overestimates of materials
4) late/early deliveries of materials
5) poor handling of materials

Whereas, in the human category, such factors often include:

1) operatives' attitudes towards C&D waste management
2) lack of waste management support from management
3) lack of waste management/minimisation considerations at the design stage

C&D waste can be reduced through having life-cycle considerations at design and reusing/recycling of materials during the construction. However, since each construction project is unique, benefits derived from waste management vary greatly from project to project. Despite this, good waste management practices could save up to 2% of the total construction cost. Recently, various approaches have been proposed to address C&D waste, with some being qualitative and some being quantitative. Despite these efforts, these models have shown varying degrees of success. This is due to the high costs, and the lack of incentives, to implement them. Overall, cost and financial considerations in managing waste are universal and remain undiminished in the psyche of people involved in construction worldwide.

Waste minimisation is a result of construction's quest to manage C&D waste effectively. It is believed that minimising C&D waste can help

construction become more efficient and sustainable over long term. It has been argued that regulations and economic incentives are effective tools to help minimise waste. But it has been shown that although regulations could help reduce C&D waste, the reduction is only sustainable if it is driven by the sector itself. Thus far, efforts to minimise C&D waste have been through the use of technologies. For example, McGrath (2001) offered a waste minimisation software called SMARTWaste; while Building Research Association of New Zealand (BRANZ) developed the REBRI guidance material. Huang et al (2002) used mechanical sorting techniques to recycle construction waste. Li et al (2005) utilised mapping technologies such as GPS and GIS used to track and reduce onsite C&D waste. Osmani (2011) proposed using Building Information Modelling (BIM) to help minimise C&D waste. Despite their usefulness, one thing that has prevented the uptake of these tools is the sector's reluctance to implement new ideas and systems. However, the continuous development of C&D waste minimisation methods over the last 15 years shows the maturity of construction worldwide in this area.

The final frontier of C&D waste management is zero waste. In theory, zero waste can be achieved through 100% recycling or reusing materials; but since this total efficiency is impossible to achieve, zero waste could be understood as a new standard for systems efficiency and integration. Although currently there is no single definition of zero waste, many programmes exist to promote zero waste at national level. At the industry level, however, there is a limited amount of studies on zero waste. In construction, although zero waste has not seemed to gain momentum, attention has been given to this recently. For instance, Alexander (2002) argued that systems integration across the whole sector can ensure successful implementation of zero waste. Rubinstein (2012) produced a practical

guideline to help builders and contractors achieve zero C&D waste; while Kinuthia & Nidzam (2011) demonstrated that if appropriate effort and technologies are utilised, a construction zero waste objective is achievable in both economic and environmental terms. Overall, the body of knowledge concerning zero waste, particularly zero waste in construction, is very small worldwide. Of those available, most tend to describe zero waste rather than offering any real insights into the concept. As such, there is significant knowledge gap that needs to be filled.

Overall, future research into C&D waste management/minimisation is urgently needed to bridge the above-mentioned knowledge gaps. Given the limited research in this area, it is indeed a fertile ground for researchers. This study aims to make a contribution to this body of knowledge of C&D waste management/minimisation by:

1) providing insights into the current state-of-affair of C&D waste management/minimisation research; and consequently
2) proposing necessary future work/developments in order to promote and implement C&D management/minimisation

A comprehensive analysis of literature pertaining to C&D waste management and minimisation has been provided. Steps are undertaken include:

i. Classifying literature into 3 categories C&D waste management, C&D waste minimisation and zero waste in construction
ii. Using major search engine such as Google and Yahoo! to scan the internet for readily-available documents online
iii. Using major journal portals such as Elsevier or Taylor & Francis Online to

scan and obtain industry-specific publications

iv.   Restricting literature publication between 2000 to date to ensure they are all current and up-to-date

In particular, journal papers from the highly respected C&D waste management-focused Journals were chosen. These Journals include: Resources Conservation and Recycling, Waste Management, Waste Management and Research, Construction Management and Economics, Building and Environment, Journal of Construction Engineering and Management, Engineering, Construction and Architectural Management and Journal of Industrial Ecology.

In total, 71 papers have been reviewed. Of this, 51 papers discussed C&D waste management, comprising 72%; 18 focused on C&D waste minimisation, comprising 25%; and 2 papers mentioned zero waste in the construction sector, making up 3%. Although there is still much work in these 3 areas to successfully promote and implement C&D waste management in construction, the analysis has shown:

1) C&D waste management is a mature topic
2) C&D waste minimisation has been embraced by the construction industry, although there is a degree of uncertainty as to how it achieves this goal. This comes from the lack of understanding regarding the benefits of C&D waste minimisation as well as a lack of compelling arguments for implementation
3) Zero waste is the least developed area of C&D waste management research. Due to the limited amount of literature on this topic, meaningful discussions on zero waste in C&D are rare

Of all considerations relating to C&D waste management, economics is still the major considerations by construction in spite of suggestions that other considerations such as environmental and social aspects should be taken into account. Therefore, when considering waste management, waste minimisation and ultimately zero waste in construction, the economic aspects should be thoroughly demonstrated to convince the industry of its financial benefits. This is important because without economic imperatives, it is unlikely such a programme will take off. Therefore, this gap needs to be filled as soon as possible.

3.2 MASSEY UNIVERSITY

DRAFTING MODERN LEAN CONSTRUCTION CONTRACTS

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ABSTRACT

parties such as the client, contractor, and subcontractor. They are typically written in traditional legal language. Research was done to establish if construction contracts could be written in modern plain language resulting is a 'lean' contract without losing end-user's intent. A lean contract uses minimal number of words and adopts a structure and writing style that is consistent with modern drafting style guides.

The research method used was a combination of document content analysis and action research with in-depth collaboration between the researcher and end-users.

Two contrasting cases on writing contracts were involved. In the first case a 40,000-word design and build contract was re-written into a 29,000-word leaner plain English contract. It was restructured more logically with similar clauses grouped together under time, financial, and quality obligations. The author of the original contract and an industry committee validated and confirmed the revised contract had preserved the core concepts. In the second case a new renovation and small projects contract was written afresh based on an industry policy committee's concept outline. Following iterative reviews, the committee confirmed the final 4,800-word plain English contract fulfilled their requirements and end-user needs. The Plain English Commission, UK, subsequently accredited the contract with its 'Clear English Standard'. The Construction Industry Development Board Malaysia will publish this contract in December 2014.

End-user validations in both cases helped draw the conclusion that by adopting a modern legal drafting structure and style, construction contracts for any project type can be leaner without losing end-user intent – whether writing a new contract or re-writing an existing contract. The finding could lead to other traditionally styled contracts to be re-written to make them leaner. Lean construction contracts serve the needs of regular users and occasional users like dispute resolvers better.

Keywords: Construction contracts, contract law, lean contracts, modern legal drafting, plain language.

AMEER ALI, N. (b)

Statutory adjudication – the need for a legislation framework

STATUTORY ADJUDICATION – THE NEED FOR A LEGISLATION FRAMEWORK

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ABSTRACT

Statutory adjudication is now commonly used to resolve construction disputes in over a dozen jurisdictions. Although there are similar themes in the various Acts, many concepts and details differ. Two main adjudication models are the UK model, which provides for adjudication of all disputes, and the New South Wales (NSW) model focused on progress payment disputes. New Zealand (NZ) followed the UK model while Singapore followed the NSW model – each with modifications. The Malaysian Act came into effect in April 2014 after a ten-year initiative. Although the objectives were nearly identical to the NZ model, the Act restricts adjudication to payment disputes and, bucking worldwide trend, limited to only contracts in writing. Incongruently, the Act has the longest adjudication duration and elaborate provisions on document discovery, hearings, and use of experts.

Using a combination of legal document analysis of primary legislation, law reports, industry reports, and responses to questionnaires, research was done to compare core differences in the various Acts with a focus on the NZ and Malaysian Acts and establish the rationale for the preferred Malaysian adjudication model. An adjudication legislation framework is proposed. The framework determines industry needs and preferences before an appropriate adjudication model is recommended.

Among the key components identified and incorporated in the framework include the name of the Act and objectives, legislative drafting style, types of contracts governed, who may be an adjudicator, how they are appointed, types of disputes that may be adjudicated, adjudication durations, and how costs are controlled.

The findings suggest the key reason for the incongruence within the Malaysian Act stems from compromises made on concepts during the development of the Act.

The framework can help prevent such and other anomalies in new legislation and in existing ones when being reviewed. It can also help when considering expanding adjudication beyond the construction industry – possibly through an 'Adjudication Act'.

Keywords: Adjudication Act, adjudication legislation framework, adjudication models, comparative adjudication, statutory adjudication.

IMPROVING HEALTH AND WELL-BEING IN LOW DECILE CLASSROOMS WITH A SOLAR VENTILATION SYSTEM

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BACKGROUND

Children spend the second largest proportion of their time at school. The high density of occupants in classrooms gives challenges to reach adequate ventilation (Jurelionis *et al* 2008). Nearly all New Zealand classrooms depend entirely on natural ventilation via open windows (Cutler-Welsh 2006). However, New Zealand classrooms are grossly under ventilated in cold weather and have excessively high levels of bacteria which potentially lead to adverse respiratory infections and other health effects (Bassett *et al* 1999, McIntosh 2011). Inadequate ventilation was also linked to an increase in students' absenteeism (Bartlett *et al* 2004). Conventional mechanical ventilation systems are capital and energy expensive, which is seldom for most New Zealand schools, especially as the Ministry of Education has recently introduced capped budgets for energy. However, the school day is closely aligned to the availability of solar radiation, meaning schools are ideal environments for utilising free solar heated ventilation. The proposed solar ventilation system has been pilot-tested in a dwelling in Masterton (New Zealand) during the 2010 winter and simultaneously achieved acceptable ventilation and sufficient free heat to achieve a comfortable temperature.

AIMS OF THE PRIMARY SCHOOL INTERVENTION STUDY

• To investigate exposure to airborne bacteria, chemical pollutants, particulate matter, temperature, relative humidity, *streptococcus sp* bacteria in students and absenteeism level in twelve classrooms and to assess the changes when the ventilation system is operating vs. not operating,

• To examine whether this intervention is sufficient to provide a healthy classroom environment in accordance with World Health Organisation (WHO) recommendations.

RESEARCH DESIGN AND METHODS

The fieldwork was undertaken from May to September (School term 2 and 3) in 2013 and in 2014. Prior to the fieldwork commencing, twelve solar heated ventilation systems were installed, on the north facing roof of twelve classrooms. Six classrooms were active while

the remaining six classrooms did form a control group (ventilation system disabled). This monitoring pattern was reversed every school term. Throat swab testing was monthly performed to identify *streptococcus* infections. Total airborne bacteria load was estimated in term 3 both years using a metagenomics approach (Next Generation Sequencing). In all classrooms, every two minutes, the level of carbon dioxide, carbon monoxide, formaldehyde, temperature, relative humidity, ventilation flow rate, and heater use were monitored. Data were weekly collected on absenteeism and the absent child's parents/guardian were contacted and interviewed about absenteeism using a standard health questionnaire. For two weeks in August 2013 and August 2014, two classrooms were equipped with a particulate matter (PM) sampler to monitor PM2.5 microns and PM10 microns on an hourly time-scale. Elemental composition of the particulate matter was also measured using Ion Beam Analysis (GNS Science).

PRELIMINARY RESULTS
The data collection ended in October 2014. At the time of the abstract writing most of the results need to be analysed, however, some preliminary results are available from the first winter fieldwork.

At the classroom level:
- For half the time, the incoming air reached temperatures above 30˚C. Thus the solar heated ventilation system played a positive role on increasing the classroom temperature and reducing heaters usage.
- The flow rate of incoming air peaked at 83m^3/h. At this flow rate, it will take 2.5 hours to change the whole volume of a classroom (assuming an approximate classroom volume of 200m^3).
- For at least two thirds of the school day, all classrooms (active and control) were within the 40% - 60% relative humidity and 18˚C - 24˚C temperature range (WHO recommended level).
- To achieve a similar temperature level, the heater usage in the control classrooms was 2.5 times higher than in adjacent active classrooms. The solar heated ventilation systems contributed significantly to energy saving to the schools.
- Two thirds of active classrooms showed higher percentage of time exposure to carbon dioxide level following the recommended level (<1000ppm) than the control classroom.
- Using the metagenomics approach, the airborne bacteria results showed more dissimilarity inter-schools than intra-school (active vs. control). Each school showed its own microenvironment.
- The preliminary results of the particulate matter (PM) monitoring showed a significantly elevated PM concentrations occurred in classrooms when they are occupied by children due to re-entrained dust (unrelated to outdoor conditions). Higher concentrations occurred in the control classrooms than in active classrooms.

At the student's level:
- First year results showed that a positive occurrence to *Group A Streptococcus* in students steadily decreasing from June to September (10.7% in June, 8.2% in July, 6.5% in August, 3.7% in August/Sept, 0.6% in September). More analysis is needed to investigate if this decrease is due to the intervention or to a medical follow up (use of medication).

CONCLUSION
Preliminary results showed that the intervention had a very positive impact on the school environment (decrease of the carbon dioxide level, decrease of re-entrained dust level) and did help in saving energy (2.5 times less

purchased energy). However, all these results need to be confirmed with the analysis of the second winter data.

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HAJI KARIMIAN, S.

Benchmarking framework for performance improvement of the road maintenance services in the New Zealand roading sector

BENCHMARKING FRAMEWORK FOR PERFORMANCE IMPROVEMENT OF THE ROAD MAINTENANCE SERVICES IN THE NEW ZEALAND ROADING SECTOR

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ABSTRACT

Purpose

This research aims to establish for the New Zealand highway operations and maintenance sector the best practice benchmark techniques, benchmarking opportunities in the road sector, relevant international comparators for benchmarking, and barriers and risks to benchmarking.

Knowledge gap and research questions

In 2013, the New Zealand Transport Agency (NZTA) began to commission network outcomes contract for the maintenance of the NZ highways. The contract was meant for nationwide use across 23 networks. However, there is no available and New Zealand specific framework for comparing, contrasting, and analyzing the performance of contractors carrying out operations and maintenance (OM) services within each network (NZTA, 2014). The NZTA would like research to be carried out to develop a robust framework for benchmarking the operations and maintenance of the OM services within the nation's roading networks. The developed framework will be utilized by the agency to measure performance across both the state highway and local roading sector. This research aims to bridge the knowledge gap by seeking answers to the following research questions:

1) What suitable benchmarking methodologies for OM services are currently in use in other roading agencies and similar industries in New Zealand and overseas?
2) What high level drivers are evident in the best practice performers in these other jurisdictions and/ or sectors?
3) How could such successful methodologies be adapted to the specifics of the roading sector in New Zealand?

Research objectives

As a key outcome of the above enquiries, the research will aim to develop a framework for measuring the performance, quality and cost of OM services within the NZ road sector. The framework will be used for the following purposes:

a) Translating performance, quality and cost of the OM operations into a level of service and value-for-money model for use in evaluating and comparing OM service performance across the NZ sector.
b) Comparing OM cost and performance between networks within New Zealand

and against comparable overseas organisations.

c) Providing a schema for the design and development of a working benchmarking model.

Research method

The research will be carried out in four stages over two to three years as follows:

i. Literature and best-practice review of suitable benchmarking methodologies for OM services currently in use in other roading agencies and similar industries in New Zealand and overseas.

ii. Focus group meeting with experts in the roading and allied sectors to validate the identified high level drivers that underpin best practice performance in allied sectors.

iii. Online structured surveys amongst consultants, contractors and policy makers in the roading sector aimed at providing a quantitative assessment and priority ranking of the identified parameters for the development of a benchmarking framework for the OM services. The model will be developed using the SPSS-based multivariate analysis, the exact variant of which will be determined by the nature of the established parameters.

iv. Industry validation workshop on the feasibility/ practicality of the roll-out of the developed model in the roading sector.

Keywords: Benchmarking, Performance improvement, Productivity, Road maintenance, Roading sector.

Strategic justification for the study

This research contributes to the ethos of systematic problem-solving and industry connectedness which are key underpinnings of SEAT Profile (Massey University Strategic

Plan, 2011). Being focused on the research needs of the roading industry, the research offers a platform for contributing to the Vision and Strategic Goals of the College of Sciences and Massey University. This is moreso that the NZ Government spends $2.5 - $3 billion annually in maintaining, operating and renewing the 23 roading networks in New Zealand (National Infrastructure Unit, 2011). In addition, the central government's investment in the roading infrastructure is about 1.4% of the GDP (NZ Treasury, 2012; NZTA, 2009). These investments are strategic levers for ramping up sustainable economic growth and development (Cunningham, 2010; Page, 2010). This research aims to establish a framework for optimizing the outcome of this multibillion dollar investment in the roading system. The research focus therefore contributes to capacity development of the BE Cluster and the CoS "*Industrial Innovation*" platform through construction research.

ANTICIPATED FINDINGS OF THE STUDY

The research will aim to develop a framework for monitoring, measuring and reporting performance on schedule, scope, quality and cost of maintenance services within the NZ road sector. The framework will be used for the following purposes:

1. Translating performance on schedule, scope, quality and cost of the road pavement maintenance operations into a level of service and value-for-money model for use in evaluating and comparing road pavement maintenance and rehabilitation service performance across the NZ roading sector.

2. Comparing maintenance cost and performance between networks within New Zealand and against comparable overseas organisations.

3. Providing a schema for the design and development of a working

benchmarking model for timely performance improvement.

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OKAKPU, A; EGBELAKIN, T. and PHIPPS, R.

Refurbishment of old existing buildings for energy conservation

REFURBISHMENT OF OLD EXISTING BUILDINGS FOR ENERGY CONSERVATION

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ABSTRACT

Motivation: Expected life spans of building are generally decreasing due to the overall impact of climate change and reduced energy conservation capacity of the building components.

Knowledge Gap: Previous research have highlighted that the use of new and old materials for refurbishment without proper investigation can cause severe environmental health hazard to the occupants, and increased occupancy and operational costs. Hence, the need to investigate the compatibility of existing and new building materials used in the refurbishment of old buildings.

Aim and objectives: The aim of this study is to develop a guide to aid the selection of compatible building materials considering environmental health hazard, occupant comfort, and the long term cost effectiveness against the expected design life span of the building.

Research method: This study will investigate on the embodied energy of different building materials such as Polyvinyl Chloride (PVC), Fiber reinforced polymer (FRP) and light concrete against the conventionally used materials such as timber and steel in New Zealand. A case study method, comparing recently refurbished buildings in four selected regions in New Zealand will be conducted. First, the compatibility of new and old materials will be assessed. Second, the cost of energy in production, casting stage and life span of the building during its usage will be investigated. Lastly, a questionnaire survey from the building occupants to assess occupants' comfort will also be conducted. The research results will be analysed using simulation software.

Preliminary or anticipated findings: The findings may include recommendations on how to enhance conservation of energy and occupant's comfort, reduced health risk, and reduced building operational cost.

Research significance: The research findings would provide a clear understanding regarding the compatibility of older and newer materials to enhance building sustainability and energy conservation.

Keywords: Building refurbishment, Energy conservation, Building life span, Compatibility, Life cycle cost.

INTRODUCTION

Energy conservation in old existing buildings can be improved by the application of different energy-saving measures and sustainable

materials. These buildings require upgrade as a result of degradations and the impact of climatic change in the environment. Nowadays, climatic change is an urgent problem requiring immediate action. Therefore, old existing buildings should adapt to bioclimatic design through energy efficient refurbishment in order to improve their environmental performance and reduce the amount of energy they consume (DTI, 2003).

The use of these materials in refurbishment is essential if a building project is to be considered sustainable (Environmental Building News, 2001). Typically the construction industry enters the materials market at the point of selection and procurement, usually at the design stages. Before selecting a material, there are issues such as the energy conservation of the constituent materials, the compatibility of the materials with the existing ones, the cost

effectiveness and the seismic resistance of each material need to be understood. The designers and project team members should be able to assess these factors with the design life span of the building. These will however help to deliver more sustainable projects that could minimize its environmental impact (Behzad Sodagar, 2013). Most studies had centered on the comparing embodied energy of constituent materials. However, the (Counsel for Research and Innovation in Building Research (CIB), 1999) state that significant issues of concerned for product manufacturing are: reducing the embodied amount of material and energy of the products. This includes renewable materials, low-energy recycling, increasing durability and technical life expectancy. Also, includes low emissions from products in use, repair ability and recyclability. Figure 1 demonstrates the embodied energy in a house by volume of material.
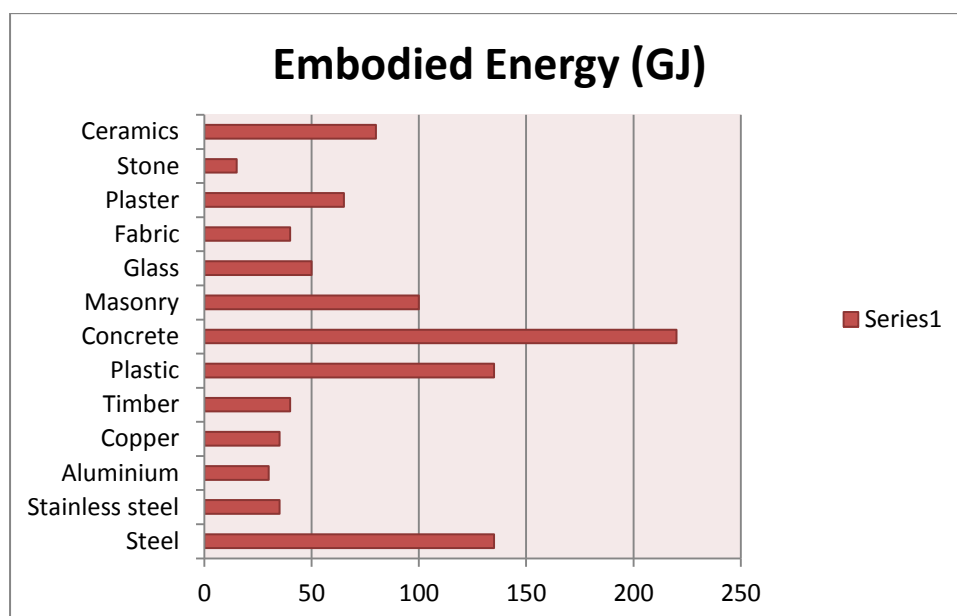
Figure 1: Embodied energy in a house by volume of material (Source: CSIRO, 2002)

One of the most critical factors in considering the environmental impacts of any material is

the need to move beyond the material itself and more clearly understand its context, where and

how it is used, maintained, abused, recovered or discarded and dumped, Green building Council Australia (2010). Too often, the environmental impact of materials could be addressed in isolation from their total content such that comparisons are made about 'material "X" being better than material Y." As true as it may be in some instances, there are ranges of other possibilities where the opposite could be just as true. Assessing materials without knowing or understanding their full life-cycle and environmental impact has the potential to result in a one dimensional outlook of how they might impact on the environment and therefore question their ultimate value of being specified in the first place (Centre For Design (CFD), 2002). However, the development of a sustainable built environment will largely rely on well informed building upgrade for existing infrastructure (Castleton et al, 2010). Cost effective materials with low embodied energy could be used to improve existing buildings (Jayasinghe Chinta, 2011). However, the compatibility issues with old materials, material recovery, expected life span of the building, long term cost effectiveness in simultaneous with climate change for a longer period need to be examined.

Overall, for a building to be sustainable, it should be constructed using locally sourced materials (Melia et al, 2014). Hence there is a need for an approach that lifts sustainable materials into a decision guideline for proper refurbishment. This, in turn, will improve occupant comfort, and the long term cost effectiveness against the expected design life span of the building.

RESEARCH AIM AND OBJECTIVES

The research seeks to provide answers to the following questions:
1. What are the different sustainable building materials for building refurbishment available in New Zealand?
2. What materials are best able to provide an increase to a building life span to meet clients' expectation?
3. Are the installation procedures for these materials cost effectively and with reduced risk of implementation?
4. Are the materials compatible, and energy conserving?

RESEARCH METHOD

This study will investigate on the embodied energy of different building materials such as Polyvinyl Chloride (PVC), Fiber reinforced polymer (FRP) and light concrete against the conventionally used materials such as timber and steel in New Zealand. A case study method, comparing recently refurbished buildings in four selected regions in New Zealand will be conducted. First, the compatibility of new and old materials will be assessed. Second, the cost of energy in production, casting stage and life span of the building during its usage will be investigated. Lastly, a questionnaire survey from the building occupants to assess occupants' comfort will also be conducted. The research results will be analysed using simulation software. A careful selection of eco-friendly may be the fastest way for builders to start integrating sustainable renovation concepts in old buildings.

ANTICIPATED FINDINGS

The energy conservation capacity of refurbished buildings

The emergy of sustainable building materials available in the community

Analysis of refurbished home occupant satisfaction.

Create awareness to construction sectors and clients on the cost, life span and new application approach for sustainable building materials.

RESEARCH SIGNIFICANCE

Sustainable refurbishment gives clear advantages in cost, time, community impact, and avoidance of building degradation.

It enhances the reuse of existing infrastructure and protection of existing communities.

It also offers significant reduction in energy use of existing buildings for short and long term purposes.

The life span of buildings is well protected when the materials are compatible.

This study will provide recommendations that will enlighten the construction industry and the clients on the need to select suitable refurbishment materials on long term efficiency and cost for improving building sustainability. The industry will be able to understand and compare efficiency, cost effectiveness and expected life span of buildings with the emergy of PVC, FRP, concrete and that of timber and steel.

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SECTION IV

RESEARCH PAPERS BASED ON RECENTLY COMPLETED BUILT ENVIRONMENT RESEARCH AT THE UNIVERSITIES

4.1 An overview of the research papers submitted at the symposium

BACKGROUND

One of the key aims of the annual symposium series is to showcase and document recently completed and on-going built environment research at the universities. This year, we began to encourage the submission of full research papers which have not been published elsewhere.

Paper review process

The papers were subjected to double blind peer review process by experts in the research areas who are members of the Scientific and Technical Committee (S&TC). Details of the S&TC members are shown on page 3 of these Proceedings.

The key criteria for acceptance of the papers for inclusion in the Proceedings included relevance and research quality based on the reviewers' assessment of the extent to which the manuscript addressed the following questions:

a) Does the paper title reflect the content?
b) Is the subject matter of the paper original? (I.e. does it present new knowledge?)
c) Is the abstract properly written with clear indication of the problem/ motivation, gap in the literature, aim/ objective, research method (including sampling frames, data gathering process & data analysis), key findings, and implications for industry practice and further research?
d) Do the research design, implementation and report demonstrate sound methodical approach and academic rigour?
e) Does the paper provide an in-depth and critical review of current literature in the subject area?
f) Are the objectives or research questions clearly outlined?
g) Is the research method clear and appropriately justified?
h) Is the English and syntax of the paper satisfactory? Is there clarity in flow of thoughts?
i) Are the conclusions & recommendations based on the reported work?
j) Were sources properly cited in the body of the report and well referenced in the reference list? Does the depth of the reference list compiled from cited sources demonstrate proper review of current state of knowledge in the subject area?
k) Overall, do you consider the findings/ expected findings easy to apply and useful to the needs of the industry?

Actually the review process recognised three main categories of papers submitted for review:

Review paper: A paper that provides a significant insight and critical analysis of the literature into a specific topic, deemed to be of high relevance in any field of the built environment. The quality of the references and the depth of the critical review of literature were the key criteria for acceptance of the work for inclusion in the Proceedings. Consideration was also taken of new information that presented published data in new ways or that

further enhanced or furthered our collective understanding of the knowledge.

Research paper: This included original research based on sound methical approach and that demonstrated academic rigour through reasonable scope and in-depth analysis using appropriate and justified analytical techniques.

Practice paper/ Technical note: This included a well-documented case study or report that demonstrates quality by providing accurate data and analysis of a specific problem in the built environment, by potential applicability, or by clear technological innovation.

Guidelines and templates were provided to authors in the symposium portal dedicated for abstract and full paper submissions (see http://construction.massey.ac.nz/nzbers-2014_abstracts.htm).

Prizes and certificates

Full research papers submitted by research students and which were accepted for inclusion in the Proceedings after the blind peer-review process were rated by the reviewers. Prizes – in the form of $100 gift vouchers - were given to the student authors who won the best research paper awards in each of the participating universities. To be included in the best paper award, the submission must be made within the submission deadline.

Students who submitted extended abstracts and which were accepted for inclusion in the Proceedings received $20 gift voucher if they presented their work at the symposium.

OVERVIEW OF THE RESEARCH PAPERS

A total of fifteen full research papers were submitted for the symposium. The submitters were from AUT, Massey University and the NZIQS. Unfortunately, no submissions came from the other participating universities. Out of the fifteen submissions, eleven were accepted after the peer-review process. However, the authors of two papers which were accepted subject to major revisions could not satisfactorily address the quality issues pointed out by the reviewers before the re-submission deadline.

Summary of the nine research papers that made it through to inclusion in the Proceedings is as follows.

AUT research papers

Rajeh, M: *Impact of procurement systems on transaction costs: A structural equation modelling methodology*

Rajeh's work examined transaction costs (TCs) involved in the traditional and design-build procurement systems in the New Zealand construction industry. Based on a combination of questionnaire survey and case study validations, the study attempted to fill a knowledge gap by developing a conceptual model for the relationship between project delivery systems and the TCs.

The results suggest that project delivery systems have indirect effect on TCs. This effect is fully mediated by the costs of information, procurement, administration, and enforcement. Applying the developed models to 'real world' cases, it was found that TCs in the Traditional systems amounts to 18.5% of the annual salary cost of a project manager, while in the Design-Build systems, it amounts to 14.5% of the annual salary cost of a project manager. The findings have practical implications on construction business practice due to their robust empirical nature and theoretical framework, which might enhance the

performance of the construction industry. Rajeh's paper is included in this section, while his presentation can be accessed online at

http://construction.massey.ac.nz/NZBERS-2014_AUT_Rajeh-M_presentation.pdf

Zaeri, F. and Rotimi, J. O. B: *Developing activity cycle based diagram for simulating a bridge construction operation*

Concerned about the lack of established guidelines for scheduling and controlling the uncertainties, complexities and repetitions which characterise bridge construction projects in New Zealand, Zaeri and Rotimi investigated how the planning and management of bridge construction projects could be facilitated through the application of EZStrobe – a simulation-based planning and scheduling tool. Based on an in-depth case study of a multi-million dollar bridge project, the authors developed activity-based simulation models which can assist in the scheduling and control of the inherent challenges in bridge construction projects with a view to improving delivery to cost, time and quality expectations.

Zaeri and Rotimi's paper is included in this section, while the presentation can be accessed online at

http://construction.massey.ac.nz/NZBERS-2014_AUT_Zaeri-F_presentation.pdf

Massey research papers

Bound, M. and Flemmer, C: *Occupants' Perspectives of a Five Green Star Certified School Building*

The recent introduction of the NABERSNZ building performance rating tool addresses the technical aspects of office building performance; there is a lack of tool for post-occupancy evaluation (POE) of green buildings. To fill this gap, Bound and Flemmer expanded the existing tool to a POE model and used it to assess the level of satisfaction of staff occupying a 5 Star green school building. The results of the case study that involved occupants' survey showed that the occupants' overall experience in their green school building was significantly worse than the level expected of a building of less than five years old. The use of the developed POE model could provide valuable feedback to designers, owners, occupiers, managers and other industry professionals in ensuring that the completed green building would perform to the expected green star rating level, including satisfaction of occupants in the operation phase.

Bound and Flemmer's paper is included in this section, while the presentation is available online at

http://construction.massey.ac.nz/NZBERS-2014_Massey_Bound-M_presentation.pdf

Ji, C. and Domingo, N: *Critical determinants of construction tendering prices in New Zealand - Quantity surveyors' perspectives*

There is little research on the priority factors that influence tendering prices in New Zealand. Motivated by this knowledge gap, Ji and Domingo surveyed 156 quantity surveyors and found that poor tender documentation was perceived as the most important factor underlying reliable pre-tender cost estimation and tender price. Rank-ordering of the relative importance of the cost-influencing factors could assist quantity surveyors to prepare more reliable pre-tender construction estimates, as well as assist in effective cost control at the construction stage. Ji's paper is included in this section, while her presentation is available at

http://construction.massey.ac.nz/NZBERS-2014_Massey_Ji-C_presentation.pdf

Onyeizu, E: *The Delusion of Green Certification - The case of New Zealand Green office buildings*

Through extensive review of existing literature, Onyeizu examined the resultant consequence of green certification of office buildings in the construction industry and found that the motivation for green buildings has shifted from being the right thing to do to the quest for financial benefits that are attributed to greenness. The author also found that office buildings have become extensively glazed and highly dependent on artificial air conditioning systems. The consequences of these features are shown to be significant mainly in terms of the inefficient use of energy and indoor environment control dilemma.

Onyeizu's paper is included in this section; the presentation is available online at

http://construction.massey.ac.nz/NZBERS-2014_Massey_Onyeizu-E_presentation.pdf

Shahzad, W.M, Mbachu, J. and Domingo, N: *Prefab content versus cost and time savings in construction projects: A regression analysis*

There is little research on the quantifiable benefits of prefabrication technology to convince clients to increase its uptake in the industry. Motivated by this knowledge gap, Shahzad, Mbachu and Domingo investigated the correlations between prefab contents and the corresponding cost and time savings in construction projects. Results showed that cost and time performance improved with increase in the building prefab content in the buildings within certain limits. Prefab contents ranged from 30 – 90% of the final contract sums for all

prefab types used in the projects, while the time and cost performance ranged from 50-130% and 40-120%, respectively. These results are expected to provide the empirical evidence that decision makers need to employ more of the technology in the industry, and hence contribute to improving its wider up-take.

Shahzad *et al*'s paper is included in this section; the presentation is available online at http://construction.massey.ac.nz/NZBERS-2014_Massey_Shahzad-W_presentation.pdf

Taylor, S. and Mbachu, J: *Profiling and mitigating risks in construction contracts*

Currently in New Zealand, there is little or no information on how to profile and respond appropriately to risks in construction contracts. As a result contractors do overcompensate for risks or undercompensate and therefore get dangerously exposed to risks. To contribute to filling the knowledge gap, Taylor and Mbachu investigated the critical contractual risk factors in the New Zealand construction industry, their risk profiles and mitigating measures. Results highlighted 21 risk factors which were segregated into 6 broad categories, the most significant being site conditions. Being cautious of the priority risk factors and application of the identified most effective risk mitigation measures could guide contractors and the project team to more appropriately budget for and respond to risks thereby ensuring more satisfactory project outcomes.

Taylor and Mbachu's paper is included in this section.

Zhao, L., Mbachu, J. and Domingo, N: *Influence of socio-economic conditions on building costs in New Zealand*

In practice, estimators of building costs only focus on immediate project cost variables. Influence of key socio-economic factors (SEFs) on cost estimates and underpinning variables is scarcely considered, due largely to a gap in the knowledge of which SEFs significantly influence building costs and extent of the influences. Zhao, Mbachu and Domingo aimed to bridge this knowledge gap by examining time series trends in key socio-economic indicators (SEIs) and building costs with a view to ascertaining which SEIs significantly influenced annual changes in building costs over a 12 year period – 2001 to 2013. Results showed that out of 18 SEIs analysed in the study, only 11 were reliable influencers of

building cost trend over the study period. Annual changes in house prices were found to be the most significant influencer of building cost trend. Overall, it was recommended that construction cost estimators should monitor future movements in the identified 11 SEIs to understand their correlational effects on building cost estimate over a given forecast horizon for a project. This would minimize forecast risks and ensure more reliable cost estimation.

Zhao *et al*'s paper is included in this section. The presentation can be accessed online at

http://construction.massey.ac.nz/NZBERS-2014_Massey_Zhao-L_presentation.pdf

4.1 AUCKLAND UNIVERSITY OF TECHNOLOGY (AUT)

IMPACT OF PROCUREMENT SYSTEMS ON TRANSACTION COSTS: A STRUCTURAL EQUATION MODELLING METHODOLOGY

Mohammed Rajeh

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ABSTRACT

Within construction procurement, Transaction cost economics (TCE) offers a mechanism to understand 'unseen' costs associated with the pre and post-contract work. Pre-contract, these include costs related to information gathering and procurement. Post-contract they include activities of contract administration and enforcement. This paper aims to estimate transaction costs (TCs) for different delivery systems used in construction projects in New Zealand, specifically the Traditional and Design-Build.

This study develops a conceptual model for the relationship between project delivery systems and TCs. The model was operationalized and developed into a questionnaire. A cross-sectional sample approach was deployed, involving pilot and survey questionnaires. Data was sought from construction professionals in management, design and operations. TCs were measured using professionals' time-spent in procurement as a surrogate for cost. Likert rating scale 1-5 was used in evaluation, which involved comparing the traditional and design-build systems. Data was triangulated with 'real world' cases to test and explain the developed model. The test included Validity and Reliability, Path Analysis, Regression Analysis, Factor Analysis, and Structural Equation Modelling (SEM). The primary analytical technique used was SEM to yield information on Goodness-of-Fit, model development and comparison, and confirmatory strategies. SPSS Amos 21 was used for data analysis and model development.

The results suggest that project delivery systems have indirect effect on TCs. This effect is fully mediated by the costs of information, procurement, administration, and enforcement. Applying the developed models to 'real world' cases, it was found that TCs in the Traditional systems amounts to 18.5% of the annual salary cost of a project manager, while in the Design-Build systems, it amounts to 14.5% of the annual salary cost of a project manager. The findings have practical implications on construction business practice due to their robust empirical nature and theoretical framework, which might enhance the performance of the construction industry.

KEYWORDS: Construction, Procurement Systems, Structural Equation Modelling, Transaction Costs.

INTRODUCTION

Transaction costs (TCs) are the price that market participants have to pay in order to reach an agreement, develop rules to implement this agreement, and establish the appropriate

delivery system as part of the agreement. In construction, TCs are primarily linked to costs at the pre and post-contract phases. Pre-contract costs borne by construction owners in information search and procurement. Post-contract costs borne by construction owners in contract administration and enforcement (Lynch, 1996; Rindfleisch & Heide, 1997; Williamson, 2010b; Li et al., 2013). These unseen costs are incurred because of professionals' time-spent in procurement activities, which can be considered as a waste of social resources and wealth (Wenan & Mengjun, 2010; Wenan & Tianhua, 2010). Thus, they are among the important factors that affect the construction projects' performance. So far, there have only been a few attempts to apply the transaction cost framework to determine the 'unseen' costs in procurement in the construction industry. This is even more unknown within New Zealand's construction industry.

This study examines the relationship between project delivery systems and TCs in the framework of New Zealand's construction industry. Three central issues are explored. First, what are transaction costs? Second, to what extent are the TCs in construction related to its procurement? Third, can a construction firm improve its procurement practices in New Zealand?

In addressing the first issue, a search for a robust conceptualization of TCs is required. Transaction costs might tentatively be associated with the professionals' time-spent on procurement during the pre and post-contract phases. But is procurement activities described in terms of information search, negotiation and preparing bid documentation, contract administration, and contract enforcement? Evidently the definition of TCs in construction requires considerable thought and reflection.

The second issue lies in determining whether the TCs of a construction project relates to its procurement practices, or there are other factors such as uncertainties in the transaction environment that influence the TCs. An initial response from practitioners and academics might be that best practice procurement is more likely to achieve superior project execution.

Given that the most suitable procurement practice leads to improved productivity within construction, the third issue arises: Can a construction firm improve its procurement practices in New Zealand? Solely focusing on the design of formal procurement processes and procedures is not enough for cost savings, minimizing claims, and reducing conflict and dispute. There is a need to consider the interaction of uncertainties in the transaction environment, and the unseen costs of information, procurement, contract administration, and contract enforcement in the procurement decision.

There are relatively few studies that have attempted to apply the concept of TC across a wide range of construction centric topics. For example, Winch (2001) applied the concept of TC to evaluate the project organization and determine the appropriate governance structure. A study by Eccles (1981) used the TCs to evaluate construction market with a focus on sub-contracting. Lynch (1996) adopted the transaction costs framework to determine the appropriate delivery systems for construction projects. A study conducted by Dudkin and Valila (2005) tried to measure and evaluate transaction costs in public private partnership projects (PPPs) in the U.K. Recently, a study conducted by Li et al. (2013) evaluated the project performance based on TCs incurred.

The majority of studies applying TC concept in construction have different definitions of the concept, and focusing on theoretical and qualitative aspects of the concept. For example,

some researchers define TCs as the contract cost while others call it procurement cost. Williamson (1985) in the organization theory (TCE) defines transaction costs to include the costs of drafting, negotiating, contract administration, and contract enforcement. Some authors have suggested including other costs such as costs of acquiring information, legal, organizational (Joskow, 2002), and costs of breaching contractual agreements (Rahman & Kumaraswamy, 2002). In the context of a contractual arrangement, TCE has traditionally examined the customer-supplier relationship. With the assumption that this relationship is associated with TCs including costs of information, negotiation, competitive advantage, contract administration and management, market structure, enforcement and measuring/monitoring of performance (Heide & Stump, 1995; Artz, 1999; Melese & Franck, 2005).

In construction projects, Turner and Simister (2001) identified a different set of TCs throughout the project lifecycle such as specifying the product and the worked method in the tender documentation, managing variation to the project specification and process specification during project delivery. Moreover, Hughes et al. (2006) classified TCs in three project phases: - In the pre-tendering phase, mainly the costs of marketing and information search were included. In the tendering phase, it is the costs of bidding and negotiation. While in the post-tendering phase, it is the costs of dispute resolution, monitoring and control, and contract enforcement. Similarly, the study by Wittington (2008) included TCs from the costs of advertisement and bids preparation and award, to the cost of contract execution. Finally, according to Lingard et al. (1998) one should distinguish between the pre and post-contract transaction costs. Pre-contract costs incurred in information, communication, negotiation, bids documentation, and project preliminary design.

Post-contract costs incurred in disputes resolution, contract administration and enforcement. In summary, concepts related to transaction costs are inconsistent in definition and there is little agreement how the concept is constructed. This means inconsistency in data, and renders data analysis almost impossible (Farajian, 2010).

Throughout this research the term transaction costs refers to costs borne by construction owners because of professionals' time-spent on procurement in the pre and post-contract phases. In the pre-contract phase, TCs include the costs of information search and project procurement. While in post-contract phase, TCs include the costs of contract administration and enforcement. In construction projects, the chosen delivery systems may significantly influence costs of information, procurement, administration, and enforcement, which in turn considerably affect the TCs. According to Williamson (1981), the key sources of TCs are economic actors' behavioral assumptions (e.g. opportunistically and bounded rationality) and transaction characteristics such as asset specificity, uncertainty, frequency, complexity, and contestability. The opportunity costs relate to renegotiation and delays in delivery, which may significantly undermine expected benefits of the project (Ho & Tsui, 2009). Similarly, if the construction owners outsourced project activities, this in turn could involve extra TCs such as negotiation, measuring, and monitoring costs because of opportunistic behavior of the actors involved in the contractual agreement (Frank et al., 2007). Bounded rationality of the contractual parties may cause another set of costs such as those incurred in information search and procurement. This is reflected in administrative, technical, and professional staff growing at the expense of tradesmen and operatives (Lockyer & Scholarios, 2007). Therefore, as information cost increases, there will be higher transaction costs incurred.

Transaction characteristics such as uncertainty and complexity affect the ability of contracting parties to fully define contingencies in the contract. Uncertainties are external and internal factors that affect the project execution (Walker & Pryke, 2009; Jin & Zhang, 2011; Li et al., 2013). Political, legal, social, economical, technological and competition all refer to external environmental uncertainties. While corporate culture, project location, finance and ownership, and information systems all refer to internal environmental uncertainties (Ford & Slocum, 1977; Marcus, 2005; Grimm et al., 2006; Elliott et al., 2008; Foss & Foss, 2008). Winch (1989) identified other set of uncertainties within the construction process such as task, natural, organizational, and contracting uncertainties that cause most of the problems in construction. The high level of uncertainties forces contractors to jack up their bids, file numerous claims, substantial extra work and rework, and antagonistic relationships with owners, which end up in dispute and conflict. Those in turn are more likely to increase TCs because of information incompleteness, the time-spent in contract documentation and negotiation, increased number of staff for contract administration and enforcement of the contract such as quality control etc.

The construction projects are described as unique, complex, uncertain, and high-risk. In such an environment, questionable decisions on planning and design can be made in the pre-contract phase, and disagreements, change orders, claims, conflicts, and disputes can occur in the post-contract phase. In addition, because of the one-off production operation in construction, the procurement process has to begin from scratch every time the client purchases a good or service. These problems contribute to increase the unseen costs (TCs) in project procurement. It is anticipated that applying the TC concept in procurement decision may lead to improve the projects'

performance. Which could lead to an improvement of the procurement process through better contractual agreements, enhanced long-term strategic procurement approaches, improved cost estimation, and defining the most feasible contractual approach under certain circumstances. However, measuring and evaluating TCs in construction projects is always difficult and often broad and subjective (Dudkin & Valila, 2005; Ho & Tsui, 2009; Solino & Gago de Santos, 2010).

Although, previous work on applying the TC concept in construction provides useful information, but there have been only a few studies attempting to quantify TCs in construction. There are very few studies that have explored links between TCs and project delivery systems, and determining the impact of the adopted delivery systems on the magnitude of transaction costs in construction. This research established through relevant literature a thorough compilation of the definition of client-borne TCs in project procurement by joining the views of previous researches, and an empirical study to find the impact of project delivery systems on TCs. This study looks outside traditional construction practices to other fields of study especially organization theory. A better balance of best practices with insightful theories would benefit the construction industry. Also, the current research estimates client-borne TCs at the individual level of construction professionals conducting procurement activities, different from Dudkin and Valila (2005) in the UK (infrastructure projects) and Whittington (2008) in the US (infrastructure projects) who focused on costs incurred at the project level only.

Since productivity is a function of cost versus revenues, developing and improved understanding of the basis of costs offers significant potential to affect construction productivity. More so that the New Zealand construction industry has poor productivity

(Tran & Tookey, 2011) records and extensively making efforts to have a 20% increase in productivity by 2020 (see www.buildingvalue.co.nz). There is a current pressing needs to examine the relationship between project delivery systems and TCs in the New Zealand construction industry. The research project is a unique study in New Zealand that quantifies TCs in construction procurement, and there has been no research before empirically estimate TCs of construction procurement.

THEORETICAL FRAMEWORK

A conceptual model was developed on the basis of theoretical expectations and previous empirical studies by incorporating the constructs with their corresponding measures. It models the direct and an indirect relationship between constructs (i.e. information, procurement, contract administration, contract enforcement, project delivery systems, and TCs). In this study, it is assumed that Information (INFO), Procurement (PROC), Administration (ADMIN), and Enforcement (ENFO) costs collectively determine the Transaction cost (TCs) for the delivery system used.

"Information cost" (INFO) is defined as a factor involving two key activities namely information gathering and communication. "Procurement cost" (PROC) is attributable to six key activities namely attending meetings, preliminary design, translation of client's needs, transition observation, training, and site visits (Hobbs, 1996; Solino & Gago de Santos, 2010). Transaction cost theory is based on the assumption of bounded rationality and opportunism of human behavior and the characteristics of transactions such as uncertainty (Williamson, 1985). This is reflected in administrative, technical, and professional staff growing at the expense of

tradesmen and operatives (Lockyer & Scholarios, 2007). Therefore, as information cost increases, there will be higher transaction costs incurred. In this study, information and procurement costs are incurred because of professionals' daily time-spent in information gathering and procurement.

"Contract Administration cost" (ADMIN) is associated with three key activities: contract administration, conflicts resolution, and decision-making. "Contract Enforcement cost" (ENFO) is defined as a factor involving two key activities namely enforcement (monitoring and control) and verifying compliances. The source of enforcement cost is uncertainties about transaction compliance with specified terms, possible changes in the quality of goods and services, the level of damages to a transacting party arising from contractual non-compliance, and the use of third party in solving disputes (Hobbs, 1996; Solino & Gago de Santos, 2010). Therefore the consequences of enforcing the contract are tangible forms of transaction costs. For example personnel time, auditing fees, inspection charges and investments in measurement devices, arbitration, legal court fees, and costs to bring social pressure. While, the source of administration cost is uncertainties about the willingness of others to trade on certain terms, comply with terms of the contract, and decision-making. These in turn is reflected in tangible forms of transaction costs such as personnel time, travel expense, communication, consulting/service fees, licensing fees, and insurance premiums (Solino & Gago de Santos, 2010). Contract administration and enforcement costs are included in cost estimates as unforeseen and management contingencies. In this study, contract administration and enforcement costs are due to professionals' daily time-spent in implementing the contract terms and conditions (Lynch, 1996; Tridico, 2007; Farajian, 2010). All these

procurement attributes are important for understanding transaction costs in procurement.

Using this framework of factors and dimensions of transaction cost theory, a hypothetical diagram is presented in Figure 1. The direction of the arrow and the sign represent hypothesized relations among the constructs. The corresponding hypotheses are as follows:

H1:   Project delivery systems (SYSTM) would have a significant direct effect on the costs of information (INFO), procurement (PPRO), contract administration (ADMIN) and enforcement (ENFO).

H2:   The costs of information (INFO), procurement (PPRO), contract administration (ADMIN) and enforcement (ENFO) would mediate the relationship between project delivery systems (SYSTM) and transaction costs (TCs).

H3:   Pre-contract TCs, borne by the client in information gathering and procurement, are significantly higher in the Traditional systems than in Design-Build systems.

H4:   Post-contract TCs, borne by the client in contract administration and enforcement, are significantly higher in the Design-Build systems than in Traditional systems.
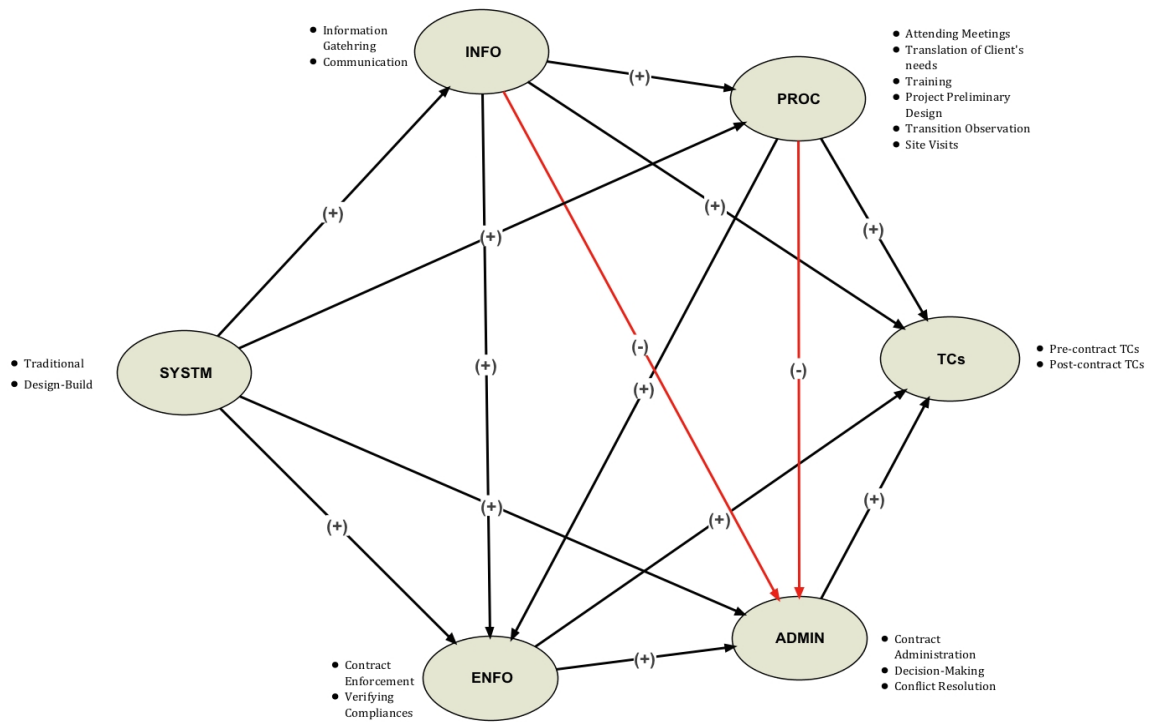
Figure 1: Conceptual model of the link between project delivery system and TCs

The determinants of TCs are presented in Table 1. These determinants were used to estimate the overall TCs for different delivery systems, specifically the Traditional and Design-Build systems for comparison.

Table 1: Constructs and initial measures of Transaction Costs

Construct	Indicator	Description
Information Cost (INFO)	Information Gathering (IG)	Getting information about: potential suppliers/contractors and their behavior, labour market, and prices of construction materials. They are a function of opportunity costs of agent's time and personnel time (Gabre-Madhin, 2001; Baiden et al., 2006).
	Communication (CM)	Effective communication resulting in better cooperation among project stakeholders that eliminates uncertainties in terms of individuals' roles and responsibilities, hence reducing TCs (De Silva et al., 2008; Yang et al., 2009).
Procurement Cost (PROC)	Attending Meetings (AM)	Meetings are a major form of communication during project execution. These include pre-bid, pre-construction, progress, and safety or tool box meetings (Klinger & Susong, 2006; Mincks & Johnston, 2010)

	Translation of Client's Needs **(TN)**	Translation of client's needs in terms of specifications, functional requirements and constrains, and to translate them into perspective information that can be communicated with a contractor (Anumba & Evbuomwan, 2002; Lindahl & Ryd, 2007)
	Project Preliminary Design **(PD)**	Project preliminary design is the first phase of design process. It aims to formalize approved design scheme into more detailed sketches of architectural, structural, and service components. Project managers coordinate a series of meetings with users and the design team for information gathering (Loosemore, 2003).
	Transition Observation **(TZ)**	Transition observation including change to procedures and role or responsibilities (Rahman & Kumaraswamy, 2004; Pryke & Pearson, 2006).
	Training **(TR)**	In training project managers aim at improving the procurement performance, supervision of all procurement activities, and decision-making processes of a project (Edum-Fotwe & McCaffer, 2000; Walker & Rowlinson, 2007).
	Site Visits **(SV)**	Site visits could be for coordination, inspection, resolving dispute, and other interactions (Walker & Shen, 2002).
Administration Cost (**ADMIN**)	Contract Administration **(AD)**	Contract administration such as change order and claims administration (Bajari & Tadelis, 2001a; Cibinic Jr et al., 2006).
	Conflicts Resolution **(CR)**	Dispute resolution aims at providing effective resolutions to construction disputes and enabling clients to avoid conflict as possible. This include negotiation, renegotiation, mediation, and arbitration that need the deployment of extra resources (Gebken & Gibson, 2006).
	Decision-Making **(DM)**	Decision making for example dealing with contractor's problems, making policies, and coordinating with local and central Authorities (Bardhan, 2002; Thomson & Jackson, 2007).
Enforcement Cost (**ENFO**)	Contract Enforcement **(EN)**	Enforcement activities such as monitoring and control, and contract enforcement mechanisms (Ryall & Samspson, 2008).
	Verifying Compliances **(VC)**	Verifying compliances such as time spent in inspection and translation of client's needs (Ryall & Samspson, 2008).

RESEARCH APPROACH

This study investigates the relationship between project delivery systems and TCs in the New Zealand construction industry, and consequently develops a model for this relationship. The model was operationalized and developed into a questionnaire. A cross-sectional sample approach was deployed, involving pilot questionnaire, survey questionnaire and 'real world' cases. Data was sought from professionals in management, design and operations (i.e. Project Managers, Architects, Engineers, Quantity Surveyors, and Procurement Officers). These professionals represented several construction organizations and Councils staff in NZ major city centres (Auckland, Hamilton, Wellington, Christchurch, and Dunedin). TCs were measured using time-spent conducting procurement related activities as a surrogate for cost. Professionals evaluate their time-spent in

procurement activities using a Likert-Scale 1-5 in which 1 denoted *very low* and 5 *very high*, comparing the Traditional and Design-Build delivery systems.

In the first stage, a qualitative method is used seeking experts' opinions on the terminology included in the proposed wide range industry survey questionnaires. A pilot questionnaire was conducted via email among six project managers, an architect, and a civil engineer working on ongoing projects. Based on the feedback received, the questions were refined. A quantitative method was used in the second stage seeking information through a questionnaire survey administered via a web-link (SurveyMonkey). 96 responses (but 74 usable) were received from a sampled population of 320 (23% response). The valid dataset was then tested for Validity and Reliability, Path Analysis, Regression analysis, and Factor analysis utilizing Structural Equation Modelling (SEM). SEM technique was used to yield information on Goodness-of-Fit, model development and comparison, and confirmatory strategies. SPSS Amos 21 was used for data analysis and model development. Finally, in the third stage and for results verification and generalization, a quantitative method was deployed seeking information from real-life cases (projects). Six projects in the Auckland Regional Area were chosen; four projects were procured using Traditional delivery system and two projects were procured using Design-Build system. The data collected were used to test the developed models (Traditional and Design-Build). TCs were calculated using regression equations based on the factor loadings in these models.

RESULTS AND FINDINGS

Demographic information

The results obtained from the wide industry survey show that the respondents' main areas of activity are: Infrastructure (63.64%),

Housing (35.71%), Commercial (25.71%), and Industrial (11.43%). Regarding the respondents' role in the construction process: Project managers (41.43%), Architects (14.29%), Engineers (17.14%), Surveyors (8.57%), Construction Managers (15.71%), and others (i.e. Procurement officers, 22.86%). Further, 25.72% of the respondents have less than 10 years of work experience in the construction industry, 15.71% have less than 20 years experience, 31.43% have more than 20 years experience, with 27.14% have more than 30 years. Regarding contract values of projects handled by the participants, 38.57% of the respondents were involved in projects of less than \$1 million, 30% of respondents were involved in projects of \$5 million or less, 8.57% involved in project of less than \$10 million, 15.71% involved in project of less than \$20 million, 5.71% involved in projects of less than \$30 million, and 11.43% involved in project of more than \$30 million in value. Apparently, the Traditional delivery system is widely used by state owned organizations throughout New Zealand.

Analysis Of Information And Procurement Costs

Respondents were asked to evaluate (using a Likert-Scale 1-5, with 1 denoting *very low* and 5 *very high*) the time-spent daily in information search and procurement activities relative to other project activities. The results show (fig. 2) that the time-spent in information gathering and project preliminary design for Design-Build system is significantly higher than the Traditional system. While the time-spent in communication, attending meetings, translation of client's needs, and transition observation for the Traditional system is higher than the

Design-build system. The time-spent on training for both systems is similar.
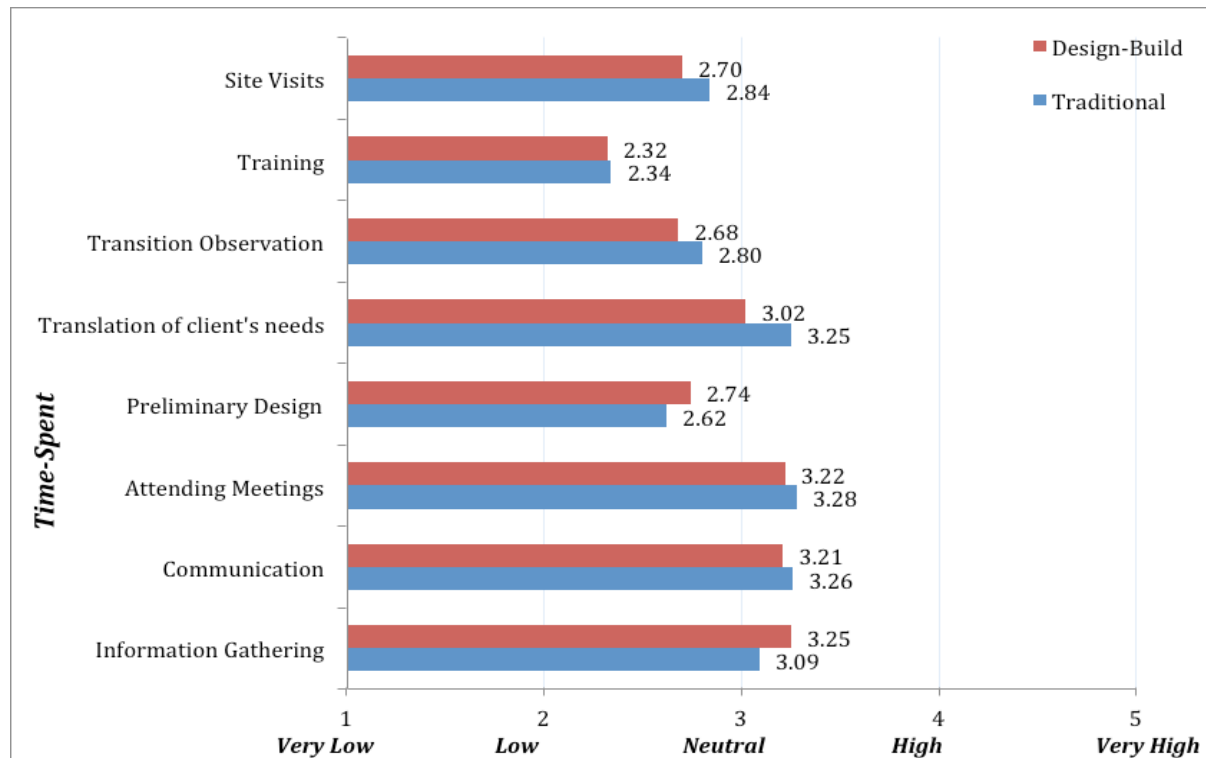
Figure 2: Time-Spent in Information and Procurement

Because the time-spent is used as a surrogate of cost, thus it is apparent that pre-contract TCs for the Traditional systems are higher than Design-Build systems. As mentioned earlier, in the Traditional delivery systems the design is very often completed before construction begins, thus pre-contract TCs are likely to be higher because of the time-spent in defining the project scope before construction begins. Figure 2 shows that the most important drivers of TCs at the pre-contract stage are information gathering, communication, attending meetings,

and translation of client's needs. Therefore, a strategy for executing a project should focus on minimizing these particular costs categories, for example this may be achieved by integrating the design and construction phases.

Analysis of administration and enforcement costs

Respondents were required to evaluate (using a Likert-Scale 1-5 in which 1 denoted *very low* and 5 *very high*) the time-spent in contract administration and

enforcement (post-contract TCs) relative to other project activities. The results show (fig. 3) that the time-spent in contract administration, conflict resolution, decision-making, enforcement, and verifying compliances for the Traditional systems is significantly higher than Design-Build systems.
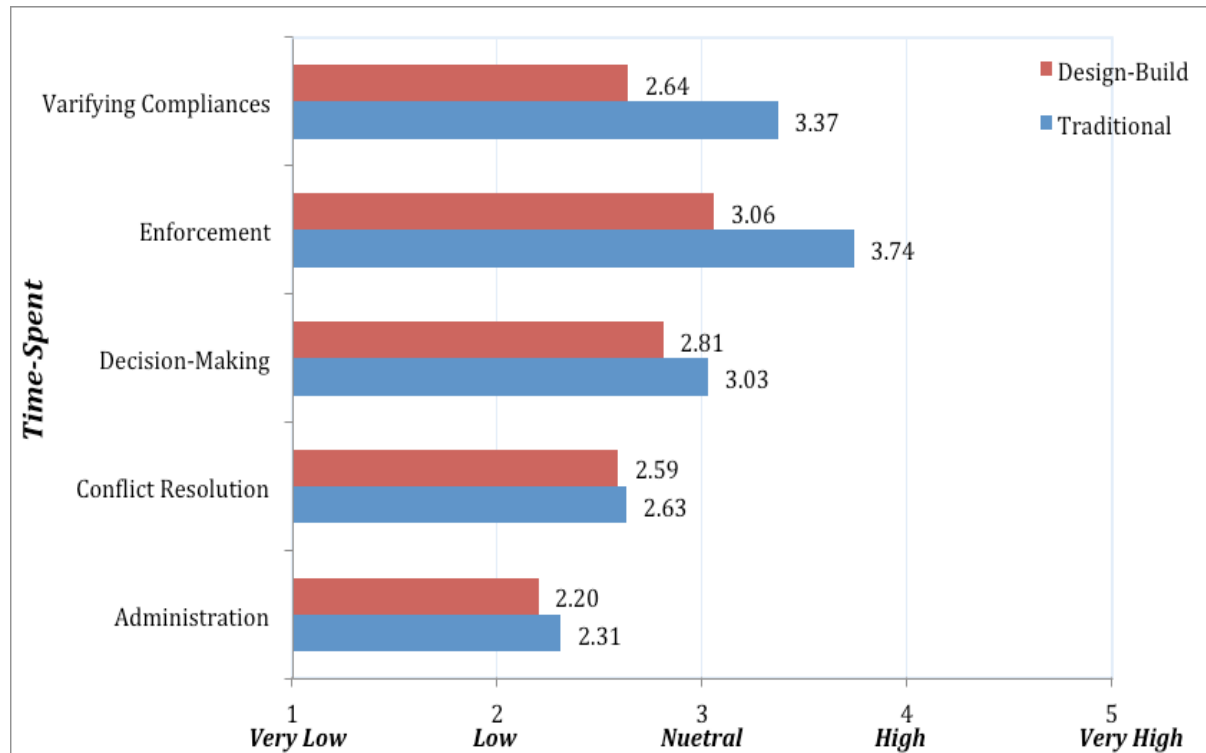
Figure 3: Time-Spent in Contract Administration and Enforcement

Figure 3 therefore depicts that post-contract TCs for the Traditional systems are higher than Design-Build systems using time-spent as a proxy. The main contributors to higher TC at the post-contract stage are decision-making, enforcement, and verifying compliances. Therefore, it is suggested that early contractor involvement at the design phase could be client's strategy for minimizing the costs associated with these cost drivers.

Analysis of SEM results

Data in the previous section have been analyzed using bar charts, but it has limited evidence to support the validity and reliability of the various measures. Validity and reliability of indicators can change when embedded in a theoretical context (Hair et al., 2012). Therefor, for generalized the results this section presents the analyses of Validity and Reliability, Path Analysis, Regression Analysis, Factor Analysis, and SEM. The primary analytical technique used was SEM to yield information on Goodness-of-Fit, model development and comparison, and confirmatory strategies. SPSS Amos 21 statistical software was used for data analysis and model development.

Theoretically, SEM encompasses two types of models: the measurement model and the structural model. The measurement model incorporates confirmatory factor analysis, which is concerned with how satisfactory the variables measure the latent variables, also in addressing issues such as validity and reliability. The structural model reflects multi-regression analysis and path analysis that model the relationship between the latent variables through outlining the explained and unexplained variance. This is equivalent to the examination of the relationship by the regression models (Molenaar et al., 2000). Typically, the measurement model includes the overall variables without causal relationships among them, and the structural model identifies the nature and existence of relationships among variables.

Reliability and Validity Test

Validity and reliability are essential features of a quantitative research inquiry (Li et al., 2012). Prior to data analysis using SEM and to confirm the constructs internal consistency, the scales of the items used to measure each construct are tested for reliability (Hair et al., 2007). Researchers (Amaratunga et al., 2002; Saunders et al., 2011) indicated that reliability

is important for the consistency of research findings offered by the data collection techniques used. Cronbach's alpha values (Table 2) were measured by utilizing SPSS 20, to determine the intercorrelation and reliability of the constructs. Cronbach's test tells how well a set of observed variables measures a single unidimensional latent construct (Gerbing & Anderson, 1988). A Cronbach's alpha coefficient of $\alpha > 0.7$ is considered acceptable reliability for a set of observed items (De Vaus, 2002).

Table 2.0 shows that all Cronbach's alpha coefficients calculated are above the threshold level of $\alpha > 0.7$, which suggests that the set of observed variables are good measures of a single unidimensional latent construct (Gerbing & Anderson, 1988). All factors loading (Fig.1) of the measurement items should be above 0.5 for good model fit. After constructs were tested for reliability and validity, the measurement and structural model are evaluated using confirmatory factor analysis. Model evaluation including examines: the model identification, the relative value of Chi-square, and goodness-of-fit indices.

Table 2: Reliability test of Constructs

Items	Item Correlation Traditional	Item Correlation Design-Build	Cronbach's Alpha Traditional	Cronbach's Alpha Design-Build
Traditional System			.822	.830
Design-Build System			.827	.830
Attending Meeting	.611	.650	.785	.808
Communication	.743	.777	.778	.800
Information	.687	.732	.804	.804

Translation of Client's Needs	.751	.827	.802	.798
Training	.327	.570	.801	.812
Project Preliminary Design	.368	.640	.798	.807
Conflict Resolution	.396	.232	.794	.829
Transition Observation	.463	.646	.776	.809
Verifying Compliances	.548	.606	.788	.811
Decision Making	.779	.751	.782	.801
Enforcement	.647	.691	.784	.804
Site Visits	.708	.684	.822	.805
Administration	.664	.675	.827	.805

Model Goodness-of-Fit Evaluation

A confirmatory factor analysis was conducted for both models (the Traditional and Design-build models) to examine the models identification, the relative value of Chi-square, and goodness-of-fit indices. The developed models using structural equation modelling are over identified, which means the number of parameters is less than the number of observed covariances and variances. In this instance, the degree of freedom augmented and the possibility that the model fits in the population is plausible. Also, the measurement portion of the model is examined so that every latent variable has its scale.

Table 3: Model identification and goodness-of-fit indices

Items	Traditional	Design–Build	Recommended Levels
Model identification	Over identified	Over identified	
Degree of Freedom df	77	77	
Relative Chi-square X^2 / df	2.72	2.72	< 3.0
Root Mean Square Residual RMR	0.09	0.091	< 0.05
Goodness-of-fit index GFI	0.975	0.98	> 0.9

| Adjusted goodness-of-fit index *AGFI* | 0.966 | 0.973 | > 0.8 |
| Parsimonious goodness-0f-fit index *PGFI* | 0.715 | 0.719 | > 0.5 |

For acceptable model fits, the goodness-of-fit index (GFI) should be greater than 0.9; the adjusted goodness-of-fit index (AGFI) greater than 0.8; the parsimonious goodness-of-fi index (PGFI) greater than 0.5; the root mean square residual (RMR) should be less than 0.09; and the relative value of chi-square (X^2 / df) should be less than 3.0 (Hair et al., 2012; Li et al., 2013).

Table 3.0 shows that all the parameters except RMR are within the recommended limits for good fit model, which means that the traditional and design-build models fits the data well. The RMR indices become difficult to interpret if a questionnaire contains items evaluated based on Likert-Scale 1-5, however values as high as 0.09 are deemed acceptable (Hu & Bentler, 1999; Kline, 2011). Lastly, as shown in Table 2 all the constructs are significantly correlated with each other.

Model development: Traditional and Design-Build Models

This study aims at estimating TCs for two delivery systems used in construction projects in New Zealand, specifically for the Traditional and Design–Build delivery systems for comparison. Relationships were proposed in this study through direct and indirect relationships among constructs. Single head arrow pointing towards a variable with path coefficient represents direct relationship, while an indirect relationship is represented with intervening variable (i.e. mediator and moderator variable). The theoretical framework (fig. 1) of the relationships between TCs, project delivery systems, and information, procurement, administration, and enforcement costs was developed to structural model. According to Gerbing and Anderson (1988), developing and assessing a structural model provides an excellent and comprehensive confirmatory evaluation of construct validity.

Amos 21 was utilized to develop the pattern of relationships among the constructs. The structural models were recursive (repeated or related relationships among variables), which means all paths proceeded from a predictor construct to the resulting construct. Meanwhile, a non-recursive relationship between any two constructs implies that their relationship is causal and they influence each other. As stated by Hair et al. (2012), the situation of a causal relationship is unlikely with cross-sectional data. The resulting paths from conducting SEM using Amos 21 were indicated on a path diagram, which depicts the relationships among

variables through principal regression equations that were solved for various parameters.

Finally, in this study the costs of information, procurement or contracting, administration, and enforcement were hypothesized through first-order factors (direct relationship). Transaction costs were hypothesized through a second-order structure, and project delivery systems impact was also hypothesized through a

second-order structure. The hypothesized relationships were finally presented in two comprehensive models: for the Traditional (fig. 4) and Design-Build (fig. 5) delivery systems. The models explain the hypothesized impact of project delivery systems on TCs. They were used to test the developed Hypotheses and estimate TCs, by means of factor loadings and regression relation between constructs.
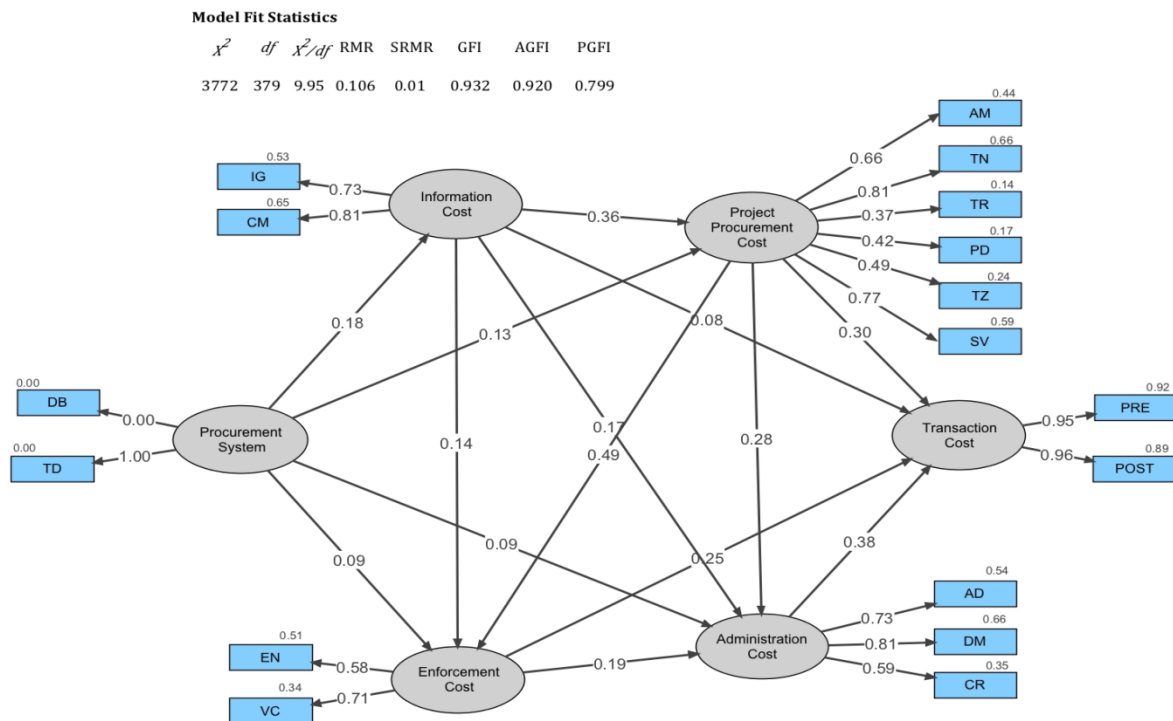
Figure 4: The Traditional Model
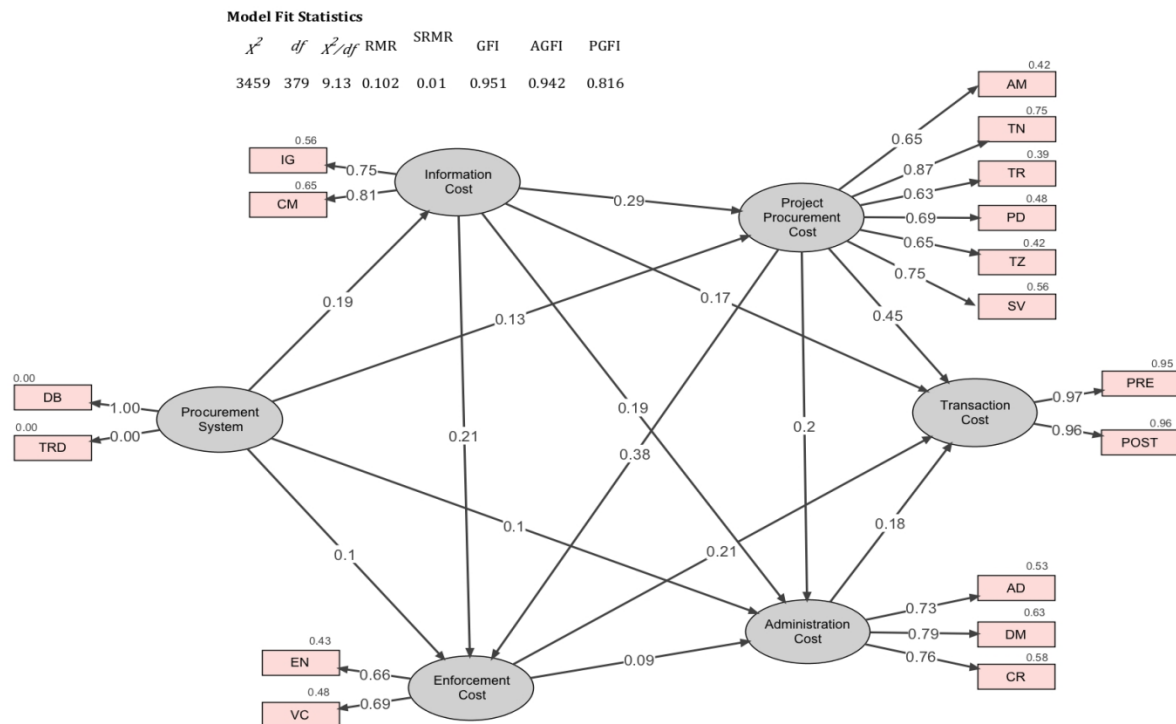
Figure 5: Design-Build Model

Hypothesized Relationships

The structural models (fig. 4 and 5) reflect multi-regression analysis and path analysis that model the relationships between the latent variables by outlining the explained and unexplained variance. Sign, size, and statistical significance of the path coefficients represent the strength of relationships among the constructs. The hypothesized relationships were determined by testing the developed models using Amos 21. Maximum likelihood and bootstrap function were used to estimate hypothesized paths with a resampling size (a so-called "Bootstrapping" exercise) of 1000. The hypothesized relationships as shown in fig.

4 and 5, and based on path coefficients are positive and significant (i.e. $\beta > 0.01$).

Further, the Traditional and Design-Build models are used to test the study Hypotheses. They provide support for the study Hypotheses (1 and 2) through the significance of the paths coefficients. For instance, as shown in the models, Hypothesis 1 *(Project delivery systems would have a significant direct effect on the costs of information, procurement, contract administration and enforcement)* is supported. INFO is significantly influenced by SYSTM at $\beta = 0.18$ for the Traditional and $\beta = 0.19$ for Design-Build. Also, SYSTM has a substantial effect on PPRO at $\beta = 0.13$ for both systems. Further, SYSTM has a significant effect on

ADMIN at $\beta = 0.09$ for the Traditional and $\beta = 0.1$ for Design-Build. Finally, SYSTM significantly influence ENFO at $\beta = 0.09$ for the Traditional and $\beta = 0.1$ for Design-Build.

Hypothesis 2 *(INFO, PPRO, ADMIN and ENFO would mediate the relationship between SYSTM and TCs)* is also supported. INFO fully mediates the relationship between SYSTM and TCs, which is significant at $\beta = 0.26$ *(SYSTM$\rightarrow$ INFO$\rightarrow$ TCs)* for the Traditional and $\beta = 0.36$ for Design-Build. Also, PPRO is fully mediated the relationship between SYSTM and TCs, which is significant at $\beta = 0.43$ for the Traditional and $\beta = 0.58$ for Design-Build. Further, ADMIN mediates the relationship between SYSTM and TCs, which is substantial at $\beta = 0.47$ for the Traditional and $\beta = 0.28$ for the Design-Build. Finally, ENFO mediates the relationship between SYSTM and TCs, which is significant at $\beta = 0.34$ for the Traditional and $\beta = 0.31$ for the Design-Build.

Applying the Models Using real-life Cases

For results verification and generalization six projects were selected to test the developed models, and to calculate and compare TCs for the Traditional and Design-Build systems. The six projects comprise: four infrastructure projects, one project from residential sector, and one asset management project. Out of the six projects, two infrastructure projects (one from the Traditional and the other from Design-Build) of same contract value and duration were chosen for comparison.

A survey questionnaire was sent via e-mail to 6 subject matter experts mainly project managers involved in ongoing projects. This included four project managers working on infrastructure projects, a project manager working on asset management projects, and an architect working on residential projects. Respondents were asked to estimate their time-spent daily in conducting procurement activities. The key theme is to set a benchmark on how to calculate TCs in construction procurement using the developed models, with the intention of this practice to be carried out for other project delivery systems used in construction. The findings from this questionnaire provide a further insight to the understanding of TCs in construction. Also, by conducting this practice, bias can be minimized and the validity/generalization of the findings can be enhanced.

Table 4 shows that four of the projects (case 1 to 4) were procured using the traditional delivery system. The two infrastructure projects that were chosen for comparison are: Case 2 and 5. Case 2 is a project for the improvement of a main road in West Auckland procured in a Traditional delivery system, with a contract value of NZ$50M and scheduled to be delivered in 48 months. Case 5 is a NZ$40M project for upgrading a main road in Central Auckland, scheduled to be completed in 48 months and procured in a Design-Build delivery system.

Table 4: Project's Demographic Information

Case	Project Type	Contract Value	Project Duration	Delivery System
Case 1	Infrastructure	$25 million	60 months	Traditional
Case 2	Infrastructure	$50 million	48 months	Traditional
Case 3	Infrastructure	$654,000	12 months	Traditional
Case 4	Infrastructure	$600,000	8 months	Traditional
Case 5	Infrastructure	$40 million	48 months	Design-Build
Case 6	Housing	$2.8 million	12 months	Design-Build

Table 5 summarizes the estimated time-spent by the project manager at the pre and post-contract phases for Case 2. Data analysis shows that the project manager spent in aggregate $5^{1/}_{2}$ hrs. in conducting procurement activities. However, the total time might have a percentage of overlaps between activities, which might compromise the aggregate time-spent on each activity alone. For instance, out of the total time-spent, this research considered the time-spent by project managers in information search, procurement, administration, decision-making, and conflict resolution as contributing to increased TCs.

While, the estimated time-spent by the Project Manager for Case 5 is summarized in Table 6. It shows that the project manager spent in aggregate $4^{3/}_{4}$ hrs. in conducting procurement activities.

Table 5: Time-Spent Estimates for Case 2

Participant's Designation	Phase	Activity	Measure	Time-spent (hrs./day)	Total Time-spent (hrs./day)
Project Manager	Pre-Contract	Information Search	IG	1/4	$1^{1/}_{4}$
			CM	1	
		Project Procurement	AM	$1^{1/}_{4}$	2
			TN	0	

			TR	0	
			PD	1/4	
			TZ	0	
			SV	1/2	
	Post-Contract	Contract Administration	AD	1/2	$1^{1/}{}_{2}$
			DM	1/2	
			CR	1/2	
		Contract Enforcement	EN	1/4	3/4
			VC	1/2	

Table 6: Time-Spent Estimates for Case 5

Participant's Designation	Phase	Activity	Measure	Time-spent (hrs./day)	Total Time-spent (hrs./day)
Project Manager	Pre-Contract	Information Search	IG	1/4	3/4
			CM	1/2	
		Project Procurement	AM	1	$1^{1/}{}_{2}$
			TN	0	
			TR	0	
			PD	0	
			TZ	0	
			SV	1/2	
	Post-Contract	Contract Administration	AD	1/2	$1^{3/}{}_{4}$
			DM	1	
			CR	1/4	
		Contract	EN	1/4	3/4

		Enforcement	VC	1/2	

To calculate TCs for the two delivery systems in a way that it aids clients' procurement decisions, Hypotheses (3 and 4) assumed that pre and post-contract TCs are higher in the Traditional systems than in Design-Build systems. For instance, the models can be used to estimate and evaluate the root causes of high TCs. They are calculated on the basis of regression equation analysis, which is explained by the interrelationship strength coefficients between latent variables in the developed models. Simple and multi regression analyses were employed for predicting the time-spent. Simple regression involves measuring a single measured dependent variable, while multi-regression involves more than one measured independent variables. Accordingly, TCs were predicted in accordance to the procedures described below.

For the Traditional delivery systems

1. Predicted time-spent in information search

$$INFO = B + 0.81*CM + 0.73*IG$$

2. Predicted time-spent in procurement

$$PPRO = B + 0.66*AM + 0.81*TN + 0.38*TR + 0.42*PD + 0.49*TZ + 0.77*SV$$

3. Predicted time-spent in contract administration

$$ADMIN = B + 0.73*AD + 0.81*DM + 0.6*CR$$

4. Predicted time-spent in contract enforcement

$$ENFO = B + 0.59*VC + 0.71*EN$$

5. Predicted total time-spent with mediation and moderation effects

$$TS = B + 0.36*INFO + 0.3*PPRO + 0.08* INFO *PPRO \ 0.19*ENFO + 0.38*ADMIN + 0.25*ENFO*ADMIN$$

6. Predicted Transaction costs

$$TCs = TS*HR$$

Where:

B is a constant where to anchor the line slope in the Traditional model, *B = 0* when the linear relationship starts at 0,0 origin

HR is the hourly-rate for a construction professional

Case 2

Applying the steps 1-6 to calculate TCs using Table 5

1. ***INFO*** *= 0.99 hrs. /day*

2. ***PPRO*** *= 1.32 hrs. /day*

3. ***ADMIN*** *= 1.07 hrs. /day*

4. ***ENFO*** *= 0.47 hrs. /day*

5. **TS** = *1.478 hrs. /day*

6. **TCs** = 1.478 * 65 = $96.1/day

Note: For an experienced project manager such as in this case, the annual salary is NZ$135,000 (i.e. Hourly-rate $65/hr.) obtained from:

http://www.careers.govt.nz/jobs/management-consulting/project-manager/

The results show that the magnitude of TCs, as a result of Project Manager performing procurement activities, is **$96.1** per day. Thus, for a project procured in a traditional delivery system with contract value of NZ$50 million, and scheduled to be complete in 48 months as in case 2, the total TCs incurred while a Project Manager performs procurement activities is equal to **$99,951**. Representing **18.5%** of the annual salary cost of a Project Manager.

For Design-Build delivery systems

1. Predicted time-spent in information search

$$INFO = B + 0.81*CM + 0.75*IG$$

2. Predicted time-spent in procurement

$$PPRO = B + 0.65*AM + 0.87*TN + 0.63*TR + 0.69*PD + 0.65*TZ + 0.75*SV$$

3. Predicted time-spent in contract administration

$$ADMIN = B + 0.73*AD + 0.79*DM + 0.76*CR$$

4. Predicted time-spent in contract enforcement

$$ENFO = B + 0.66*VC + 0.69*EN$$

5. Predicted total time-spent with Mediation & Moderation effects

$$TS = B + 0.29*INFO + 0.45*PPRO + 0.17*INFO*PPRO + 0.09*ENFO + 0.18*ADMIN + 0.21*ENFO*ADMIN$$

6. Predicted Transaction costs

$$TCs = TS*HR$$

Case 5

Applying the steps 1-6 to calculate TCs using Table 6

1. **INFO** = *0.578 hrs. /day*

2. **PPRO** = *1.025 hrs. /day*

3. **ADMIN** = *1.345 hrs. /day*

4. **ENFO** = *0.503 hrs. /day*

5. **TS** = *1.159 hrs. /day*

6. **TCs** = 1.159 * 65 = $75.34/day

The results show that the magnitude of TCs, as a result of project manager performing procurement activities, is **$75.34** per day. Thus, for a project procured in a Design-Build delivery system with contract value of NZ$40 million, and scheduled to be complete in 48 months as in case 5, the total TCs incurred

while a project manager conducts procurement activities is equal to **$78,354** (worked out on 260 working days/year). Representing **14.5%** of the annual salary cost of a Project Manager.

DISCUSSION

To estimates the TCs for different delivery systems in line with Williamson (1998) wherein human and environmental forces were considered the most important contributory factors to TCs; cognitive mapping and path models were used to depict and interpret various factors highlighted in Table 1. Reliability and validity of the eight constructs (in Table 2) focused on by this study are satisfactory. The Goodness-of-Fit Indices of the structural models (Tablet 3) are also quite satisfactory for both models. Models for Traditional and Design-Build systems were developed to test Hypotheses of the study. Sign, size, and statistical significance of the path coefficients represent the strength of relationships among constructs. The hypothesized relationships in the models were tested using SPSS Amos 21. Maximum likelihood and bootstrap function were used to estimate hypothesized paths with resampling of 1000. The results indicate that all path coefficients were statistically significant at $\beta > 0.01$ (fig. 4 and 5). In addition, the results of applying the models to real life cases confirmed the hypothesized relationships between the project delivery systems and the magnitude of the pre and post-contract TCs. Summaries of

Hypotheses testing are discussed in further detail in the next section.

"*Project delivery systems would have a direct significant effect on the costs of information, procurement, contract administration and enforcement*".

The figure 4 and 5 confirms that the project delivery systems have a direct effect on the costs of information, procurement, contract administration and enforcement. The effect of the Traditional system on information cost is significant at $\beta = 0.18$ while for Design-Build system, it is significant at $\beta = 0.19$. Therefor both systems have similar impact on information cost. Project complexity and uncertainty is the main contributor to high information cost whether the project is procured using Traditional or Design-Build. Similarly, the project delivery systems have a direct effect on procurement cost. It is significant at $\beta = 0.13$ for both systems. Both human and environmental uncertainties are the most contributors to higher procurement cost.

Procurement's impact on contract administration cost is significant for both systems at $\beta = 0.09$ and $\beta = 0.1$ respectively. The results show that conflict, disputes, and decision-making are the main factors that influenced contract administration cost. Also, project delivery systems have a significant direct impact on contract enforcement cost at β

= *0.09* and *β = 0.1* respectively (fig. 4 and 5). Conflict, disputes, and decision-making are the main factors that influenced the contract enforcement cost.

> "*TCs are higher in the Traditional systems than in Design-Build systems*"

In addition, the results of applying the models to real-life cases confirmed Hypotheses (3 and 4), which assume pre and post TCs are higher in the Traditional system than Design-Build system. TCs represents **18.5%** of the annual salary cost of a Project Manager in the Traditional system, and represents **14.5%** of the annual salary cost of a Project Manager in the Design-Build system.

Implications of TCs

This study finds there is a significant relationship between project delivery systems, information cost, procurement cost, contract administration and enforcement costs, and TCs for construction projects. The finding has implications for construction business practice because the research is empirical in nature, relied on construction professionals experience, case studies, and feedback. Also, the study is based on a robust theoretical framework (fig. 1) that illustrates the impact of TCs on procurement decision, and the associated practice in construction projects. The findings allow organizational and economic implications of TCs to be assessed, which demonstrates how the adoption of the TCs perspective alters the

organizational dynamics of the construction and project delivery systems.

The developed models will inform strategic thinking with regards to the importance of identifying unseen cost in construction procurement. Solely focusing on the design of formal procurement processes and procedures is not enough for cost savings, minimizing claims, and reducing conflict and disputes in construction projects. There is a further need to consider the interaction of transaction costs, and the costs of information, procurement, contract administration, and contract enforcement, which has been clearly demonstrated by the current study investigation.

CONCLUSION

Transaction cost evaluation provides a practical framework for selecting the appropriate delivery systems in construction. Many researchers have applied the TCE concept in different topics in construction (Eccles, 1981; Gunnarson & Levitt, 1982; Reve & Levitt, 1984; Winch, 1989; Lynch, 1996; Bremer & Kok, 2000; Bajari & Tadelis, 2001b; Turner & Simister, 2001; Miller et al., 2002; Dudkin & Valila, 2005; Antinori & Sathaye, 2007; Whittington, 2008; Ho & Tsui, 2009; Farajian, 2010; Solino & Gago de Santos, 2010; Aibinu et al., 2011). However, there are only a few studies that attempt to quantify TCs in construction. This study has shown the potential for estimating the magnitude of TCs for two project delivery systems in

construction. Hence the TCs associated with the pre and post contract phases (e.g. information, procurement and contracting, administration, and enforcement) on projects procured through Traditional and Design-Build systems are determined.

A cross-sectional sample approach was deployed; involving pilot and survey questionnaires, and the results of the investigation was verified using 'real world' cases. Data was collected from construction professionals in management, design and operations (e.g. Project Managers, Architects, Engineers, Quantity Surveyors, and Procurement Officers). TCs were measured using time-spent on procurement related activities as a surrogate for cost. The participants evaluated their time-spent (using a Likert Scale 1-5) on procurement activities, within projects procured through Traditional and Design-Build delivery systems. The collected data was analyzed using a structural equation modelling technique.

The pre and post-contract TCs are determined through a developed path analysis model or structural model utilizing SPSS 20 and Amos 21. Structural and measurement models were used to determine: firstly, the existence of a single latent independent variable as a result of a set of measurement items, and secondly, the relationship between the latent variable and observed variables by means of the path direction and coefficients strength. In conclusion, for projects that have the same

contract value with the same scheduled delivery time, it was found that the amount of TCs relative to Project Managers' annual salary cost was **18.5%** and **14.5%** for the Traditional and Design-Build delivery systems respectively.

Finally, regression equations were formulated to guide decision-makers on the use of the developed models for estimating in-house TCs borne by clients because of professionals' involvement in conducting procurement activities. The developed models could benefit construction owners practices through: firstly, improving the ability to estimate unseen procurement costs; secondly, ensuring adequate funding because of certainties in cost estimation; and finally defining the most appropriate delivery system under certain circumstances.

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Developing activity-based cycle diagram for simulating a bridge construction operation

DEVELOPING ACTIVITY-BASED CYCLE DIAGRAM FOR SIMULATING A BRIDGE CONSTRUCTION OPERATION

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ABSTRACT

Proper planning and control of activities on a construction project is central to successful performance. However the planning function is cumbersome due to the inherent features of construction operations such as high repetitiveness, complexity and uniqueness. Also the more modern the construction methods used, the more tedious planning becomes requiring deeper project analysis.

Bridge construction projects are more challenging among construction projects from the perspective of planning and management, especially with process automation in bridge construction works. For example, incremental launching is an automation recently employed in many bridge projects that increases the level of planning/ management issues. The dilemma that bridge construction projects face today is that schedulers accomplish the planning of a bridge project based on their experiences since construction methods are often new and there is no specific WBS/conceptual framework yet.

The aim of the current study is to facilitate bridge construction projects planning and management by introducing a new technological-based tool (simulation). The paper describes the process followed in the development of a conceptual framework/ WBS which accounts for the interaction between the varieties of resources involved on a case study (bridge) project where the incremental launching method is used. An Activity Cycle Diagram is produced alongside conceptual framework and process models with the intent of illustrating the key steps in the simulation modelling procedure. The developed models can eventually assist in scheduling and controlling inherent features; uncertainties, complexities, and repetitions in bridge construction projects, consequently improving their delivery. The study shows the potential application of the simulation-based tool called EZStrobe.

KEYWORDS: Activity Based Cycle Diagram, Bridge Construction Operation, Conceptual Model, System Behaviour, Simulating Procedure, EZStrobe.

INTRODUCTION

Construction projects or operations are a collection of activities that are linked together through resources which are used for their accomplishment according to their logical sequence (Halpin & Riggs, 1992). These series of activities make a chain that defines a project's activity cycle. According to Shi

(1997) the cycle could either be closed or an opened loop with complex interdependencies of resources that are consumed by the project. The task of every project manager is to plan for the use of resources in a manner that supports these logical sequences required of construction operations. This task is made cumbersome by the complexity and dynamic characteristics of construction projects with Halpin and Riggs (1992) suggesting that the planning function is crucial, knowledge-intensive, often ill-structured and a challenging stage in every development project.

In bridge construction projects (BCP) the planning and analysis function is even more complex because such projects are associated with uncertainties arising from their construction sequence and associated constraints, resourcing issues and structural inadequacies (Chan & Lu, 2012). Ailland, Bargstädt, and Hollermann (2010) conclude that planning methods that feature adequate adaptability; support the description of parallel processes, unexpected incidents and stochastic and fuzzy parameters are therefore to be encouraged for non-stationary construction projects.

A host of simulation-based techniques for scheduling construction projects are in use. Some are/are not specific to the construction industry, while some others have been developed to deal with specific conditions like repetitive or cyclic performances. The selection of an appropriate simulation tool requires prior understanding of and analysis of a construction project.

In the current study, the authors investigate the potentials for the application of simulation-based technique for facilitating the scheduling and management of a bridge construction project that is based in New Zealand. The study takes into cognisance, constraints/uncertainties and complex interactions among the bridge

project's components, towards developing a simulation model for the project. The field investigation undertaken is described within the paper to demonstrate the capabilities of EZStrobe simulation tool in developing a conceptual model and eventually scheduling a bridge construction project that uses an incremental launching method.

LITERATURE REVIEW

Simulation Techniques and Tools

There is a host of techniques for planning construction projects. Most of these are not specific to the construction industry while some others have been developed to address specific features of construction operations such as its repetitiveness. The basic steps involved in any planning procedure are: 1/ identifying project activities and determining their duration, 2/ sequencing the activities in a logical manner, and 3/ preparing the project schedule (Hajjar, 1999).

Wu, Borrmann, Rank, Beißert, and König (2009) insists that the creation of a manual schedule of construction projects is time-consuming. Construction project scheduling basically relies on the knowledge and expertise of planners. Therefore, some researches capture human knowledge to overcome the scheduling issues. The developed system on the basis of human knowledge could represent the expertise in the form of a set of computational-based data and rules. The case-based reasoning techniques developed by Mikulakova, König, Tauscher, and Beucke (2008) is an example of such systems. Another example is integrated knowledge-based systems for estimating and scheduling of construction projects' costs presented by A. Mohamed and Celik (2002).

There are other techniques like graph based techniques which have been employed to

analyse project's tasks, estimate their duration, and identify the minimum time required to complete projects. The most common one is Critical Path Method (CPM) that is used for drawing up robust schedules. It has also been used in the technique presented by Koo, Fischer, and Kunz (2007) to support the rapid development of sequencing alternatives in construction schedules.

Some inherent features of construction projects like complexity and uncertainty enclose any estimation of activity's duration, and consequently make a higher critical schedule. Therefore, to address this problem, Pontrandolfo (2000) used PERT-state and PERT-Path techniques with a focus on network complexity and time uncertainty. Further, the repetitive feature of construction projects have been addressed using Petri-Nets based approach proposed by Biruk and Jaśkowski (2008).

Achieving almost optimum solutions by considering resource consumption and project duration is an aim of recent researches. In this way, multi-constraint optimization algorithms are proposed. This approach presented by Beißert, König, and Bargstädt (2007) was able to generate valid execution schedules considering different construction requirements and execution constraints. Beißert, König, and Bargstädt (2008) applied a simulation approach on the basis of constraints which they called Greedy Randomized Adaptive Search Procedures (GRASP). GRASP is a meta-heuristic technique that generates valid and optimized solutions rapidly. Another optimization model applied in scheduling of linear construction projects is a genetic algorithm-based multi objective optimization that was introduced by Senouci and Al-Derham (2008).

Even though knowledge-based systems have addressed construction projects characteristics within scheduling techniques, they only provide partial schedules. Additionally, extra effort is required to adapt them for practical use. The other drawbacks of such methods, as König, Beißert, and Bargstädt (2007) mentioned, are the tedious and time-consuming progress in the preparation of the input data, and performing a multitude of simulation runs to achieve a significant set of solution. An example is the Monte Carlo simulation technique.

To overcome these aforementioned issues, R. y. Huang, Chen, and Sun (2004) implemented a computer simulation tool called CYCLONE. CYCLONE has been applied in the standardization of mould systems in construction procedure automation, which resulted in increased productivity and improved operational efficiency. Extensive application of computer simulation in construction projects as proposed by Gonzalez-Quevedo, AbouRizk, Iseley, and Halpin (1993), are found in numerous areas such as bridge works, tunnel projects, reverse circulation foundation pile works, concrete delivery from pre-mix concrete plant, sewage works, and road works. A developed tool called Simphony^{TM} is a powerful simulation-based modelling approach among those applied in tunnelling works. Fernando, Er, Mohamed, AbouRizk, and Ruwanpura (2003) proposed this model for evaluating different construction alternatives, planning, risk analysis and lean construction process.

Analysis of literature on construction simulation has been done by El Ghandour (2007) using three analysing tools: 1/ based on definition of construction applications areas for simulation, 2/ based on the main functions of construction simulation engines and/or languages according to the objects to be modelled, and 3/ based on tracking of the developed simulation engines and/or languages. This literature analysis on construction simulation covered the period from 1976 to

2002. The results show that some areas such as changes orders, constructability, and quality control have not enjoyed the benefits of simulation. Further, the review shows that simulation models were not able to transfer data well with other software applications within the construction domain, or with other simulation models developed in other areas. There were no flexible generic elements to cover all types of data that need to be transferred. Resource-based simulation engines started in 1987 with Paul and Chew (1987) and followed by researchers within 1992 to 1994. When the Activity Based Cycle was introduced by Shi (1999) cited in (El Ghandour, 2007) , the attention to resource-based simulation declined. In the period of 1976 until 2002, there was a trend for developing simulation models based on process or activity elements. Concurrently, new trends such as product-based and function-based approaches have evolved. El Ghandour (2007) suggests that these new trends are the most interesting ones within Research and Design (R & D) in the coming decade.

Decision Making Progress in Construction Activities

Construction engineering is traditionally based on experience and heuristic rules from the prospect of planning and management (Fu, 2013). There is a need to make the right decisions by the project management team. In the other words, project management is challenged to balance trade-offs among different objectives before and during a project (Fu, 2013). There are various techniques and tools that have been developed to support managers with making the right decisions.

According to Mawdesley, Askew, and Al-Jibouri (2004) managers perform planning based on experience rather than careful analysis. In a study of four project planners, for a period of one week, Mawdesley et al. (2004)

conclude that project planners made their decisions based on personal preferences. Mawdesley et al. (2004) found that planning procedures differ among the planners for two main reasons, even though construction methods were almost similar on their projects. The first reason relate to the unique feature of construction operations. The second reason is associated with the experience of the managers which enabled them to know the planning problems in advance and then acted reflexively to resolve them. Therefore, the decision making process seems to be subjective and rely highly on individual planners' intuition, knowledge, and experience (Fu, 2013; Mawdesley et al., 2004). In the absence of formalized and systematic approaches in construction projects planning, most of managers approach decision making based on their years of field experience, judgement, and rules of thumb rather than theory and analysis (Fu, 2013). Construction managers depend on their skills and common sense during their daily decisions (Y. Mohamed & AbouRizk, 2005) . Further, they are unable to track the ultimate effects of their decision on the project's productivity and final cost when they use traditional project management tools, because different effective feedback loops are formed due to mutual interactions between organization effective factors (Y. Mohamed & AbouRizk, 2005).

The use of conventional decision making tools does not allow construction managers to evaluate final effects of different alternatives as there are complex interactions among a variety of organizational and operational effective parameters Y. Mohamed and AbouRizk (2005). The examples of these parameters are 'work start time and finish time', 'duration of work and rest period', 'shift work' and 'the amount of overtime during the week'. In this regard, Y. Mohamed and AbouRizk (2005) proposed that the main problems with most of traditional modelling approaches are that they are only able to capture system interactions at either the

operation level or context level of feedback between the context (organizational) level and operation level variables inside the desired systems. Therefore, the complicated behaviours of construction systems cannot be captured especially over the long-term life cycle of that system (Y. Mohamed & AbouRizk, 2005).

Alvanchi (2011) introduced and validated a hybrid approach to improve decision making process by addressing such feedbacks. In this way, Alvanchi (2011) expresses that the contribution of decision making process and organizational policies into project fluctuations over time, on one side, and the uniqueness of construction projects on the other side, always highlight the needs of human communication and judgement during project execution. Therefore, the support of decision making process has received lots of attention in most research that deal with process modelling in construction management. In addition to linear and non-linear optimization models, simulation-based techniques were used for supporting decision making. As Tecnomatix (2006) (cited in (Ailland et al., 2010)) indicated, the use of simulation tools is increasingly attractive when a process is more complex and there are multiple influences which must be taken into account. AbouRizk, Halpin, and Lutz (1992); Song, Wang, and AbouRizk (2006) suggest that modelling and simulation of construction process could support construction planning and assist managers/ planners with reducing the risks associated budget, time and quality. Unfortunately, the use of computationally based modelling approaches such as realistic simulation has been limited in construction industries (Devulapalli, 2002). With the advances in technology in the last decade, simulation models have been developed and evaluated from the aspect of decision making support. Devulapalli (2002) explains that realistic simulation models are able to capture all the inherent uncertainty in project data.

Policy analysis tools have been developed and implemented by Devulapalli (2002) in bridge construction operation, where efficient management of the scarce resource is the most important challenge. The method helps decision makers to manage funds effectively and maintain bridges. Further, Devulapalli (2002) developed the policy analysis tool using discrete event simulation, for predicting network health under different scenarios to facilitate the discrete Salem Bridge System.

Decision makers also need to be supported from another prospects such as changing the logic of construction process in a cost-effective way. When mathematical modelling approach is not available, simulation modelling can be useful to achieve the most suitable solution to the construction problem since it could help planners to predict the effect of decisions on such changes in the project without implementing those changes in reality. As Devulapalli (2002) mentioned Discrete Event based simulation (DES) is the most powerful and suitable tool to support decision making in projects where uniqueness, complexity, and dynamism are prominent. Recent development of DES in construction engineering has made the interfaces between operations research and computer science possible. Construction managers are able to improve their operations by experimenting different possible scenarios provided by DES. Thus simulation assists their decision making by determining the best strategy for execution of specific operation in practice (Devulapalli, 2002).

As previously explained, the use of simulation in the construction sector has not received the deserved attention because its implementation requires knowledge and effort. Y. Mohamed and AbouRizk (2005) recent studies to remove this obstacle, focused on developing simulation tools that reduce model development and experimentation time on the construction engineer's side, by packaging most of the

required knowledge into the tool itself. Y. Mohamed and AbouRizk (2005) believe that such intelligent tools can influence the way of implementing simulation in day-to-day decision making progress in construction. A combination of simulation experiments along with decision makers' knowledge could provide construction operations with helpful recommendations (in terms of various scenario analyses) that ensure the projects' achievement (AbouRizk (2010).

Simulation of Construction Projects

The ineffectiveness of traditional construction planning methodologies to support today's project features have been suggested by Sriprasert and Dawood (2002) as the main reason for project failures and low productivity. Thus, proper planning is important to ensure timely and economical completion of projects (Puri, 2012). Project planners would therefore need to seek integrated approaches using new technologies in construction management processes. Simulation has thus evolved as a useful model-building tool in the construction domain. This evolution provides construction planners/managers with tools that enable them to quickly model construction operations without requiring them to possess extensive knowledge of simulation techniques (Y. Mohamed & AbouRizk, 2005). Cheng and Feng (2003) have indicated that project planners could use simulation to predict the performance of construction operations in terms of process flows and resource selection. Simulations have also been employed in productivity measurement, risk and site planning (Sawhney, AbouRizk, & Halpin, 1998).

Simulation modelling methodologies vary depending on the nature of the projects to be modelled, and in the construction domain, simulations are applicable to a wide spectrum of operations (Y. Mohamed & AbouRizk, 2005). For example, AbouRizk, Halpin, Mohamed, and Hermann (2011) demonstrate the usefulness of simulation on the design of construction operation involving multiple interacting factors that produce unpredictable outcomes, and stochastic events which are difficult to anticipate. Moreover, Appleton, Patra, Mohamed, and AbourRizk (2002) conclude that construction simulation is a well-tested decision making tool that allows users to analyse various production scenarios at the pre-construction phase of projects. Thus analysts and construction industry personnel could experiment with different construction technologies and estimate their impact on schedules and costs (Appleton et al., 2002). Additionally, Lucko, Swaminathan, Benjamin, and Madden (2009), show how simulation technology benefits construction industry users by using existing process-related data from schedules as inputs to create a functioning simulation model with little or no user intervention. Most research approaches deal with construction process modelling in support of the decision making process.

Simulation of Bridge Construction Projects

The inherent features of bridge construction projects, which arise from their performance sequences, constraints, resourcing issues and structural adequacies, make their planning and analysis more complex (Chan & Lu, 2012). Hohmann (1997) (as cited in (Ailland et al., 2010)) indicated that factors such as shifting boundary conditions, project time and cost constraints, difficult logistical requirements and the high probability of unexpected incidents occurring , are common to non-stationary construction processes like bridge works. Bridge work planners would therefore need to employ scheduling techniques that are able to give better control and steer the use of resources more efficiently.

Kim (2007) described simulation as a building and investigation process for a computerised model of a system which captures various time measures such as real time, and expanded and compressed time, to improve the behaviour of a process or system. Simulation is able to model any system with any set of conditions in a more practical way since it runs the computerised model of a system rather than finding an analytical solution. This potential of simulation makes it more advantageous than traditional scheduling methods like CPM and PERT. In other words, the considered system does not need to be analytically managed. Moreover, fewer assumptions are required when simulation is used to schedule construction projects.

In the simulation approach, individual activities, and any interdependencies among them, and resource availability are taken into account. This capability makes simulation suitable for the detailed investigation of construction schedules (Wu, Borrmann, Beißert, König, & Rank, 2010). Although simulations have been successfully developed and implemented, more attention is required for its implementation on bridge construction processes.

A few examples of studies that have applied simulation within the bridge construction domain include work done by Ailland et al. (2010), AbouRizk and Dozzi (1993), R. Huang, Grigoriadis, and Halpin (1994), Chan and Lu (2005) and Marzouk, Said, and El-Said (2008). In their work, AbouRizk and Dozzi (1993) used CYCLONE to facilitate dispute resolution in bridge jacking operations. R. Huang et al. (1994) simulated construction operations in a cable-stayed bridge in Washington by using DISCO simulation software. Chan and Lu (2005) used SDESA to simulate field processes for a pre-cast bridge, resulting in optimal solutions to the pre-cast segment inventory problems.

Others like Marzouk, ElDein, and ElSaid (2007) utilized a simulation model such as STROBOSCOPE as a simulation engine which was coded by Visual basic 6.0 to develop a special purpose simulation model to assist in the planning of bridge deck construction. This simulation engine considers uncertainties and the interaction amongst resources used for the construction work. Marzouk et al. (2007) modelled the 15th May Bridge located in Cairo, Egypt which was constructed using an incremental launching technique. Marzouk et al. (2007) examined the results of the developed model and illustrate its capabilities in modelling two construction methods; single form and multiple form. A sensitivity analysis was performed in their study to evaluate the performance of the system under different combinations of resources. The study eventually enabled planners to estimate the duration and production rate in each combination within those different methods of bridge construction and also provided them with more understandable results for the impact of assigned resources when estimating project duration.

Another research study undertaken on bridge construction by Said, Marzouk, and El-Said (2009), reflects how simulation can facilitate construction process planning. Said et al. (2009) had employed a developed STROBOSCOPE simulation engine, called 'Bridge-Sim' in a case study of the El-Warrak Bridge in Cairo, Egypt, to estimate the total duration of deck execution and the associated total costs. Said et al. (2009) suggests that Bridge-Sim also enables planners and contractors to evaluate different scenarios of construction plant utilization which represents various combinations of construction methods, crew formations, and construction sequencing. For example they compared the cast-in-place on falsework method and cantilever carriage construction methods for the El-Warrak Bridge. Simulating the two construction process

methods demonstrated the potent capabilities of simulation methods in the creation of comprehensive documentation systems that helps planners in analysing construction alternatives where the project involves many repetitive activities, complex interdependencies between construction resources, and uncertainties.

STROBOSCOPE seems to be the most advanced simulation engine used in the above examples. It was developed by Martinez (1996) and provides the modeller/user with simpler characteristics of activity based simulators such as CYCLONE coupled with the modelling power of general purpose simulation languages. Martinez (1998, 2001) made further enhancements by developing another version called EZStrobe that does not require programming or coding. It is easier to learn and capable of modelling complex problems with little effort. The current study uses EZStrobe to explore its implementation on a bridge construction operation where a novel construction method is applied.

RESEARCH APPROACH

Research can be classified into five categories, based on the purpose of the study (Gray, 2004). These categories are: experimental or quasi-experimental research, phenomenological research, analytical surveys, action research, and heuristic inquiry. The current research does not seek to generate a new theory for construction management/planning, but to explore the capabilities of technological-based modelling methods in construction projects. The main objective is to explore how modelling methods can benefit New Zealand construction sector. Thus the research is both experimental and analytical in line with Gray's classification.

Since the implementation of simulation in New Zealand construction is new, a fieldwork study using a case study project has been selected to conduct this research. The research is designed based on a single/embedded approach in line with Stufflebeam, Madaus, and Kellaghan (2000) to improve, not to prove, planning and scheduling of construction projects. The research objectives of the study are firstly to build a conceptual framework of a bridge construction project where a new method of construction is involved. Secondly the research intends to modify and develop the framework to make it applicable for simulating bridge construction operations, using EZStrobe programme.

In the initial stage of the research, the study carried out thorough fieldwork study to understand the system behaviour. Some data were collected using direct observation and field note techniques. The primary data is in line with simulation procedure for developing a conceptual framework. The collected data include the following information: 1/ the duration of construction activities, 2/ the sequences of performance, 3/ resource allocation and interaction, 4/ identifying the influence of incidents on duration, 5/ identifying the various types of uncertainties and incidents which commonly occur on construction sites, 6/ tracking decision making ability, and 7/ identifying the interaction among human resources.

The case study project involves the construction of four ramps to link a tunnel to a main Highway in New Zealand. Two of the ramps enter the tunnel and two others exit the tunnel. The particular process

studied involves the delivery and installation of precast T-beams, using relatively new construction technique. There was no solid Work Break-down Structure (WBS) or conceptual framework developed for the project.

Approximately, three onsite months was spent observing the process and collecting the required data. During the observation period, project documents such as Three weeks Look-Ahead Plan, Last Planner data sheets and some progress meeting reports were also collected. The data collected was used to develop a framework and then a conceptual model, modified to be fed into the EZStrobe simulation programme. Both frameworks are required to be verified in future studies using comparative analysis between the results of simulation and existing plan (either resulting from Microsoft Project Professional or Last Planner System).

SIMULATION PROCEDURE

Understanding the System Behaviour/ Initial Conceptual Model

There are several basic steps that have been suggested in literature for the development of simulation models. However the steps used in the current study, in line with suggestions made by Robinson (2012) and Al-Ghtani, are: 1/ Identifying work tasks, 2/ Defining resources, 3/ Determining the logic of processing of resources, 4/ Building a model of the process, and 5/ Preparing a diagram of the model.

Authors attempted to create a conceptual model of the selected case study (Zaeri & Rotimi, 2014; Zaeri, Rotimi, & McCorquodale, 2014) . They used the primary collected data and built an initial conceptual model. Further in line with Akhavian and Behzadan (2013), one of the

model has been developed in which considered the states of the resources. As Halpin and Riggs (1992) suggested, identification of the activity status is important since it can help developing the skeletal framework of a construction operation. Therefore, three major resources involved in beam erection operation were taken into account and their associated statuses have been denoted by traffic light symbols.

The developed conceptual model provided a diagrammatic representation of the operations performed in a way that the sequence of work performance, the dependencies among them and their required resources were depicted. With these key operational process determined, the tasks of undertaking time and motion studies on the operations becomes less cumbersome.

Subsequently, by the selection EZStrobe as a simulation tool in the current study, it has been found that the previous model even covered the knowledge on the system behavior but still need to be developed in more details toward being used in EZStrobe program. The procedure of developing the conceptual framework are presented in next sections.

Modifying Conceptual Model Using EZStrobe Standards

EZStrobe is an entirely graphical discrete event simulation system based on extended and annotated Activity Cycle Diagrams and the Three-Phase Activity Scanning paradigm. It has been built in Microsoft Visio and is add-on to and uses STROBOSCOPE's simulation engine. Simulating progress in EZStrobe starts with using custom drag-and-drop graphics and do not require any programming (http://www.EZStrobe.com/2009/10/EZStrobe.html).

Therefore at the early stage of modifying the conceptual model toward its feeding into

EZStrobe, it is required to know about the graphical elements included in this program. Therefore the EZStrobe standards provided in Martinez (2001) research has been used at this stage.

Based on the examples of implementation of simulation in construction projects included in research works done by Martinez (1998, 2001); Marzouk et al. (2007); Marzouk et al. (2008); Marzouk, Zein, and Elsaid (2006) the steps of simulating procedure are summarized as below:

1- Defining Queues, Activities, Conditions needed to start Activity, and Outcome of Activity.
2- Identifying and assigning the content of each Queue.
3- Identifying the types of link should be drawn to connect Queue and Activity.
4- Assigning the annotations to the link:
   4-1 Drawing a link to connect Queue to Activity: Therefore, annotation indicates the required conditions for Activity to start.
   Note that if the link connects Combi and Queue, then annotation includes one more section to present how many units will be released (if possible) from the connected Queue.
   4-2 Drawing a link to connect Activity to any Node: Therefore, annotation represents the amount of resource that will be released through the link each time an instance of the predecessor activity ends.
5- Estimating the duration of each Activity:
   5-1 Using Uniform distribution sample

to estimate duration of Combi.
   5-2 Using Probability distribution sample to estimate the duration of Normal Activity.
6- Creating Probabilistic Branch to connect Fork to any other node except Combi. In this way developer determines that which route should be followed regarding to each condition.
7- Parameterizing the models:
   The Parameters option in EZStrobe allow the designer/developer to assign a symbolic name and description to these values. Also, the model parameters page can present the amount of material (resources) to be moved, the number of machines to be used, the hourly cost of equipment/machines, and some other indirect cost parameters. It should be noticed that using parameters option let developer to create generic models that adapt to a wide range of similar operations, where such models can be used by specifying appropriate parameter value later.
8- Customizing Output:
   This step can be accomplished using Results option provided in EZStrobe. This option allow modeler to define the formulas to measure the performances which their associated parameters already entered in previous step.

In relation to the steps outlined above, steps 1, 2, have been completed and presented in table 1, and figures 1 and 2.

Table 1: Required information to build the ABC conventional model

Conditions Needed to Start	Activity	Outcome of Activity
- Loaded truck Idle at site	Beam delivery in Gantry area	- Gantry crane ready to load

Conditions Needed to Start	Activity	Outcome of Activity
- Empty Gantry Crane waiting to load		- Truck ready to Haul - Super T beam Idle
- Loaded Gantry ready to move down - Unloaded Truck ready to Haul	Moving down the beam to do preparation (including stranding the stress bars and timbering works over the beam)	- Super T Idle on the ground (Ready for preparation) - Unloaded Gantry crane idle
- Empty Gantry waiting to Load - Super T Beam Ready to Lift	Lifting up the Super T-beam	- Super T beam Idle on the Gantry crane - Loaded Gantry Idle
- Loaded Gantry ready to move forward - Super T Beam Idle	Launching the Gantry forward	- Loaded Gantry ready to deliver beam on the desired place - Super T beam Ready to be placed
- Loaded Gantry idle on the top of the span - Supports ready for beam placement - Super T Beam ready to be placed	Placing the Super T beam	- Unloaded Gantry Idle - Super T beam ready to be fixed on the supports
- Unloaded Gantry idle - Gantry area is empty	Preparation of the Gantry for next round	- Gantry crane ready to load - Truck ready to Haul - Super T beam Idle

The information on Table 1 is captured to layout the conventional ACD model (see figure 1). The model illustrates the sequence of activities and the way of that an activity receives the required resource(s). The states of the resources also have been considered in this model which helps in developing the further model using EZStrobe standards. This conventional model can be used to express the main concepts of a model (object) which is aimed to be simulated.

In simple terms, the process investigated includes the installation of precast super-T beams between bridge spans from the south to the northward ramp. The T-beams are delivered with trucks to the loading area, where they are picked up by the Gantry Crane. The Gantry Crane then lifts the beams (whether intermediate or edge) to the placement points. The entire process from delivery to placement is dependent on the availability of certain resources and constraints which are very often not indicated in normal MSProject/ schedules. Examples of some of the constraints are: shape of the curve of T-beam, edge or intermediate one, length of the beam, placement in between of two piers/abutment and pier, and location of span which may need traffic closure.

With the conventional model developed (figure 1), the next model (see figure 2) is developed based on EZStrobe standards. In some cases, where the queue in Conventional model identified as

superfluous one, then it can be removed in ACD EZStrobe. For example, consider the queue named as "Unloaded truck idle and ready to Haul", this queue can be removed and being replaced with Haul activity. In this way, the model presents that the Haul activity can be initiated immediately after the Combi activity named as "Beam Delivery to Gantry Area" finishes. It means that the conditions needed for "Haul" activity to start is completely satisfied by the outcome of "Beam Delivery to Gantry Area".
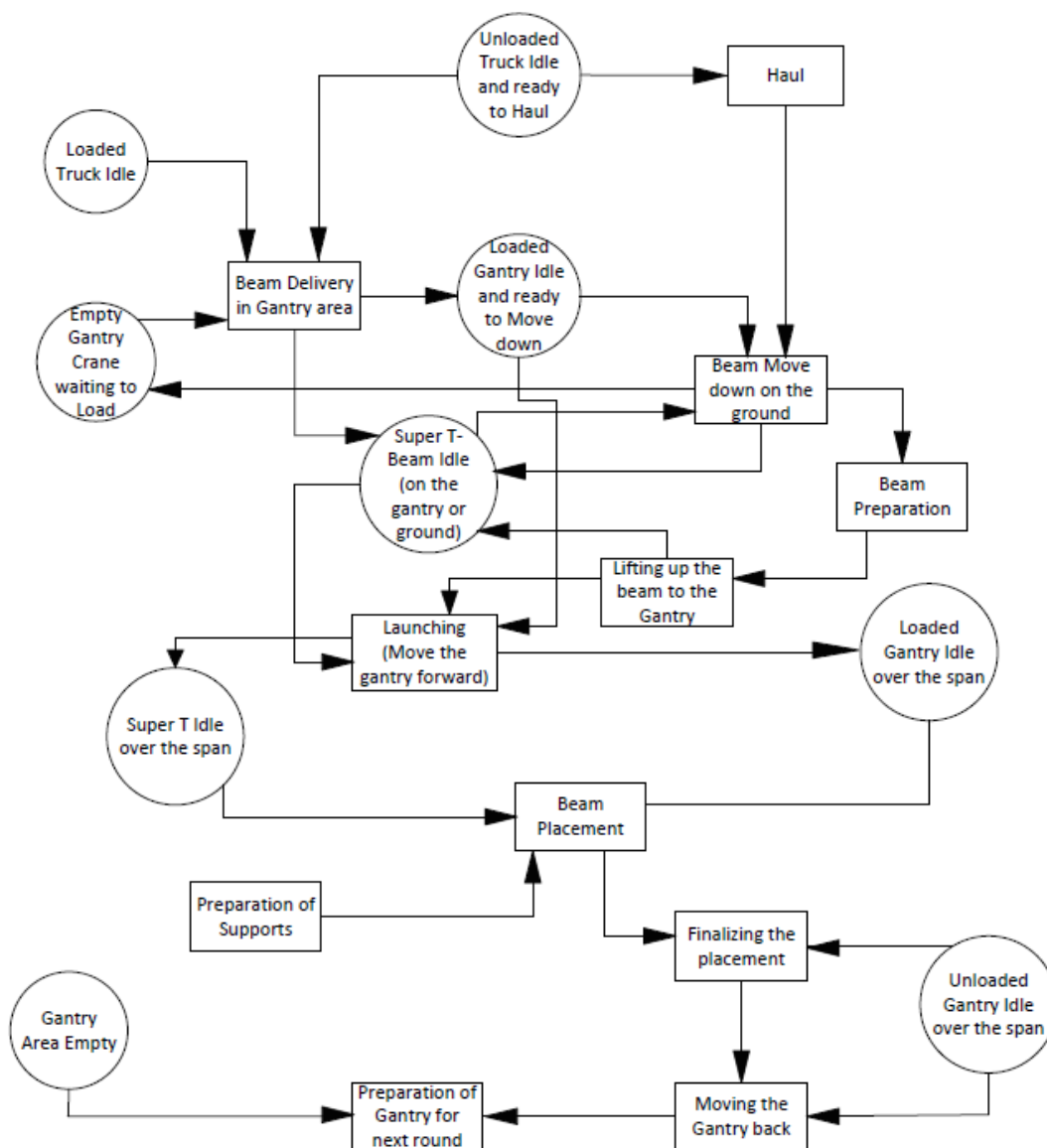
Figure 1: ABC Conventional Model for Beam Delivery Operation using Launching Gantry
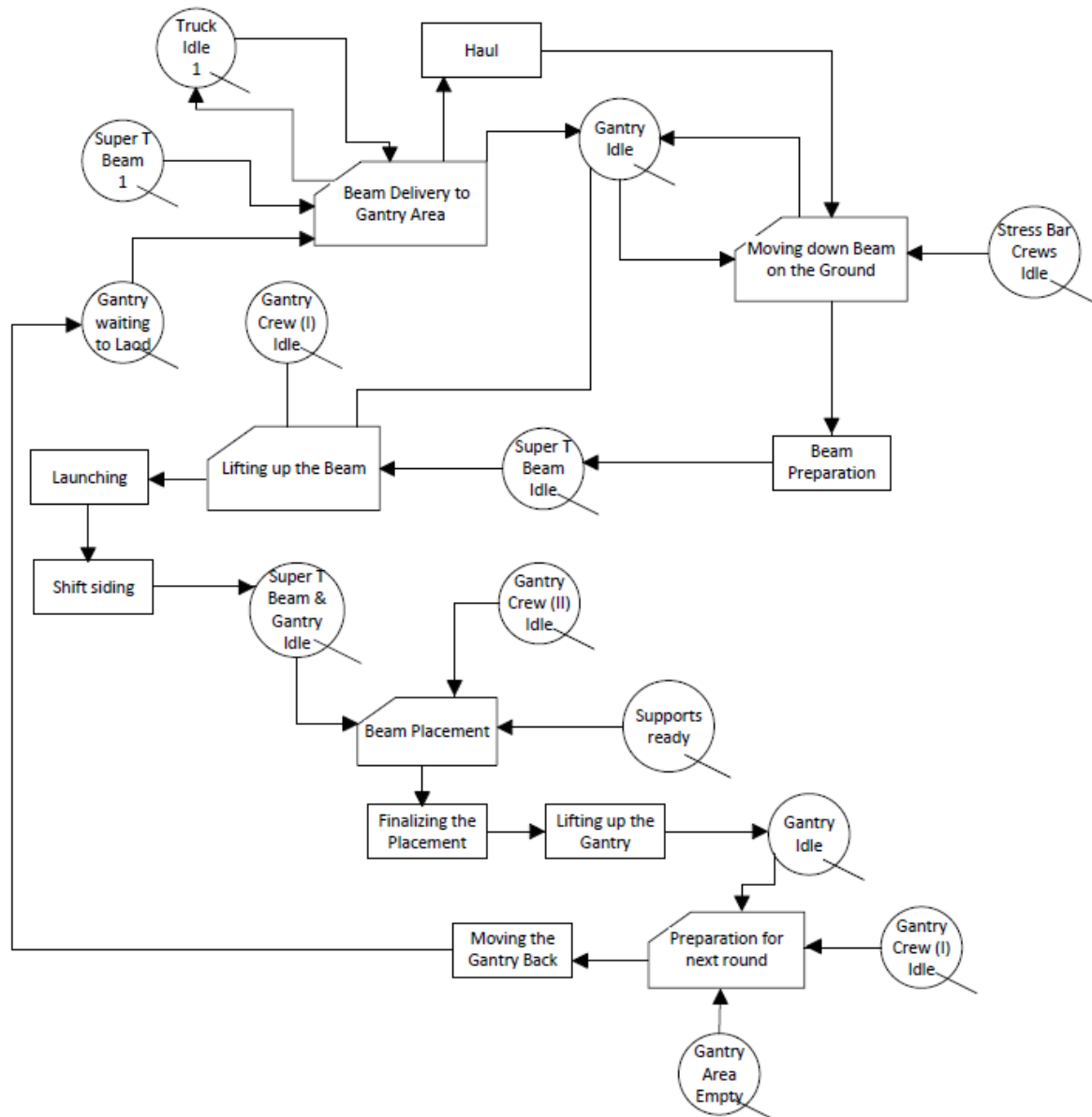
Figure 2: EZStrobe ABC Model for Beam Delivery Operation using Launching Gantry

As mentioned earlier, EZStrobe allows a Modeller to consider probability situation within the modelling. It can be done using Fork and Branch Link elements. As an example, consider the situation that Gantry crane is broke down. Then Fork element lets the Modeller

considering two different conditions: 1/ if the probability of Gantry break-down is 5% (for example), then the progress should be routed through performing the Repair Activity, and 2/ in the case of 95% probability, the Gantry works on the routine progress directly switch to next Activity; Launching (see figure 3).
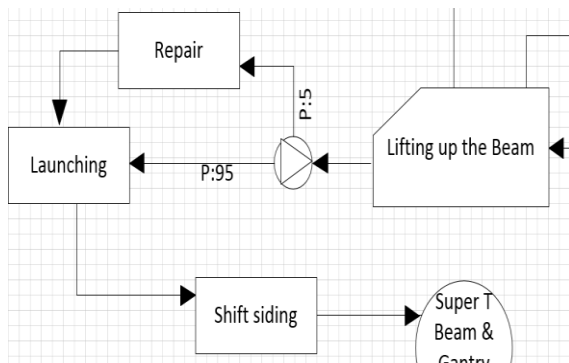
Figure 3: EZStrobe ACD model including Fork and Branch link in the case of Gantry Breakdown

As another example, consider a parameter which has been found important from the aspect of its effect on the duration of the operation in the current fieldwork study. This parameter is associated with the types of the Super T beam (whether edge or intermediate), as the method of placement varies depending on the beam type. Therefore, the model can be developed in this particular section as shown in figure 4. The probability's annotation has been assigned assuming the span includes two edge beams and 4 intermediate beams.
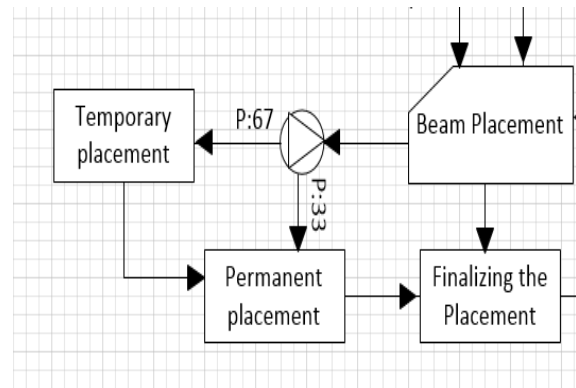
Figure 4: EZStrobe ACD model including Fork and Branch Link to Present the Procedure of Two Different Methods of Beam Placement

Since the main purpose of simulating an operation is to obtain statistical measures of performance, therefore, developing the ACD model in more detail can lead to more accurate results.

In future research, the authors will continue the simulation steps and subsequently run a simulation for this case study project. By so doing, a comparison of the simulation model with durations resulting from normal schedule (MSP) will be undertaken and hopefully this could improve process activities for the next construction phase for the remaining ramps. The capability of EZStrobe could then be explored and verified.

CONCLUSION

The objective of this study is to develop an ACD model for simulating bridge construction operation. It has been found that analysing the system behaviour plays a vital role in scheduling any complex process. Complexity and uniqueness of systems on one hand, and deployment of new methods of construction on the other hand makes planning and scheduling activities more cumbersome.

The review of the studies on construction/bridge construction operations shows that some advanced technologies could overcome such issues. Simulation-based method is the recent technique that its implementation in construction has been verified from different aspects, such as estimation of duration, decision making support, tracking performance, and estimation of cost. Among those, STROBOSCOPE engine and its simplest version, EZStrobe are found by researchers as useful simulation-based tools in bridge construction. This study therefore employed EZStrobe standards to achieve its objective. The ACD model developed for the case study (bridge construction) project uses an incremental launching technique which is unique to New Zealand. The case study therefore provides an opportunity to present the software enables planners to consider resources' statuses, different logic and constraint decisions and operational methods from the early stage of scheduling. This is the advantage of simulation technique over other planning and scheduling software.

This research contributes to construction operations management and scheduling by providing a conceptual framework for this specific method of bridge construction (incremental launching). The model eventually would be applied to simulate bridge construction operations and assist in their planning and management. The study is significant to New Zealand because the implementation of simulation technique is new to its construction industry. In future works, the EZStrobe simulation will be run using the developed ACD to present more potentials of its application.

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4.2 MASSEY UNIVERSITY

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Occupants' perspectives of a five green star certified school building

OCCUPANTS' PERSPECTIVES OF A FIVE GREEN STAR CERTIFIED SCHOOL BUILDING

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ABSTRACT

This study compares the satisfaction of occupants of a New Zealand Five Green Star certified primary school with the building's assessment results and with international studies on Green Building occupant perspectives. School staff were surveyed on their satisfaction with factors such as operational, environmental, and personal control using a web-based survey and a 5-point Likert scale.

The staff were most satisfied with operational aspects such as the building image, adequate work space, cleanliness, availability of meeting rooms and facilities. They were least satisfied with temperature, air quality and their level of control of heating, cooling, ventilation and lighting. These findings are similar to those from international green building studies.

Contrary to the findings of other studies, the school occupants were satisfied with the level of noise in the building and felt that their health was worse in their green building than it had been when they occupied conventional buildings.

In the Green Star rating, the school earned the maximum points available for internal noise levels and thermal comfort parameters despite the latter being unsatisfactory to the occupants. The integration of post-occupancy evaluations into Green Star certification programmes will provide valuable feedback to designers, owners, occupier, managers and industry professionals.

Keywords: Green building, indoor environment quality, occupant satisfaction, post-occupancy evaluation.

INTRODUCTION

Worldwide, the built environment accounts for about 33% of total energy use, 30% of raw material use, 35% of greenhouse gas emissions and 35% of solid waste (Isover, 2008). There is increasing pressure to reduce this significant environmental impact by making the built environment more sustainable through green building construction. In response to this, a number of international organisations have developed assessment tools to certify the level of environmental performance of buildings.

The New Zealand Green Building Council (NZGBC) was established in 2005 to oversee sustainable construction in New Zealand and has recently certified its 100th green building (Howe, 2014). Its Green Star rating scheme consists of eight weighted environmental impact categories and an innovation category with credits awarded in each. Green buildings are rated as 4 Star (score 45-59), 5 Star (score

60-74) and 6 Star (score 75-100) signifying 'Best Practice', 'New Zealand Excellence' and 'World Leadership' respectively (NZGBC, 2014a).

The rating scheme has credits for factors which can have either a positive or a negative impact on the building occupants. For example, provision of natural light and clean air usually improve occupant health and productivity but energy efficiency and optimal space utilisation may lead to workspaces with poor temperature control and problems with noise. It is estimated that occupant salaries account for over 90% of the total costs in the life cycle of a building (Corona, 2012). This far outweighs operating costs (such as the cost of energy) and it is therefore essential that sustainable construction must satisfy the building users and maximize their productivity. Post occupancy evaluation (POE) is a way to measure the satisfaction of building occupants. It is not currently included in the Green Star rating scheme, but there are credits for conducting POE's under the LEED certification scheme used in America (Dykes, 2012). In New Zealand, the biggest barriers to the growth of green buildings are low client demand, high design and construction cost and low perceived benefits (Bond & Perrett, 2012). It is generally agreed that POE's provide valuable feedback that can be used to optimise the design of green buildings and stimulate the growth in sustainable construction (Baird, 2010; Bordass et al., 2006; Meir et al., 2009). The benefits and limitations of POE's are discussed in the next section, with additional focus on POE's on school buildings which are surprisingly rare compared with those for other types of buildings (Meir et al., 2009).

The work presented here is a study of the adult occupants' perceptions of a 5 Green Star certified primary school that has been operational since February 2013. Firstly, the Green Star rating is examined to see where the building scored well and where the building features were weak. Next, a survey of the building occupants is used to see whether the occupants' perceptions align with credits the school achieved under the Green Star rating scheme. Finally, the occupants' perceptions are compared with those of other international green building users.

LITERATURE REVIEW

The drive to make the built environment more sustainable means that buildings must become increasingly efficient in terms of energy and resource use and it is important that this efficiency does not come at the expense of the occupant's experience. Green building certification is a measure of the sustainability of a building and POE is a measure of the satisfaction of the occupants using tools such as occupant surveys and 'walk-through' observations by building professionals. Meir et al. (2009) provides a comprehensive history of POE's. This review looks at the studies into the correlations between green certification and occupant satisfaction, POE evaluations of school buildings and the advantages and limitations of POE's.

Occupant satisfaction with green buildings

International studies on POE's of green buildings include Baird, 2010; Best & Purdey, 2012; Brown & Gorgolewski, 2013; Brown et al., 2009; Deuble & de Dear, 2014; Dykes, 2012; Frontczak & Wargocki, 2011; Hauge et al., 2011; Huizenga et al. (2006); Langston et al., 2008; Leaman & Bordass, 2007; Paul & Taylor, 2008, and Sellers & Fiore, 2013. There is general consensus that occupants were satisfied with the building image, furniture, cleaning, meeting rooms and the lighting (aside from problems with glare). In addition, most occupants felt that their health and productivity improved in green buildings.

Most studies found that occupants were dissatisfied with noise control and Brown &

Gorgolewski, 2013, have gone so far as to describe noise as "a popular plague" of green buildings. Other unsatisfactory aspects were lack of storage space, glare from lighting (both artificial lighting and natural lighting), temperature (too cold in winter and too hot in summer) and personal control over the indoor air environment. Several studies showed that personal control of temperature and lighting improved occupant satisfaction and that there was good correlation between green building rating and occupant satisfaction (Best & Purdey, 2012; Brown et al., 2009; Frontczak & Wargocki, 2011; Huizenga et al., 2006).

POE for educational buildings

The belief that school design quality is linked to education quality led to the 'Building Schools for the Future' (BSF) programme in Britain (CABE, 2006). However, an audit of 52 schools built under the BSF scheme found that half of the schools were poor or mediocre quality design. A similar assessment of American schools in Colorado found that the average educational suitability of the schools was in the poor range (DKF, 2005).

Although POE's are particularly important in school buildings, they are very uncommon. Meir et al., 2009, review 100 POE studies and note that only 8 of these involve educational buildings. Further, where a POE was conducted it was usually done to showcase a successful school building as a marketing tool for the construction industry. Marley et al., 2012, investigated LEED-certified British schools and found that two thirds of schools did not conduct a POE (despite the LEED certification process including credits for conducting a POE) because they were unaware of its purpose and benefits and lacked funding to do it. Of those schools that did conduct POE's, 80% did not consider the students' perspective. Watson, 2003, opines that POE's done by all building

users/all the people affected by the building (students, teachers, managers, etc.) are best.

Amongst the few POE studies for educational buildings, the common findings are that occupants are most troubled by noise, followed by unsatisfactory air temperature and air quality caused by energy efficiency targets. Workspace design and management were generally satisfactory (Jamaludin et al., 2013; Langston et al., 2008; Watson, 2003).

Advantages and limitations of POE's

POE numbers are increasing enormously and most researchers agree that they can provide valuable feedback to the designers of new buildings (Meir et al., 2009; Watson, 2003). However they suffer from non-standard protocols and methods so that the findings are not always comparable (Marley et al., 2013). Hauge et al., 2011, observe that POE studies generally have mixed results; some building users are satisfied and some are not. The particular building operation itself may be complex and poorly understood by its occupants and consequently unsatisfactory. Brown & Gorgolewski, 2013, report that a quarter of the occupants were unhappy with their control of the heating, ventilation and air conditioning (HVAC) system in a building but found that the main reason for dissatisfaction was that they had not read the operating instructions and did not know how to use the control. Finally, few POE's include physical measurements; the occupants may say that they find the building too hot but temperature is not measured to see whether it lies in the thermal comfort range. There is the potential for occupants to use the POE as a vehicle for complaints about general workplace issues unrelated to the building performance (Deuble & de Dear, 2014).

METHODOLOGY

Baird, 2010, describes the POE's of a wide range of international green buildings and his work formed the basis for the development of the questionnaire survey used in this research. The current survey was web-based and the survey link was circulated to all 11 staff at the primary school via the principal in order to get the voluntary and anonymous staff perspective on the indoor environment quality of their workplace. The children attending the school were not surveyed because they were too young to give their informed consent to the process. The survey consisted of 27 questions. The first 13 questions concerned demographical and background information such as the age and sex of the respondent, average hours and days spent in the building and location of their workspace. The remainder of the questions were workspace environment statements designed to gauge individual's perceptions on 40 individual factors using a five-point Likert interval scale with '5' being the optimal score. The respondents were typically requested to rate the statements from 'disagree completely' to 'agree completely' or 'completely unsatisfactory' to 'completely satisfactory'. Other statements required a rating of satisfaction with factors such as temperature from 'much too cold' to 'much too hot' and whether the environment made the occupant feel 'dreadful' to 'very well'.

These factors were assembled into four broad categories, namely, operational factors, environmental factors, levels of personal control and satisfaction levels. Within the categories, the following characteristics were surveyed:

- Operational: building image; standard of cleaning; building, desk and storage space; availability of meeting rooms; furniture and facilities.
- Environmental factors:
  - Temperature and air quality in summer, winter and overall; temperature stability; draughtiness; humidity levels and freshness.
  - Lighting: too much or too little natural light and artificial lighting; glare levels from natural and artificial lighting and overall lighting levels.
  - Noise levels overall; impact from noise within the occupants' workspace and from outside areas.
- Personal control: control over heating; cooling; ventilation; noise and lighting.
- Satisfaction: with the building design; occupant needs; overall comfort; productivity levels and health.

Occupants were also able to comment on the aspects of the operational, environmental, personal control and satisfaction categories that they felt strongly about.

The responses were analysed and a mean value based on a five point scale was produced for each question or statement. The averages were converted to percentages to enable direct comparison with the 7-point scale used in Baird's research (Baird, 2010) on international green buildings. The occupants' views of the school building were also compared with the Green Star rating assessment for the school.

RESULTS

Valid surveys were completed in mid 2014 by 8 of the 11 staff at the school. Although this sample size is too small for statistical analysis, the findings are still of interest.

Demographics of the occupants (staff)

Two of the eight respondents were male and 75% of all respondents were over 30 years of age. The school was their normal place of work and they had all worked in the same building for over a year. On average, they worked 4-5.5

hours per day and 5.25 days per week. Half of the respondents worked in a classroom and 38% of people had moved workspaces over the past year. Most respondents shared office space with colleagues. 75% of respondents had their desks situated at a window. The two respondents who had a desk away from a window were both based in a classroom. The average time that respondents spent at their computer screens and desks was between 2-3.5

hours each work day.

Building Operational Factors

The occupants' perceptions of operational factors for the school and the findings reported in Baird, 2010, for a range of international green buildings, are summarised in Table 1.

Table 1: Operational factors compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
The building presents a good image to visitors	80.00%	80.29%
There is adequate space in the building	82.60%	68.71%
There is adequate space at your desk/workspace	80.00%	61.71%
Storage space is adequate	45.00%	60.00%
Standard of cleaning is good	80.00%	75.29%
The furniture in your work area is good	67.60%	74.00%
Meeting rooms are always available	87.60%	73.57%
Facilities meet requirements	75.00%	76.00%

The staff thought that the school building performed well in terms of image, work space, cleaning and facilities. They commented that there was insufficient storage space for resources. The markedly low result for adequate storage space could be due to the age of the students at the school where more resources may be required to be stored compared to older children in schools or in other types of buildings. A respondent also commented that the furniture and doors were far too heavy but it was not clear whether this was from a child's or adult's perspective.

Generally the results in Table 1 agree with the findings of Baird's research and it is interesting to note that a lack of storage space was significant in both studies.

Building Environmental Factors

Table 2 summarises the occupants' satisfaction with the various aspects of the school building indoor environment quality and the findings from Baird, 2010.

Aside from noise level, the school staff were less satisfied with all major environmental factors than the occupants reported in Baird's research. Staff were very dissatisfied with the air temperature in winter and moderately satisfied with it in summer. The comments from the respondents suggest the lack of their personal control in changing their immediate environment such as temperature, air flow and lighting/glare levels had a significant effect on satisfaction levels. The respondents felt that as a result of working in the building, their health had declined with many reporting headaches and attributing the need for glasses to the lighting.

Table 2 Environmental factors compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Temperature overall satisfaction (Winter)	35.00%	63.14%
Temperature overall satisfaction (Summer)	57.60%	61.71%
Air quality overall satisfaction (Winter)	50.00%	53.00%
Air quality overall satisfaction (Summer)	52.60%	61.86%
Lighting overall satisfaction	45.00%	73.57%
Noise levels overall satisfaction	75.00%	63.14%
Design of building	65.00%	71.23%
Building suits needs	57.60%	73.71%
Comfort levels overall	52.60%	70.14%
Health has improved	32.60%	60.71%

The school achieved a rating of 5 Green Star New Zealand Excellence from the NZGBC. It received the maximum points available for ventilation rates and HVAC zoning and control. It received 2 points from an available 3 for thermal comfort. Table 2 shows that there is clearly a mismatch between the credits earned for the HVAC system and the occupant's satisfaction with the building's environmental performance.

Environmental factors such as air temperature, air quality, lighting and noise were examined in more detail.

Air Temperature

Table 3 shows the occupants' perception of temperature in the school and the findings from Baird, 2010.

Table 3 Perception of air temperature compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Temperature is not too hot or too cold (Winter)	27.60%	66.43%
Temperature is not too hot or too cold (Summer)	32.60%	60.43%
Temperature is stable (Winter)	25.00%	60.43%
Temperature is stable (Summer)	27.00%	49.00%
Overall satisfaction (Winter)	35.00%	63.14%
Overall satisfaction (Summer)	57.60%	61.71%

Compared with Baird's study, the school staff were very dissatisfied with the temperature and its fluctuations, particularly in winter. They commented that the air conditioning's inconsistent temperature was distracting and impacted on children's learning. They also said that the variations in temperature could be extreme between areas and over different periods of the day.

Air Quality

Table 4 shows the occupants' perception of air quality in the school and the findings from Baird, 2010. In general, the findings were similar and the school staff were fairly neutral about the overall air quality.

Table 4 Perception of air quality compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Air is not draughty (Winter)	42.60%	50.71%
Air is not draughty (Summer)	42.60%	46.57%
Air is not too dry or too humid (Winter)	35.00%	48.43%
Air is not too dry or too humid (Winter)	47.60%	54.57%
Air is fresh, not smelly, musty or stale (Winter)	45.00%	53.00%
Air is fresh, not smelly, musty or stale (Summer)	50.00%	55.00%
Overall satisfaction (Winter)	50.00%	63.43%
Overall satisfaction (Summer)	52.60%	61.86%

Lighting

Table 5 shows the occupants' perception of lighting in the school and the findings from Baird, 2010.

Table 5 Perception of lighting comfort compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
There is enough natural light	55.00%	56.29%
There is little glare from sunlight	45.00%	53.29%
The artificial lighting is comfortable	37.60%	59.14%
There is little glare from the artificial lighting	45.00%	48.14%
Overall satisfaction	45.00%	73.57%

Staff were reasonably satisfied with the level of natural light available but very dissatisfied with the artificial lighting. Glare from both sunlight and artificial lighting was a slight problem and overall lighting was somewhat unsatisfactory. Baird's occupants had a significantly higher overall satisfaction with the levels of lighting and glare was not of as much of a concern.

In the Green Star assessment, the school building achieved the maximum points available for daylight glare control and 2 out of 3 points available for daylighting. Although the school staff were satisfied with the natural light, they were not satisfied with either glare or the lighting overall.

Noise levels

Table 6 shows the occupants' perception of noise in the school and the findings from Baird, 2010.

Table 6 Perception of noise levels compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Satisfaction with noise level around workspace	80.00%	61.57%
Satisfaction with noise level outside	85.00%	55.29%
Overall satisfaction	75.00%	63.14%

The school performs well in terms of noise control compared to the buildings in Baird's study.

Respondents who worked in offices were slightly more satisfied with noise levels (80.00% satisfied) compared to those in classroom situations (70.00% satisfied).

In the Green Star assessment, the school building achieved the maximum points available for reducing internal noise levels although the overall building itself did not meet the prescribed acoustic standards.

Personal Control

Table 7 shows the occupants' perception of control of their indoor environment in the school and the findings from Baird, 2010.

Table 7 Occupant's personal level of control compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Control of Heating	25.00%	40.29%
Control of Cooling	25.00%	40.14%
Control of Ventilation	25.00%	48.86%
Control of Lighting	37.60%	55.00%
Control of Noise	57.60%	35.43%

Compared with Baird's study, the school staff were much less satisfied with their level of control of heating, cooling, ventilation and lighting but more satisfied with their control of noise. This agrees with many other studies showing that control of indoor environment has a significant impact on occupant satisfaction (Heerwagen, 2000).

Satisfaction

Table 8 shows the occupants' overall satisfaction with the school and the findings from Baird, 2010.

Table 8 Satisfaction levels compared to Baird, 2010

FACTOR	SCHOOL	BAIRD
Design of the building	65.00%	71.23%
Building provides for their needs	57.60%	73.71%
Overall comfort levels	52.60%	70.14%
Health has improved	32.60%	60.71%

Despite the occupants' apparent discomfort with factors such as poor temperature stability and lighting issues, they were reasonably satisfied with the design of the building and how it met their needs. As can be seen in Table 8, they seemingly do not associate their comfort levels with the building design.

The school occupants' felt that their health had deteriorated as a result of working in their new Green Building. They commented that air conditioning was a contributor to increased staff illness. Baird, 2010, found that occupants felt slightly healthier in green buildings.

Assessment of productivity is not shown in Table 8 because it was slightly different between the two studies. School staff productivity of 50% meant that their productivity was identical in standard buildings

and in the green school building. Less than 50% meant that the staff were less productive in the school building and greater than 50% meant that they were more productive in the school building. In Baird's studies, green building occupants were asked to state the percentage change in their productivity. School staff rated their productivity at 60.00% while there was an average 4.07% improvement in productivity of the occupants in Baird's study. Occupants appear to be more productive in green buildings than in conventional buildings.

CONCLUSION

The occupants' overall experience in their green school building is significantly worse than expected for a building of less than five years old. The occupants identified difficulties with a lack of storage, air temperature and quality, and lighting levels particularly with glare from natural and artificial lighting. Despite the participants' perception that they had a very low level of personal control in their indoor environment, this did not have a strong impact on their overall comfort levels. Health issues were of particular concern to the participants.

Best & Purdey, 2012, and Frontczak & Wargocki, 2011, showed that giving occupants the ability to control their indoor environment and providing knowledge on handling particular constraints, improved their overall satisfaction with indoor environment and air quality.

The subject school was assessed as a five star green building which signifies it is of 'New Zealand Excellence' standard. In assessments for schools, there is a significant weighting towards indoor environment quality with particular attention to ventilation rates, indoor air quality (as a result of materials used to finish rooms), natural and artificial lighting and noise. Energy use also is heavily weighted and this school received many points for the minimisation of energy consumption and greenhouse emissions. There appears to be an underlying assumption in the Green Star assessment process that if the technical requirements are met, then it follows that the occupant will also be satisfied. This is not

necessarily the case, as shown in this research. When occupant needs are not being met, the value of the building's green certification or energy efficiency is debatable.

DISCUSSION

This work assesses the satisfaction of the staff occupying a New Zealand Five Green Star certified primary school. The best POE's are those that include all the building users (Watson, 2003) but the students at the school were too young to give informed consent and were therefore not included in the evaluation. 8 of the 11 staff at the school participated in the study. Although this sample size is too small for statistical analysis, the findings are still of interest.

Two findings were contrary to other studies; firstly, the staff were satisfied with the level of noise in the building and, secondly, they felt that their health was worse than it had been when they occupied conventional buildings.

In common with other studies, the staff were satisfied with operational aspects such as the building image, adequate work space, cleanliness, availability of meeting rooms and facilities. They were very dissatisfied with temperature, air quality and their level of control of heating, cooling, ventilation and lighting. The Green Star assessment rating has credits for the production of a Building User Guide. Given the extent of complaints regarding the quality of the indoor environment, the production of such a guide and training in achieving optimal thermal comfort within local constraints could improve staff satisfaction with personal control and building performance.

The recent introduction of the NABERSNZ building performance rating tool (NZGBC, 2014b), while only addressing the technical aspects of office building performance, could easily be expanded to include a post-occupancy evaluation and applied to all buildings rather than specifically offices. This would provide valuable feedback to designers, owners, occupiers, managers and other industry professionals.

Developing a Green Building post-occupancy evaluation and benchmarking it as part of the certification process would assist in taking into account the human element of the building. Improving productivity, employee retention and work life quality by increasing occupant satisfaction also helps to maximise financial, social and environmental returns for the organisation.

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Critical determinants of construction tendering cost in New Zealand: Quantity surveyors' perceptions

CRITICAL DETERMINANTS OF CONSTRUCTION TENDERING COSTS IN NEW ZEALAND: QUANTITY SURVEYORS' PERCEPTIONS

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ABSTRACT

Identifying critical determinants of tendering cost is key to reliable construction cost forecasting. Thirty-seven pre-tender construction cost-influencing factors were identified in a pilot study. The identified factors were segregated into six clusters for quantitative analysis. Online questionnaire survey was used to obtain quantity surveyors' feedback on the relative importance of the identified factors. The empirical data were subjected to multi-attribute analysis. Results showed that poor tender documentation was perceived as the most important factor underlying reliable pre-tender cost estimation. Concordance analysis indicated high level of agreement amongst survey participants in the rank-ordering of the relative importance of the cost-influencing factors. The findings could assist quantity surveyors to prepare more reliable pre-tender construction estimates. It would also assist in effective cost control at the construction stage.

Key Words: Construction cost, construction cost forecasting, pre-tender estimating, tendering.

INTRODUCTION

Currently, construction market development and the level of competition between contractors is increasing rapidly in the New Zealand construction industry. It is critical for contractors to win bids to survive in this highly competitive construction arena. Even though the lowest tendering price does not mean the highest competitive price, tendering price is still critical for contractor selection over time (Wong, Holt, & Harris, 2001). Cost estimating can be defined as forecasting for total construction cost at the pre-tender stage, which is an experience-based process. Construction cost estimates can be influenced by factors such as: uncertainty, incompleteness, and unknown circumstances. These factors significantly influence accurate and reliable cost estimates. They also challenge the client's quantity surveyors to achieve cost control at the pre-tender stage.

Tender price consists of the actual cost of carrying out construction works plus mark-up. Actual cost of construction contains material cost, labour cost and plant cost, whereas, the mark-up contains costs of overheads, profits and contingencies. It is obvious that only quantitative factors can be taken into consideration when estimating tender cost in many projects. Since the nature of qualitative factors is difficult to measure, most qualitative

factors, such as client priorities, project characteristics, and procurement methods are ignored in common cost estimation methods. A firm understanding of these qualitative tender cost-influencing factors could improve the competence of quantity surveyors to prepare more reliable and accurate tender estimates. This knowledge is also critical for quantity surveyors to achieve cost control at the pre-tender stage. Even though a number of studies have been conducted in different parts of the world to identify critical determinants of tender cost, no significant research has been conducted in New Zealand to investigate the above despite there being a number of unique characteristics here. This study aims to fill the aforesaid gap in the literature by identifying critical factors influencing on tender cost in New Zealand.

LITERATURE REVIEW

Nor Azmi Ahmad, Rosnah, Napsiah, Aini, and Rizan (2012) investigated construction cost influencing factors for Industrialized Building System (IBS) projects in Malaysia. They used the method of a Relative Importance Index (RII) to rank the importance of factors. The total factors were divided into seven main groups including characteristics of general contracts, methods of procurement, attributes of contractors, design parameters and external market factors. The RII index of project characteristics, contractor attributes and market factors were higher than in other groups.

Memon, Rahman, Abdullah, and Azis (2010) investigated factors influencing construction cost in the projects of Malaysian government agencies. The questionnaire survey method was used for analysing data to rank factors. There were seven main factors, including cash flow and financial difficulties faced by contractors, poor site management and supervision (contractors), shortage of contractor experience,

insufficient site labour, and inadequate construction planning and scheduling. This study identified design changes as the lowest influential factor on the cost of construction.

A study by Tebin (2009) identified two critical determinants of tendering price: client responsibility and contractor responsibility. The study emphasised the importance of having comprehensive knowledge about the construction process by both the project client and contractor to accurately calculate the tender price.

Elhag et al. (2005) carried out a similar study to the above in the United Kingdom and investigated tendering cost influencing factors from the standpoint of quantity surveyors. The study identified 67 variables that influence tender price through a literature review and a questionnaire survey, which was used among quantity surveyors who are members of Royal Institute of Chartered Surveyors (RICS) to rank these factors according to their level of significance. Severity index computation was used for ranking all factors. Results showed a severity index more than 65%, for 52 factors, which means important factors with high agreement. Furthermore, the top ranked factor was consultant and design parameters and the bottom ranked factor was contractor attributes. This study's results indicated that designer impact on construction project cost is more significant than contractor.

Chan and Park (2005) measured and evaluated factors that influence construction cost in Singapore, based on national construction projects. The projects were divided into three main groups based on project characteristics, contract type and type of owner/consultant. The findings indicated that special requirements influence construction cost including level of technology, special skills of the contractor and publicly administered contracts. Moreover, the technical expertise of contractors, financial

factors and level of construction familiarity were also high level influence factors.

Bubshait and Al-Juwairah (2002) evaluated 42 factors taht affect construction cost in Saudi Arabia. These factors were divided into five main groups. Results indicated that material cost, incorrect planning, contractor experience, contract management and poor financial control have significant cost influence.

Another study, conducted by Akintoye and Fitzgerald (2000) in the UK identified 24 cost influencing factors, of which project complexity, scale and scope of construction, market conditions and method of construction were identified as the most significant factors.

Dissanayaka and Kumaraswamy (1999) investigated factors influencing construction cost, based on projects in Hong Kong. The study used multiple linear regressions and identified four main construction cost influential factors: level of client confidence in the construction team; payment method; risk of client's quantity variation; and complexity of construction.

According to the above discussion, different researchers have used different approaches to classify factors affecting construction cost overruns. Figure 1 summarises all the construction cost influecing factors identified from the literature under six main categories: project characteristics, client characteristics, contractor characteristics, Ttendering situation, consultant and design, external factors and market conditions, and Inaccuracy of cost estimating.
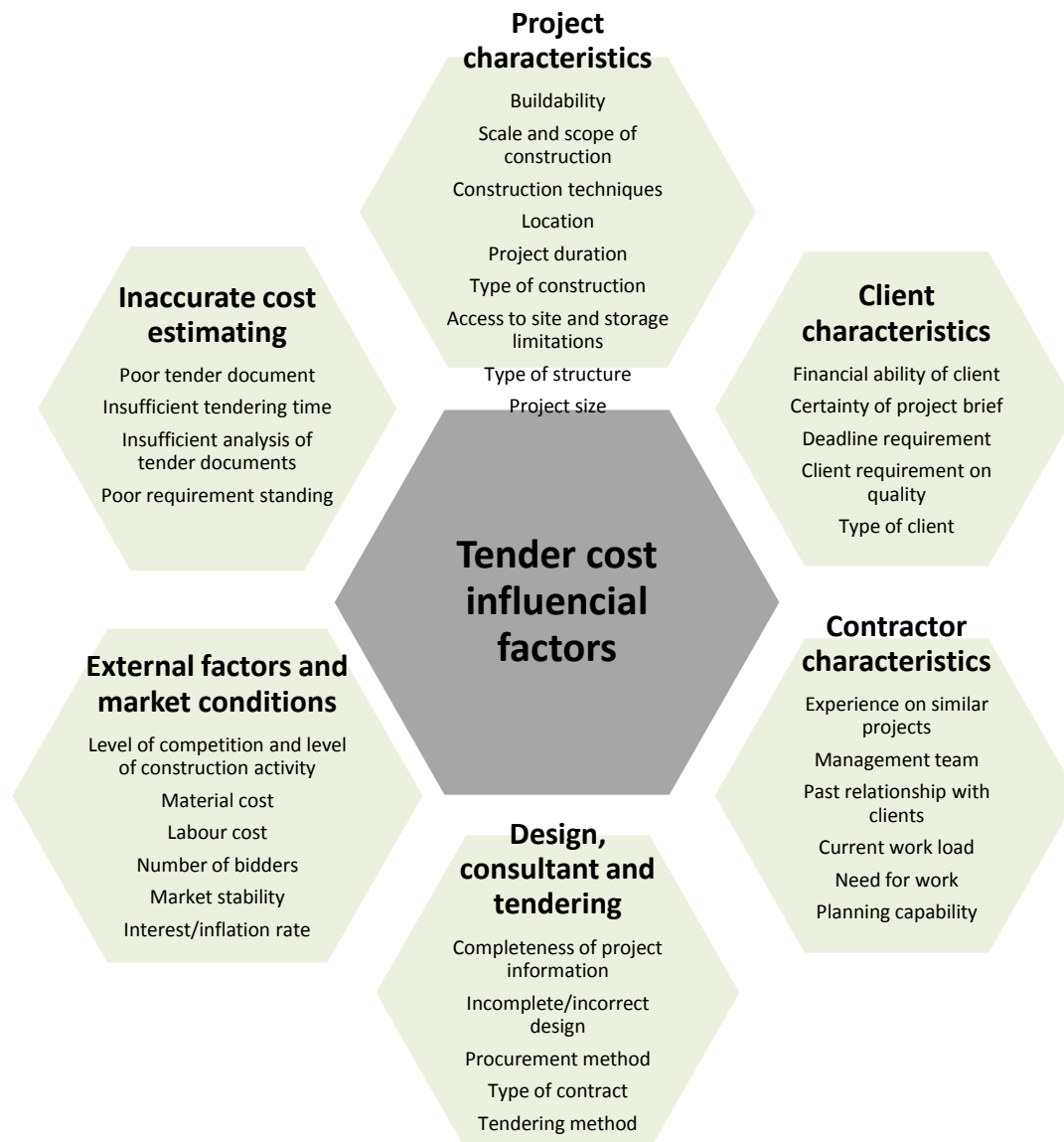
Figure1: Tender cost influential factors (compiled from literature)

Project characteristics

In the literature, project characteristics have been proven to be the most significant tender cost influencing category. A number of studies identified the size of building/floor area as one of the highest tender cost influencing factors (Sonmez, 2004; Stoy & Schalcher, 2007). Also, project location can influence tender cost as delivery charges for materials vary from location to location. Apart from the above, construction can be influenced by local government policies (Akintoye, 2000; Chan & Au, 2009; Dulaimi & Hong Guo, 2002; Elhag et al., 2005). Buildability and complexity of design are other important factors that influence the construction cost of a structure (Dulaimi and Guo, 2002). Additionally, type of structure, and construction techniques also influence construction cost. For instance, a steel structure

is more expensive than a timber framed structure (Akintoye, 2000; Chan & Au, 2009; Dulaimi & Hong Guo, 2002; Elhag et al., 2005). Construction duration is also another critical factor (Akintoye, 2000; Chan & Au, 2009; Dulaimi & Hong Guo, 2002). Long duration of construction can increase on-site labour costs, plant costs, site overheads and risks. Type of construction is another major factor that influences tender cost, as different types of buildings have different requirements such as heavy building service needs. Furthermore, Akintoye (2000) Elhag et al. (2005) identified limited access to site and storage facilities as another critical factor that influences tender price.

Client characteristics

Type of client was identified by many past researchers as another significant tender cost influencing factor (Akintoye, 2000; Chan & Au, 2009; Dulaimi & Hong Guo, 2002; Elhag et al., 2005).There are many differences between public clients and private clients, as their priorities vary. For instance, public projects need to be more accountable than private projects. The financial situation of clients can also be a significant tender cost influencing factor as there are different economic environments and payment systems for different countries. Quality requirement is another factor (Akintoye, 2000; Elhag et al., 2005). A high quality project means a high construction cost. High cost means a high tendering price from contractors. Construction deadlines indicate how long construction cost continues. Not enough construction time can increase construction cost (Elhag et al., 2005). A clear and certain project brief is important for establishing a realistic tender price (Elhag et al., 2005).

Contractor characteristics

The management team is regarded as the most important factor in terms of contractor characteristics (Elhag et al., 2005). A perfect management team with experienced staff is more expensive than others, but bring more benefits than shortfalls for most construction bidding. Moreover, capability of executing the construction plan is regarded as an influencing factor by Elhag et al. (2005). Meanwhile, contractors having experience on similar projects is important, which is the same factor as being an experienced team (Dulaimi & Hong Guo, 2002; Elhag et al., 2005). Dulaimi and Hong Guo (2002) agree that current work load is also important for tendering. However, Elhag et al. (2005) deduced it is not highly important.

What is more, past relationships between clients and contractors can affect tendering price (Chan & Au, 2009). To keep long-term relationship with clients, contractors can submit a lower price through decreasing profits. Long-term relationships will help contractors to get more projects and gain more benefit in the future. What is more, need for work is thought to be an important factor in influencing tendering cost. Need for work is decided by many factors, including idling of resource such as plant and labour. More the contractor is in need of the project, the lower the price. A lower price can improve competition (Chan & Au, 2009; Dulaimi & Hong Guo, 2002).

Tendering situation, consultant and design

There are six main factors, that influence tendering cost, grouped into tendering situation, consultant and design. Elhag et al. (2005) investigated all factors listed in this group. Absence of alteration and late change can influence tendering cost. Not enough information for the project can influence

tendering accuracy. Even though it lower costs, it can produce more variation at a later stage of construction. Therefore, it is easy to make a construction overrun. What is more, the more variations ordered by clients, the higher the costs. These three factors are regarded as the main factors in terms of consultant and design costs.

Also, Dulaimi and Hong Guo (2002) agree that the tendering situation is important for tendering cost influence. The tendering method, tendering procurement and type of contract are the main factors in terms of a bidding situation.

There are many methods for selecting contractors. The open tendering method generally produces lower tenders. More contractors can bid for projects because of limitations on the bidding company. At the same time, the elective tendering method is popular for contractors selecting jobs. The contractors, who have been pre-qualified and listed by the client, have opportunities to bid for the project. It causes higher tendering costs (Smith, Merna, & Jobling, 2006).

The traditional method and the design-build method are two main procurement methods in the bidding process. When using the traditional method, contractors simply bid for the stage of construction. Cost of tendering focuses only on construction based on a design from a separate design team (Greenhalgh and Squires,2011). However, costing the design-build method needs to cover fees for design and construction building. The tender price is based on client's plan and negotiation with clients. A lump-sum contract is popular for this method (Hughes, 2006; Ojo, Aina, & Adeyemi, 2011).

investigated by Elhag et al. (2005). They found construction competition is the most important factor. Contractors will make a tender cost lower to get the project in a highly competitive situation. Additionally, the material cost of a construction project is important for reducing the tendering sum. In estimating a tender, quantities of materials and cost of materials become more than half the total tendering price. Moreover, labour costs and inflation rates are important. Akintoye (2000) also found that stability of market conditions is an important factor. A stable construction market can make all costs of construction stable. Dulaimi and Hong Guo (2002) also agreed that the number of bidding contractors can influence tendering.

Inaccuracy of cost estimating

Making a tendering price is based on estimating experience. Inaccuracy of cost estimating influences tendering costs directly. There are many factors influencing inaccuracy of cost estimating, as found by Akintoye and Fitzgerald (2000). Based on research, the most important factor is regarded as insufficient time for estimating. Not enough estimating time will cause estimators to finish the job as soon as possible before the deadline. The details of site drawing and specifications are easily ignored, which can cause errors in estimating. Poor tender document is regarded as main factors to make inaccuracy of cost estimating. The tender document contains the drawings and specifications, which are critical for cost estimating. A poor cost document provides insufficient information about the building for accurate estimating.

External factors and market conditions

There are six main factors that influence tendering price, grouped into external factors and market conditions. All factors were

METHODOLOGY

A two-stage research methodology was selected in this research. The first stage is reviewing the relevant literature. Before

starting the following stage, thirty-seven pre-tender construction cost-influencing factors were identified and divided into six groups.

New Zealand Institute of Quantity Surveyors (NZIQS) is an official institute of quantity surveyors in New Zealand. To gain data on the factors considered important by quantity surveyors in New Zealand, all members of NZIQS were invited to participate in this research in the following stage. The link for an online questionnaire website was send to all of them via email. Up to the end of the research, 152 completed online questionnaires have been collected.

Method of data analysis

Analysing and ranking cost factors

There were 152 completed questionnaires collected form online questionnaire. For rating importance of factors, a five-point rating scale was used; rating point 5 being highest rating for most important factors and rating point 1 being for factors that were perceived to be 'not all important'.

$$SI = \left(\sum_{i=1}^{5} wi \times fi \right) \times \frac{100\%}{n}$$

(Eq. 1)

Where:

SI = Severity Index; this is computed as summation of importance rating (i.e. the mean or representative rating assigned to a specific cost factor by all the respondents);

wi = rating point, ranging from 1 to 5)

fi = frequency of response; i.e. number of responses associating a cost factor with a particular rating point.

n = total number of respondents rating a particular cost factor in the survey.

SI score of 70% and above implies that a particular cost factor is perceived as being highly important.

Table 8 to 13 summaries the find of statistical analysis for the research. It indicates that 28 factors have severity index from 70% to 88%. Severity index of remaining 9 factors is from 61% to 70%. Therefore, 27 factors are thought by quantity surveyors in New Zealand as highly important factors for tendering cost in construction project. Top three factors have more than 75% of severity index.

Measuring quantity surveyors concordance

"Coefficient of variation (COV) indicates the standard deviation as a percentage of the mean, and it is useful in comparing relative variability of different responses" (Elhag et al., 2005).

$$COV = \frac{S}{\overline{X}} \times 100\%$$

(Eq. 3)

Where:
COV = Coefficient of variation,
S = Standard deviation and
$\overline{X}$ = Weighted mean of sample.

The COV results will reflect the different opinions of all the participants form the results. A lower number of COV means higher agreement between all participants. The range

of COV for the research is from 12.71% to 25.91%, which means there is high agreement between all participants for most factors.

DISCUSSION OF RESULTS

Project characteristics

Table 1 summarises the results of the analysis of the relative importance and variance of the cost factors under project characteristics. There are 10 factors in category of project characteristics. Top six factors achieve severity index of more than 70%, which means these six factors are regard as highly important factors for influencing tendering cost in New Zealand. Two factors are ranked in top ten important factors of all. What is more, this category contains COV lower than 20% with the exception of two factors. This shows high level of agreement amongst the participants.

Table 1: Cost factors related to project characteristics

Sub-factors	SI	Total Rank	Group rank	COV
Complexity of design and construction	85%	2	1	22.46%
Buildability	83%	6	2	20.82%
Scale and scope of construction	81%	12	3	19.31%
Construction techniques	78%	19	4	18.41%
Construction location (regions / rural; urban)	75%	24	5	17.70%
Project duration	73%	28	6	15.31%
Type / function of construction(residential, commercial, industrial, office)	70%	30	7	12.71%
Access to site and storage limitation	70%	31	8	13.95%
Type of structures (steel, concrete, brick, timber, masonry)	70%	32	9	18.87%
Project size/ gross floor area	69%	34	10	14.83%

From Table 1, it could be seen that complexity of design and construction is regarded as the most important factor in this group, and overall it is the second most important factor that influence tender cost. The complexity of projects has already been investigated by Elhag et al. (2005). Complexity of project is ranked as second most important factor in project characteristics category. Additionally, Shash (1993) also addressed complexity of design and construction as being a key issue in influencing tendering cost. Buildability is ranked as the second most important factor, whose overall ranking is sixth. However, in few past studies it

has received a relatively low rank compared to this study (Akintoye, 2000; Dulaimi & Hong Guo, 2002). Results confirm that scale and scope of project is another important factor. Akintoye (2000) also approved this factor as important factor when studying cost estimating practice influencing factors. In that research, its overall ranking is second. Project size and gross floor area can be noted as the least important factor in this category as its severity index is just 69% and overall ranking is 34. However, size of floor is regarded elsewhere as highly important (Sonmez, 2004; Stoy & Schalcher, 2007). Elhag et al. (2005) indicate that site size rank as 30th of 67 factors, which is mid-level importance.

Client characteristics

Table 2 summarises the results of importance and variance analysis of the cost factors relating to the client characteristics.

There are five factors in the group of client characteristics as shown in the Table 2. Out of which, three factors are among top 10 having severity index more than 80%. This indicates that client characteristics have a high influence on tendering price in New Zealand. This group indicates a coefficient of variations ratio from 19.55% to 22.65%, which is relatively low. It shows a high agreement level for all participants.

Table 2: Cost factors relating to client characteristics

Sub-factors	SI	Total Rank	Group Rank	COV
Financial ability of client	83%	5	1	22.65%
Certainty of project brief	82%	7	2	19.60%
Deadline requirement	82%	9	3	21.36%
Client requirements on quality	79%	15	4	19.55%
Type of client (public/private)	69%	33	5	15.56%

Table 2 shows that the highest ranked factor in this category is "financial ability of client". However, according to the research done by Elhag et al. (2005) this factor has ranked as the least important factor in the category. The reason for this significant difference might be the economic environment of local industry. Compared with the United Kingdom, market of construction industry in New Zealand relatively small and has less stability. The second ranked factor of this group is "certainty of project brief" which ranked seventh overall. Type of client is regard as least important factor, which is ranked as 33 of 37. The COV values are relatively low in this category which shows strong agreement in quantity surveyors views on these factors.

Contractor characteristics

Results of the relative levels of importance of the cost factors relating to the contractor characteristics are summarised in Table 3. The table shows that six factors were clustered under this category. Severity index of all factors in the group is from 73% to 80%, which confirm the significance of these factors in tender price. However, their overall ranking vary from 13-29 showing middle range influence on tender price according to respondents views. Apart from the highest ranked factor in the category all the other factors received less than 20% COV showing high agreement between respondents. Most important factor of this group is experience on similar projects, which is ranked as 13th out of 37 factors. Previous studies by Elhag et al. (2005) and Dulaimi and Hong Guo (2002) also confirm the same result and highlighted client's experience on similar projects as an important factor to accurately predict the tender price. The second most important factor is experience and performance of management, which is ranked 14th out of 37. Ahmad et al. (2012) and Elhag et al (2005) also confirm the above findings. Planning capability is regarded as the least important factor of this group. However, Elhag et al. (2005) found it as one of top three factors in this group.

Table 3: Cost factors relating to contractor characteristics

Sub-factors	SI	Total Rank	Group Rank	COV
Experience on similar projects	80%	13	1	23.58%
Management team (suitability, experience, performance)	80%	14	2	19.86%
Past relationship with clients	79%	16	3	18.82%
Current work load	78%	18	4	19.96%
Need for work	75%	22	5	15.00%
Planning capability	73%	29	6	20.93%

Tendering conditions, consultants and design

Results of the relative importance of the cost factors relating to tendering conditions, characteristics of the consultants and the design features are summarised in Table 4. All the six factors listed under this group achieved severity index values between 68% - 85%. Completeness of project information was identified as the most significant tender price influencing factor in this category with a 21.98% COV. This shows a high level of agreement amongst the respondents. Apart from that, rankings of all the other factors are higher than 20, which show less significant impact on tender price. Interestingly, the above findings are in line with the previous research done by Elhag et al. (2005).

Table 4: Cost factors relating to tendering situations, consultants and design

Sub-factors	SI	Total Rank	Group Rank	COV
Completeness of project information	85%	3	1	21.98%
Absence of alterations and late change	76%	21	2	16.24%
Procurement method	75%	23	3	18.86%
Type of contract	74%	26	4	18.13%
Tendering method	73%	27	5	15.76%
Variation order	68%	36	6	14.68%

External factors and market condition

Table 5 presents the results of the relative importance analysis of the cost factors relating to the external and market conditions. As shown in the table, overall ranking of factors and severity index values vary significantly within the category. Results clearly indicate that some factors such as 'level of competition' and 'material cost' has significant influence on the tender price as their severity indexes are above 80% and overall rankings are 8 and 11 respectively out of 37. However, results clearly evident that the factors such as 'stability of market conditions' and 'interest/inflation rates' were not very significant on tender price. Coefficient of variation for all factors is less than 20.00%, which means results gained high agreement from participants.

Table 5: Cost factors external environment and market conditions

Sub-factors	SI	Total Rank	Group Rank	COV
Level of competition and Level of construction activity	82%	8	1	20.00%
Material cost	81%	11	2	18.76%
Labour cost /performance	79%	17	3	18.44%
Number of bidders on competitive projects	78%	20	4	17.33%
Stability of market conditions	68%	35	5	18.39%
Interest rate/inflation rate	61%	37	6	15.58%

Inaccuracies in cost estimation

Table 6 summarises the results of analysis for the cost factors associated with inaccuracies in cost estimation. The table shows that apart from the factor on 'shortage of project requirement standing', each of the other factors in this category has above 80% severity index value

and overall ranking below 10. This clearly indicates that cost estimating accuracy makes the highest influence on accuracy of tender price. Even though, COV of poor tender document is 25.91%, all the other factors have received relatively low COV. A previous study conducted by Akintoye and Fitzgerald (2000) also confirmed the above results.

Table 6: Cost factors associated with cost estimating inaccuracies.

Sub-factors	SI	Total Rank	Group Rank	COV
Poor tender document	88%	1	1	25.91%
Insufficient estimating time	83%	4	2	19.60%
Insufficient analysing of tender document	82%	10	3	20.14%
Shortage of project requirement standing	74%	25	4	18.20%

CONCLUSIONS AND RECOMMENDATIONS

Ranking and evaluating all these factors could help quantity surveyors to increase their edge. It is critical for contractors' quantity surveyors to prepare a very accurate and reliable tendering estimating for bidding, based on understanding cost-affecting factors clearly. It is also critical for quantity surveyors, who are working for a contractor, to achieve cost control at the pre-tender stage.

Based on the findings of this research, it can be concluded that poor tender document, complex design and construction and completeness of project information have been identified as the top three critical determinants of tender price in New Zealand. Also, results indicate nine factors

that are not so relevant in estimating tender price that includes: type of construction, access to site and storage, type of structure, variation order, project planning, type of client, project size, market condition, and interest/inflation rates.

Because of the time limitations of the research, an online questionnaire was the only method of data collection. For further study, interviews are recommended to add to the research. It would be meaningful to gain deeper understanding of critical cost influencing factors. Additionally, the critical factors evaluated in this research are ignored by most common cost estimating methods. In fact, most factors are difficult, time-consuming and costly to transfer into a project data system. If some personnel or organisations could create or

update a cost estimation system including these factors, it would be much appreciated by all quantity surveyors. It also would benefit the whole construction industry.

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ONYEIZU, E.

The Delusion of Green Certification: Case of New Zealand Green office buildings

THE DELUSION OF GREEN CERTIFICATION: CASE OF NEW ZEALAND GREEN OFFICE BUILDINGS

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ABSTRACT

This paper examines the resultant consequence of Green certification of office buildings in the construction industry. With focus on Auckland city, New Zealand, it analyses various aspects of the modern Green office building through the review of available literature. Firstly, it investigates the recent shift in motivation for Green buildings as a result of the crusade for Green office buildings. This is followed by an analysis on the change in office buildings' façade and indoor environment control measures in the 21st century. It is shown that the motivation for Green buildings has shifted from it being the right thing to do to the quest for financial benefits that are attributed to Green buildings. It is also shown that office buildings have become extensively glazed and highly dependent on artificial air conditioning systems. The consequences of these features are shown to be significant mainly in terms of the inefficient use of energy and indoor environment control dilemma. The effect on occupant comfort and expectations are also illustrated. This review is part of a research that investigates Green certified office buildings in New Zealand.

Keywords: Green office buildings, Glazing, Green certification, Glass Architecture, Air conditioning.

INTRODUCTION

Sustainable architecture refers to a design approach which produces technologically, materially, ecologically and environmentally stable buildings (Attmann, 2010) and indoor spaces that are conducive for their occupants. According to the author, Green architecture is an umbrella term which involves a combination of values and seeks to reduce the negative environmental impact of buildings by increasing efficiency and moderation in the utilisation of building materials, energy, and development space. Green thus requires a balance between sustainability, ecology and performance (Attmann, 2010) of which Green architecture aims to achieve. The product of this balance is a Green building (Figure 1). Yudelson (2007) grouped the characteristics of Green buildings into five broad areas: Sustainable site planning, Safeguarding water and water efficiency, Energy efficiency and renewable energy, Conservation of materials and resources, and Indoor environmental quality (IEQ).
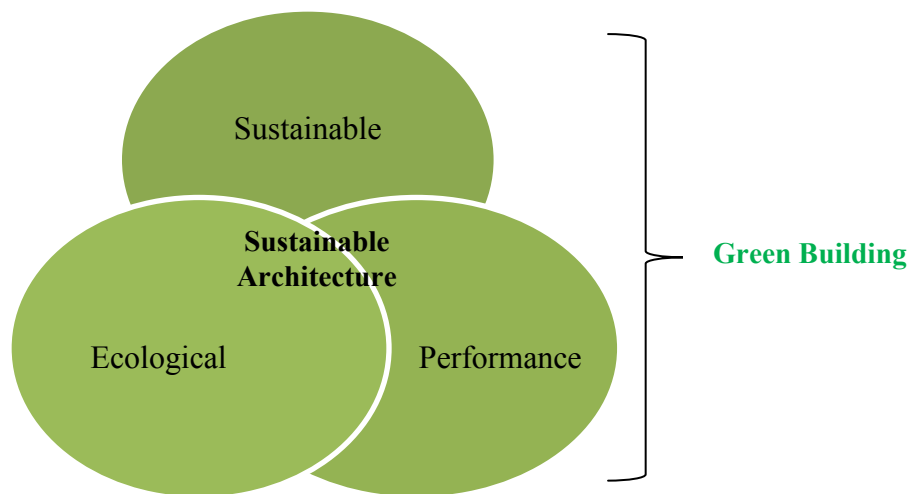
Figure 1: Relationship between categories of Green architecture. Adapted from Attmann (2010)

21st century Green architecture tends to apply generalised benchmarks that govern Green rating systems across the world. With only slight variations, Green rating tools are applied for different geographical regions with diverse local characteristics. For instance, the NZ Green rating tool is based on the Australian Green rating tools which draw its benchmarks from LEED and subsequently the BRE Environmental Assessment Method (BREEAM) (GBCA, 2009). As pointed out by Cichy (2012), their point-awarding systems are similar to each other. The difference is in the importance given to the credit points in specific categories (NZGBC, 2009). There is even a suggestion/proposal for a common rating system for Green buildings across the globe (Reed et al., 2009). In fact, three of the most common rating tools (BREEAM, LEED and Green Star, Australia (AU)) are seeking to develop common metrics that will help international stakeholders compare buildings in different cities (Kennett, 2009). As a result, there is greater similarity between the rating tools, leading to a trend towards common

concepts and technologies across the globe. This is the case of Green office buildings as discussed in this paper.

THE QUEST FOR GREEN CERTIFIED OFFICE BUILDINGS

As argued by Onyeizu (2014), recent corporate goals of pursuing sustainability through productivity have played a significant role in the growth of Green commercial buildings (von Paumgartten, 2003; Henley, 2013; Yudelson, 2008). The promise of increasing productivity and/or long term running cost savings that will offset the initial construction cost has lured many organisations to invest in Green buildings. As noted by von Paumgartten (2003), owners and operators have begun to see Green buildings as a financial business strategy. A real estate survey shows that the market is now attaching substantial monetary value to Green buildings (Fuerst & McAllister, 2008). A report by McGraw-Hill shows that the overall operation costs of a Green building in comparison to a conventional one is said to be

lower 8–9% lower (Nelson et al, 2010). Yudelson (2008) stated that projects which are not certified by a national third-party rating system, e.g. Green rating tools, will be functionally outdated the day they are completed and very likely underperform in the market as time passes. The Property Council of New Zealand released a recent report claiming that Green Star certified buildings deliver an 8.9% return on investment against 6.4% in non-certified buildings (Tunstall, 2012). A real estate specialist Charles Lockwool (2006) pointed out that trillions of dollars of commercial property around the world would soon drop in value because Green buildings are going mainstream and would render those properties less desirable.

Such claims have spurred the growth of Green buildings in the real estate market. Motivation towards building Green has now changed from being the 'right thing to do environmentally' to 'claimed financial benefits' (Figure 4) (McGraw-Hill, 2012 cited by Henley, 2013).
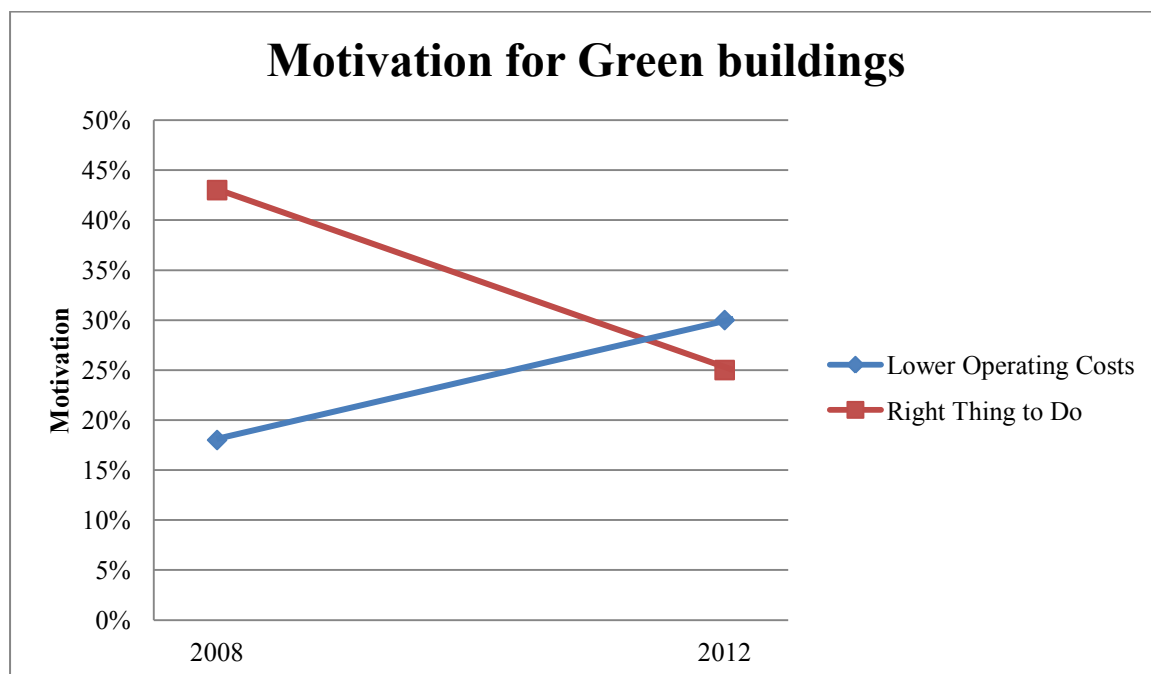
Figure 4: The recent shift in motivation for building Green. Lower operating costs include savings due to increased productivity. Source: McGraw-Hill. The business Case for Green buildings (Hensley, 2013).

According to LaSalle (2011a), the main reasons companies pursue sustainability strategies (which can earn them credits from the Green building rating systems) are to significantly increase employee health/productivity. The authors noted that CRE executives may well be pursuing Green strategies that can enhance employee productivity in the workplace. Moreover, a study by Kats (2003) of 33 Green buildings in the USA showed that a change in present value benefits of $37– $55/sq ft were achieved as a result of productivity gains.

Developers also play a significant role in the shift in motivation for Green buildings. For example, Boston Properties' Bryan J. Koop (n.d.) stated that he had learned from research that Green buildings actually improve the productivity of the people working within them. According to the senior Vice President and regional manager of this Real Estate investment trust, the IEQ of a Green building which is better than a traditional building can translate into a worker productivity increase of up to 18% (Koop, n.d.). Nelson (2008), the Vice President of RREEF Research, noted that the features of a Green building put together can increase worker productivity. The author also emphasised that the business case of Green buildings have become more compelling as the returns are becoming ever-more favourable, particularly when productivity gains are considered. Smith (2007) of Pramerica Real Estate Investors (2007) stated that the features which are typically incorporated into new Green office buildings to ensure a healthy indoor environment can generate significant gains in worker productivity. Perhaps most enticing is the idea by Kats (2003), which measures that generated productivity gains of around 1% would be equivalent to reducing property costs by 10%, which translates into about $3.00 per square foot of space. According to Nelson (2007), enlightened tenants should be motivated to pay a premium for space yielding tangible productivity gains, regardless of their energy-saving and other environmental benefits. Nelson (2007) concluded that Green buildings are fundamentally altering Real Estate market dynamics – the nature of the product demanded by tenants, constructed by developers, required by government and favoured by capital providers.

These results can be used by developers as a marketing tool to sell Green certified buildings. They also make Green certified buildings attractive to companies/organisations in their quest to increase their employees' productivity and the potential benefits associated with increased productivity. For example, Eichholtz et al. (2009) observed that firms in the oil industry and legal and financial services are major consumers of Green office spaces and support the notion of productivity benefits from Green buildings.

This change in motivation for Green buildings can be associated with the importance of the office worker (who is also the building occupant) to the success of any organisation. This draws attention to the impact of the workplace environment (i.e. IEQ) on their productivity and how this environment can be enhanced to have a positive influence on their productivity. As noted by Vischer (2008), "employers are increasingly concerned that their employees invest their energy in work rather than in coping with adverse or uncomfortable workspace conditions". Since a performing workplace is designed to optimise worker productivity (Clement-Groome, 2000), many organisations have invested a substantial amount of resources to ensure that workers are provided with the required IEQ that will encourage greater productivity. Green buildings are thus marketed with the expectation that there will be improved organisational productivity as a result of improved IEQ (Charles et al, 2004).

Some organisations which occupy these Green buildings have testified to this benefit by publishing survey results that show an increase in worker productivity. For example, a report by the New Zealand Green Building Council noted an 11.5% increase in staff productivity from a post occupancy study carried out on a certified Green building (NZGBC: Publications, 2010). A study reported by Gabe, Greenaway and Morgan (2007) concluded that there is potential for sustainable Green buildings to increase employee productivity. However, there are other findings that seem to

suggest otherwise. For instance, a report by Building Quality of Life (2009) noted that the so-called 'Green buildings' introduce unwanted levels of complication that baffle and overwhelm employees. They were of the opinion that the science of 'efficient design' to help make our buildings Greener has often failed occupants and do not take their true needs into account. McCunn and Gifford (2012) observed that Green design in office buildings does not have a positive effect on employee engagement or on environmental attitudes and behaviour.

THE GREEN OFFICE BUILDING

A Green certified building can be defined as one that achieves a given minimum amount of credits under a certain rating system. It is implied that the design of such a building is supposedly Green and that 'Greenness' is intrinsic in the very shape, envelope and style of the building. Heerwagen (2000) pointed out that Green accreditation results in a building where certain values of IEQ are achieved; thereby creating comfort conditions which induce higher worker productivity. Improving occupant productivity at a minimal cost is always welcomed in the business world. As such, marketing Green office buildings as the best environment to ensure greater worker productivity has been a major driver in the demand for Green certified office buildings. As a result of the purported benefit of greater productivity returns and more (Fullbrook et al, 2006), Green certified buildings have succeeded in attracting higher market values (Henley, 2010). For example, a study by Jones Lang LaSalle and CoreNet Global in 2010 showed that 48% of Corporate Real Estate (CRE) executives would pay up to 10% more rent to occupy a sustainable (Green) building (LaSalle, 2011a).

To provide this comfortable IEQ, Green buildings are expected to provide sufficient light for visual activities by daylighting to reduce the need for electric lighting while avoiding visual discomfort such as glare. They are also required to provide a suitable temperature for activities with good environmental control and to avoid thermal discomfort. Furthermore, a Green office environment should have good acoustics to enable easy communication and appropriate soundscape while reducing possible unwanted noise (distraction, disturbance). It is also expected to provide appropriate air quality, free from odours and contaminants. All of these should be achieved with minimal energy use (zero carbon footprint)[1]. These requirements are explained further in Yudelson (2007). When all these have been achieved, it is then claimed that they have created a comfortable work environment which will inevitably enhance the workers' productivity while being energy efficient. But to what extent is this theory a reality?

Balancing the need to create a comfortable IEQ for occupant comfort with ensuring energy efficiency seems to be the dilemma of 21st century Green office buildings. Since stakeholders are more concerned with financial gains rather than environmental gains, more attention is given to achieve an IEQ wherein occupants should be comfortable with the assumption that this will make them more productive. As a result, the sustainability and ecological responsibilities of Green architecture are downplayed as more importance has been placed on providing a comfortable working environment for the occupants.

The efficient use of energy in operating a building is a major determinant of a building's level of Greenness (Attmann, 2010). Hence, a building which does not use minimal energy

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[1] These requirements are explained further in Yudelson (2007).

throughout its lifespan may not be regarded as Green. But in the case of some Green rated buildings, the predicted energy savings are not realised. For example, during the design to renovate an Auckland office building to 5 Star Green rating, its estimated energy consumption of 170kW/sqm/yr before renovation (Wendy, 2011) increased to an energy consumption (recorded during occupancy) of 249kW/sqm/yr; an increase of 45%. Bordass (2001) pointed out that carbon dioxide emissions from supposedly Green buildings are commonly two or even three times as much as predicted.

The energy consumption problems of Green certified buildings may be due to the fact that most certification is carried out on building designs, thus on expected not actual performance of these buildings. This is the case with the New Zealand rating system, where there is no requirement to monitor the performance of buildings in-use. Indeed, it could be said that there are no Green buildings in NZ, only Green designs. Irrespective of the predicted performance of building designs, most Green certified buildings have been observed to perform below expectation, especially in terms of energy efficiency (Leaman, Thomas & Vandenberg, 2007). The authors noted that Green buildings place too much emphasis on good intentions at the design stage, rather than the practical reality of their management and use only to find that energy consumption estimates at the design stage are grossly exceeded in reality. Roaf et al, (2009) noted that current Green rating systems do not focus on a building's energy performance improvement to the extent that has been claimed. They point out that a sustainability assessment which does not focus on real energy efficiency could be misleading. Leaman and Bordass (2007) renamed such buildings 'Green Intent' buildings.

A study of occupants in a proven energy efficient building in Melbourne showed that despite its design being consistent with what is considered good practice from a sustainability perspective, the occupants were not satisfied with the noise and lighting levels in the building (Paevere & Brown, 2008). An occupancy survey of a Green certified building in Auckland showed a 10.5% increase in satisfaction after renovation attributed to the Green IEQ of the building; while the actual energy consumption recorded a 46% increase in the estimated consumption (Wendy, 2011). After a survey of sustainability and comfort issues for multi-glazed windows, Menzies and Wherett (2005) concluded that their findings do not support the hypothesis that environmental sustainability necessarily leads to improved comfort and productivity. According to the prevailing view, Green buildings should be environmentally sustainable and comfortable for occupants, but practical evidence refutes this.

The reason for this may be found in the standards and criteria set for comfort in Green buildings (IEQ criteria of Green rating tools). As explained by Onyeizu (2014), the standards of IEQ as laid out in Green rating tools neither capture nor consider in totality the varying environmental requirements and expectations of occupants. They are also not flexible enough to accommodate such variations. Cole (2003) pointed out that buildings designed with excellent Green performance standards can be severely compromised because the specifications and technical performance fail to adequately account for the users' needs, expectations and behaviour.

Another reason could be the techniques by which comfort and environmental sustainability are achieved in these buildings. Energy efficiency is better achieved with passive environmental control systems (Drake et al., 2010). This system of control assumes that human beings are able to adapt to a reasonably wide range of temperatures and can modify the

environment to suit their comfort preference (Brager & deDear, 1998; Tiwari1 et al, 2010; Tuohy et al, 2010). On the other hand, comfort is highly dependent on the expectations and perceptions of occupants, who are influenced by popular trends. As noted by Vischer (2008), the modern occupant's expectations and perception is said to be dominated by trends and technology. This has resulted in a

preference for certain IEQ criteria that cannot be achieved by passive means. Instead, they require the extensive use of mechanical systems (e.g. HAVC) to meet these expectations – a shift away from passive control systems. Thus, there is this conflict between satisfying occupants' expectations and being environmentally sustainable (Figure 5).
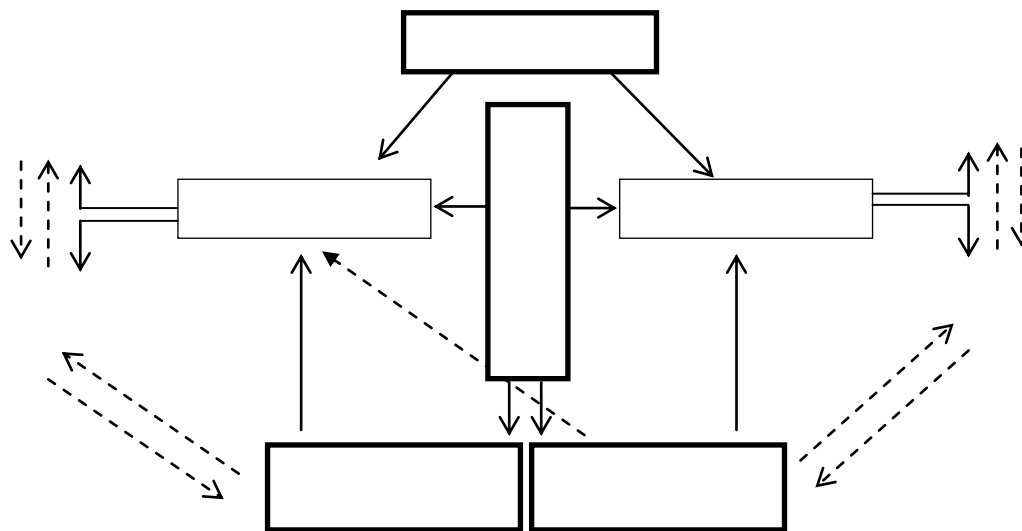
Figure 5: An illustration of indoor environment control dilemma in Green buildings. Energy efficiency and adaptable comfort on the right hand side; monotonous environment and low energy efficiency on the left hand side. Source: Author.

However, historical studies indicate that human beings are adaptable to wider environmental conditions than those that have become specified (Kwok, 2000; Nicol & Humphreys, 2002). In other words, it might be possible that comfort can be achieved in passive environments. For example, Moujalled et al., (2005) observed that occupants in free running (passive) buildings are comfortable in a wider range of conditions than those recommended. The occupant satisfaction survey carried out in the Green certified, naturally-ventilated building by Onyeizu (2014) showed high

satisfaction with the environmental conditions in this building. An indication that, in New Zealand, passive buildings are potentially sophisticated enough to provide comfortable IEQ conditions and also be environmentally sustainable.

One way of achieving greater occupant comfort with passive control system is by giving the occupants more control over the IEQ in their local environment. This way, they are responsible for changing their behaviour (and expectations) in buildings. Leaman and Bordass

(1999) noted that people who have greater control over their indoor environment are more tolerant of wider ranges of temperature. As argued by Brager and de Dear (2003), quality of life is inherently improved in environments that are enriched by a more variable sensory palette of thermal and other experiential qualities. Furthermore, the option for people to react to a specific thermal situation (as offered by passive control systems) reflects the opportunities to adapt to their environment and the possibility of achieving good levels of comfort (Drake et al., 2010). The level of comfort provided in a passively controlled environment should be tailored to satisfy the comfort needs of each occupant.

COMMON FEATURES OF THE GREEN CERTIFIED OFFICE BUILDING

The level of interest in the Green rating system is high as many organisations hope that having a Green rated building will give them more productive employees and subsequently bring in more return on this investment (von Paumgartten, 2003; Henley, 2013; Yudelson, 2008). Kats (2003) suggest that if Green design

measures can increase productivity by 1%, this would, over time, have a fiscal impact roughly equal to reducing property costs by 10%. Charles et al. (2004) noted that Green buildings are often marketed with the expectation that there will be improved organisational productivity due to an improved indoor environment.

But then, a closer look into the characteristics of Green certified buildings shows that these office buildings are mostly extensively glazed and air-conditioned. Out of 5 buildings with 5 star Green rating located in Auckland, New Zealand (Table 1) only one is naturally ventilated and it has 50% glazing. According to Kwok and Rajkovich (2010), it is important that we begin to future-proof our buildings with adaptive opportunities for passive, low energy buildings in response to the unprecedented climatic variability presented to us by climate change. The effects of these features were illustrated in Onyeizu (2014). Further discussion on these features is presented in the section below.

Table 1: Characteristics of five (5) Green Star certified office buildings in Auckland city, New Zealand. Source NZGBC: (2013a)

	5 STAR GREEN CERTIFIED BUILDINGS	THERMAL CONTROL SYSTEM	FAÇADE SYSTEM
1.	21 Queen Street, Auckland	Air conditioning system	Extensively glazing
2.	80 Queen Street, Auckland	Air conditioning system	Extensively glazing
3.	150–154 Karangahape Road, Auckland	Natural ventilation	50% glazing
4.	30 Mahuhu Crescent, Auckland	Air conditioning system	Extensively glazing
5.	Sylvia Park Auckland	Air conditioning system	Extensively glazing

Glass architecture

Glass architecture (the style of fully glazing building facades) has become very popular as the art of glazing seem to have become an integral part of a Green building. As observed by Byrd (2012), a common characteristic of many Green office buildings is a high proportion of glazing. From tropical Bangkok to warm and sunny Dubai and from continental Toronto to temperate London, highly glazed facades are the vanguard of Green office buildings. Accredited Green buildings in New Zealand often have facades which are more than 80% glazed (Byrd, 2010). Popular Green certified buildings such as 21 Queen Street and 80 Queen Street both located in Auckland are all glass buildings (NZGBC: Case Studies, 2013). The Bullitt Center, commonly known as the Greenest commercial building in United States of America, is mostly a glass building (Wilson, 2013). According to Wilson, some of the world's most prominent Green skyscrapers […] wear the mantle of Green with transparent facades.

The popularity of glass as a major indication of a building's Greenness can be said to be aided by the spread of globalisation. An effect of globalisation is that cities are copied and imitated across the world. For instance, there is a high level of similarity between the cities of New York and Tokyo as well between London and Dubai in terms of commercial infrastructure. So, it is not surprising that office buildings across the globe have the same characteristics irrespective of their locations and meteorological conditions. It has become common practice nowadays to design tall facades with extensively glazed areas. As observed by Bahaj et al, (2008), the skyline round the world is dominated by glass towers. Thomas O'Connor (2003), an architect at Smith Group, Inc., comments

"I like a lot of glass in buildings, and that is the trend in design today. Glass is back, and it's a 21st century material."

Glass was used in buildings long before the advent of Green architecture. In the 13th century, glass panes were used in houses as evidence of wealth and affluence (Butera, 2005). Green architecture enhanced its use with the potential to reduce electric lighting by daylighting and the provision of views for the psychological benefit that nature offers, and an associated massive save in energy use. (Ander, 2003; Menzies & Wherrett, 2003). Moreover, glass architecture represents a technological innovation that could be said to improve the appearance of building's façade (especially high rise) without much effort (Onyeizu & Byrd, 2011). It provides sunlight, ventilation, solar gain/loss in summer/winter and in other cases, emergency exists, as well as regulating the biological clock in the body (Aboulnaga, 2006). The simplicity of its design and installation (despite how sensitive it can be) makes it a favourite building envelope material (Onyeizu & Byrd, 2011).

The incorporation of glass architecture into Green architecture means that "the exploitation of natural light" is now possible and even commendable. As noted by Butera (2005), the architectural language of the last few decades has begun placing more and more emphasis on 'lightness' and the 'transparency' of buildings, thus pushing towards fully glazed envelopes. The emphasis on 'lightness' and 'transparency' of buildings is often associated with Green architecture, the idea being that the more transparent and light the building looks, the more Green the building will likely be. Thus, the idea that glazing leans towards sustainability becomes a justification for extensive glazing.

The other common justification for extensive glazing in office buildings is the purported

association of daylighting with increased productivity. The studies carried out by the Heschong Mahone Group (1999; 2003) quantified the effects of daylighting on human performance. Other studies have pointed out indirect relationships between access to windows and human health which can enhance productivity (see the abovementioned discussion). While acknowledging these benefits, Straube (2008) has pointed out that floor-to-ceiling glass is not required to achieve that. In fact, other survey results have shown that buildings with higher percentages of windows do not support the theory that environmental sustainability necessarily leads to improved productivity (Menzies & Wherrett, 2005). As quoted by Butera (2005)

"These buildings are the most dangerous type of buildings from the point of view of a dull and uncritical replication, hardly sustainable if well designed and definitely unsustainable if badly designed."

So, the association of glass architecture with Green architecture is equivocal (Butera, 2005; Gratia & de Herde, 2007). For instance, the unprecedented replication of glass office buildings all around the world irrespective of cultural preference and climatic conditions casts doubts on its sustainability. As mentioned earlier, Green architecture needs to be specific to geographical and climatic regions so as to accommodate local context and not alienate the core characteristics of those regions. The duplication of glass towers on every city in the world conflicts with the agenda of Green architecture and these glass towers are the dominant office buildings and the major contributors to energy use in the construction industry. Many modern office buildings have highly glazed facades (Eriksson & Blomsterberg, 2009). Gratia and de Herde (2007) found that glazed facades (double skin) increase cooling loads, while Byrd (2012) pointed out that the higher the glazing, the

more energy is required – blinds must be used to prevent glare and hence, there is subsequent use of electric light to brighten up the interior. As noted by Straube (2008) most of the gains in glazing technology over the past 25 years have been squandered on increased window areas, not on improved performance.

This does not imply that the contribution of glass architecture to Green architecture is all negative. Rather, glazing does bring benefits if it is well employed. Selection of the amount and type of glazing depends on many factors, including the orientation and location of the building. Menzies and Wherrett (2005) noted that well-oriented, high performance windows are a major part of energy efficiency in buildings. The Efficient Windows Collaborative Tools for Schools (2011) stated that windows should be sized to allow for access to daylight and views while avoiding excessive glare, solar heat gain and winter heat loss. Christoffersen et al, (2000) suggested that there is probably an optimum window size, beyond which windows in direct sunlight reduce the number of satisfied workers. Menzies and Wherrett (2005) observed that discomfort from glare is reduced in buildings if the glazed percentage does not exceed 40%. But it has been noted that sustainability has not been a major factor in the selection of windows/glazing (Menzies & Wherrett 2005). They observed that financial or performance related issues often lead designers and clients to choose less sustainable options in windows and components. Cost as the determining factor for the selection of glazing is short sighted if external shading devices such as blinds are required to reduce the negative effects of poor window components. The extra cost spent on these devices could be avoided by a reduction in glazing in the design.

It could be argued that highly glazed buildings are mainstream for Green certified and non-Green certified buildings, especially high-rise

buildings. However, it is imperative that features such as extensive glazing and the standards that stimulate are not encouraged by building regulations let only the Green building system. This is because, as Onyeizu (2014) indicated, there is a conflict between high proportions of glazing and environmental sustainability. As such, it is surprising that Green certified buildings are highly glazed (as illustrated in Onyeizu (2014)). For New Zealand, the LTV (Lighting, Thermal & Ventilation) Method for sub-tropical climates indicates a lower proportion of glazing (lower than 50%) in a building's envelope (Hyde, 1998). This is in contrast to the 70% – 80% glazing used in office buildings.

Air-conditioning

Most Green certified office buildings are air-conditioned. This means that they rely mainly on mechanical systems for their environmental control. The consequence of this is that the occupants of such buildings become finely tuned to these very narrow range/levels of IEQ and might not be comfortable in natural indoor environment conditions without time to reacclimatise (Brager & de Dear, 2000; Roaf et al, 2009). People now typically accept working patterns that are remote from the natural world; they have become accustomed to more sedentary lifestyles, and have come to expect buildings to automatically regulate indoor temperatures (Roaf, 2005). A consequence of this is an increase in the incidence of airborne infections and Sick Building Syndrome (SBS). Clausen et al. (2002) found that filters, ducts and plants of air-conditioning systems are often filthy, introducing air that is dirtier than if one simply opened the window. Raw (1992) cited in Roaf (2005) observed that a significant factor in the rise of SBS over the last two (2) decades has been the increased use of air-conditioning systems. Compared with naturally ventilated buildings, the indoor air quality in air-conditioned buildings can be worse (Roaf et

al., 2009). Roaf (2005) commented that in post 1960s buildings, designers often appear to be intent on following fashion and adhering to stereotypes – for example 'minimalism' or 'modernity' – to the extent that they produce buildings which are hard, sterile and inhuman.

Another consequence is the variations found in occupant satisfaction results in these Green buildings. While most post occupancy surveys imply that occupants are satisfied with the IEQ found in Green buildings, in-depth analysis of these results show a discrepancy between the overall and specific satisfaction indices. One example is the study of a Green building (Paevere & Brown, 2008), where it was noted that the occupants' satisfaction with 'building overall' is likely to have a greater impact on perceived productivity than aspects of IEQ. Leaman et al, (2007) also noted that Green buildings have higher perception ratings of image, health, design and meeting needs than ratings on physical indoor environment variables like temperature and ventilation. According to Leaman and Bordass (2007), Green buildings are rated better for more all-embracing summary variables such as 'comfort overall' or 'lighting overall', but when these are divided into their components, the favourable responses are less clear-cut.

As mentioned earlier in this paper, the energy performance of Green certified buildings often does not achieve the expected result of energy efficient buildings. An intriguing question which, although quite obvious, has eluded Green rating systems is how sustainable 100% air-conditioning could be. Since most Green certified office buildings are fully air-conditioned, the reliability of the Green rating tool in ensuring the energy efficiency of buildings during their operation and the total life cycle of these buildings is in doubt. This also implies that a building can achieve Green building status without reducing its energy use and subsequent carbon impact on the

environment. The only difference between such buildings and their non-Green certified counterparts is the Green label achieved through the certification process. As previously noted, the design-based certification of these buildings does not fully account for the actual energy use. Most of the time, the actual energy used in running these buildings exceeds the estimations made during their certification. This is because it is often too difficult to capture the diverse interactions and specific situations that occur in a normal workplace at the design stage. Moujalled et al. (2005) suggests that these complex interactions need to be considered if energy consumption in sustainable buildings is to be reduced.

Green rating tools have also been blamed for encouraging mechanical control systems (HAVC) which rely heavily on energy to function. As illustrated earlier, the points awarded for HVAC systems and the ease of gaining such points by merely installing HVAC encourages designers to opt for them. Hence, designers are no longer interested in the actual design of workspaces to achieve good environmental control, but are instead more concerned with what needs to be done to achieve Green certification – which installing HVAC helps to guarantee.

Finally, studies which show increased productivity that is attributed to Green buildings (Fuerst & McAllister, 2008; Kats, 2003; CABE, 2004; Heschong et al., 2003) have been criticised on the point that people tend to be influenced by predominant trends (Frontczak & Wargocki, 2011). In other words, occupants tend to follow the prevalent fashion in their preference and expectations of comfort. As such, they dislike certain environmental conditions which they are naturally adaptable to. This is most evident in office buildings where the use of mechanical systems such as HVAC is dominant. Researchers have noted that the introduction and use of new technology

has affected workers' perceptions of and attitude towards their physical environment and workspace (Cascio, 2000; Lai et al, 2002). For example, Brager and de Dear (2000) observed that occupants of buildings with centralised HVAC systems become finely tuned to the very narrow range of indoor temperatures presented by current HVAC practices. The researchers stipulated that these occupants develop high expectations for homogeneity and cool temperatures and soon become critical if thermal conditions do not match these expectations; in contrast to occupants in naturally ventilated buildings, who are more tolerant of a wider range of temperatures.

Another limitation is identifying the point at which level comfort begins to increase productivity (Czikszentmihalyi, 2003; Roaf, 2005). Whereas there might be a consensus on limits to comfort, it has yet to be determined at what point comfort affects productivity; or whether productivity is enhanced when a level of comfort is achieved. It is also worth noting that there is evidence that discomfort can be an enabler of productivity. Pepler and Warner (1968) observed that young people worked best (and were thus more productive) for short periods when they were uncomfortably cold.

CONCLUSIONS

This paper has addressed the implications of current trends and practices, supported by Green rating systems, on the facade of office buildings. A review of the literature indicated that there has been a change in the architecture of office buildings; similar building facades are becoming the norm in cities across the globe. This change is irrespective of local characteristics and the energy implications of such trends for occupant comfort and environmental sustainability.

The drivers for the certification of buildings were identified as including the real estate

market value of Green certified buildings in view of the promised increase in occupant productivity. The energy efficiency of Green certified buildings was reviewed and compared with passive design strategies. This revealed that occupant comfort and energy efficiency can be better achieved through passive designs.

 A review of the characteristics of Green certified office buildings in Auckland was carried out. It was pointed out that most of the office buildings are extensively glazed and air-conditioned. The implications of extensive glazing and air-conditioning were highlighted.

The findings have demonstrated that the crusade on and thus, quest for Green certification of office buildings lead to inappropriate architectural practices such as extensive glazing and more dependence on artificial indoor environment control systems. These practices are not energy efficient and do not uphold the concept and principles of environmental sustainability. This has resulted in Greenwashing wherein what is obtainable from these Green certified buildings do not illustrate the idea of a Green building.

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SHAHZAD, W.M.

Prefab content versus cost and time savings in construction projects: A regression analysis

PREFAB CONTENT VERSUS COST AND TIME SAVINGS IN CONSTRUCTION PROJECTS: A REGRESSION ANALYSIS

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ABSTRACT

Prefabrication technology (prefab) has various benefits, which have been widely researched and reported. Of all the documented benefits; cost and time savings are the most compelling incentives for adopting the technology. However in spite of these and numerous other benefits of the technology, its use in the construction industry has not gained the level of prominence it deserves. This is largely because the reported benefits have been anecdotal. Only few instances of quantifiable benefits have been reported; and these were mostly based on information derived from one or few isolated case studies. There is a general lack of quantifiable benefits that are based on sufficient empirical data and that are backed by statistical tests of significance. This research aimed to fill this knowledge gap by investigating whether or not prefab contents as percentages of the final contract sums could correlate significantly with the time and cost performance achieved on the projects. Using a case study research approach, 30 light to medium commercial buildings completed during the last 12 months in Auckland, New Zealand, were investigated. The project details acquired included initial cost estimate, final completion cost, estimated duration, actual duration, gross floor area and the value of prefab content as percentage of the final contract sum. Correlation and regression analyses were used to analyse the data. Results showed that cost and time performance improved with the increase in the building prefab content in the buildings within certain limits. Prefab contents ranged from 30 – 90 percents of the final contract sums for all prefab types involved in the projects, while the time and cost performance ranged from 50-130% and 40-120%, respectively. An exponential regression model of the form $y = 0.263e^{1.738x}$ was found as the best fitting curve to the cost performance versus prefab content (pc) plots based on its highest R^2 value of 0.87. The best fitting regression curve for the time performance versus pc plots, was a 2nd order polynomial of the form $y = 1.675x^2 - 0.715x + 0.601$ ($R^2 = 0.92$). Using these best fitting regression models, it was found that to achieve 100% or more in time performance, the prefab content should be at least 74%, while that of cost performance requires 77% or more prefab content. A Student T test of significance confirmed the reliability of these models within 5% significance level used in the tests. Thus, by increasing the offsite proportion of the building component up to 77%, there is 95% chance of achieving the cost and time targets, notwithstanding the influence of other extraneous factors such as weather, contract strategy, site and project characteristics. This result is expected to provide the empirical

evidence that decision makers need to employ more of the technology in the industry, and hence contribute to improving its wider up-take.

Keywords: Building systems, cost-saving, off-site manufacturing, prefabrication, time-saving.

INTRODUCTION

Prefabrication (Prefab), also commonly known as offsite manufacturing (OSM) of building components is relatively a modern and innovative construction approach in which bulk of building components are manufactured in remote offsite locations. Manufacturing of building components takes place under controlled environment in specialized factory setting for their subsequent transportation and installation at project site. Prefab is a very beneficial construction approach and numerous benefits of using prefab technology have been reported. Many industry driven panels recognize prefab as an effective solution to cut down some of the prevailing problems encountered by the construction industry including: cost over runs and delay in project completion (CACPUCI, 2009, Shahzad and Mbachu, 2012, BlismasPasquire and Gibb, 2006), poor quality of craftsmanship (DBH, 2009, Gibb and Isack, 2003) inferior environmental performance and risky health and safety conditions (CRC, 2007). Tam *et al.* (2007) reports that uptake of prefab technology is likely to address all the productivity and performance related issues of construction industry.

Despite all the acknowledged benefits of prefab, its application is generally low in construction industry. The observed uptake trend of prefab application is not as widespread as the benefits of this technology. Low uptake of prefab technology in construction process is attributed to the fact that most of the documented benefits of prefab technology are either not quantified or based on investigations of isolated case studies (Davis, 2007, CRC, 2007). Shahzad and Mbachu (2012) also report that existence of fewer evidence based benefits of prefab pivots the low uptake of this beneficial construction approach. This study is focused on filling this knowledge gap by quantifying the correlation between the percentage content of prefab employed in construction process and resulting savings of cost and time. It is important to relate proportion of prefab content in building construction with the cost and time performance that can be achieved with the application of prefab to encourage the uptake of prefab. Goodier and Gibb (2007) record that prefab is mostly adopted for its cost benefits. However, the most valued benefit of prefab over conventional construction methods is the fact that it shrinks the project completion time.

Now a days there is increasingly little differentiation between the prefab buildings and conventional buildings (Shahzad and Mbachu, 2012). Practically there is no building which is either completely prefab or completely conventional. All the conventional buildings involve some form of 'componentised' and 'panelised' prefab units or the other and similarly even completely prefab buildings involve some form of site work. Foregoing in view, having the information about the proportion of prefab which can result in 100% or more cost and time performance will not only encourage the use of prefab but it will also facilitate the project management team to have better control on project outcomes.

STUDY OBJECTIVES

The specific objectives of this study include following investigations:

1. To determine whether or not a significant relationship exists between the prefab contents of projects and the cost performance achieved on completion.

2. To also determine whether or not a significant relationship exists between the prefab contents and the time performance achieved on completion.

3. If a significant relationship is found to exist, to establish the percentage prefab contents that could result in 100% or more performance in both cost and time dimensions.

SCOPE OF STUDY

The scope of this study is limited to the case studies of 30 building projects, which were completed during the last 12 months in Auckland region. The projects investigated were light to medium commercial buildings with gross floor area range from 400m^2 to 1400m^2, and number of upper floors 1 to 3.

The initial and final project costs considered in this study are only construction costs; excluding other costs such as professional fees, consenting fees, land and land development costs etc. All the projects involved lump sum fixed price and traditional procurement system.

PREFAB IN PERSPECTIVE

The Modular Building Institute (MBI, 2010) defines prefabrication as the process of manufacturing and assembling the major building components at remote offsite locations for their subsequent onsite installation. Operationally, prefabrication is a construction innovation, which aims to take as much as

possible the construction activities away from the project site to the factory settings to ensure better quality and safer production under controlled working conditions (Haas and O'Coner, 2000). Prefabrication is also recognized as industrialized building construction approach (Kamar et al., 2011). This construction approach is seen as being more productive than the conventional construction approach (Arif and Egbu, 2010). Azman et al. (2010) see prefabrication as an evolution of onsite conventional construction techniques into more productive and innovative industrialized approach.

This technique readily supports standardisation and rapid prototyping (including 3D printing/ additive manufacturing technologies), which are expected to re-engineer the future of the construction industry (CACPUCI, 2009).

Types of Prefab

Several taxonomies exist for the classification of prefab technology. Davis Langdon and Everest (2007) classified prefab based on interfaces and connections as open-ended prefab and close-ended prefab. From a relative perspective, open-ended prefab is defined as simple panels or components which are fabricated at off-site locations using single or composite materials and brought to construction site for their assembly. Contrary to this close-ended prefab system is very complex and can only be manufactured in specialized factory settings. Examples of close ended prefab include modules, pods and whole buildings. From a geometric perspective, Bell (2009) categorized prefabrication into volumetric (i.e. modular and ready to install buildings), non-volumetric types (i.e. pre-nailed frames and panels) and the hybrid (i.e. combination of volumetric and non-volumetric). Shahzad and Mbachu (2012) extended Bell's (2009) three classes of prefab system to four: componentised prefab (i.e.

prefabricated building components and units such as precast columns and beams), panelised prefab (such as pre-nailed trusses, and the precast wall and floor panels), modular prefab (i.e. modules or pods), and whole building prefab (i.e. complete building short of foundations and onsite service connections).

Areas of Application of the Prefab Types

Davis Langdon and Everest (2004) observe that panelised or componentised prefab is best suitable for residential construction and similarly modular prefab is ideally suited to highly serviced areas, although other studies (Gibb, 1999, Bell, 2009) did not limit the application of this type of prefabrication to any area. Jailon and Poon (2010) note that the whole building prefabrication is mostly suited to portable or temporary applications such as out-door structures, holiday homes and site accommodations, or for any construction project where speed of erection is a necessity like post disaster management etc. Shahzad and Mbachu (2012) observe that there is increasingly little differentiation between the conventional building types and the 'componentised' and the 'panelised' prefabrication types. This is because conventional buildings involve some form of 'componentised' and 'panelised' prefab units or the other prefabricated units.

Why Prefab?

Several studies have explored the advantages of prefab technology. One of the major benefit of this technology is; it reduces the project cost and compresses the time period required to complete the project (Lusby-TaylorAinger and Ogden, 2004, MBI, 2010). Prefab technology helps on time delivery of project (Bell, 2009). Gibb (1999) reports that quality of construction improves with the application of prefab. Further to this, prefab enables improved onsite

health and safety conditions (Lu, 2009), reduced onsite material wastage and environmental impacts. Prefabricated construction reduces whole life cycle costs of buildings (Shahzad and Mbachu, 2012). Tam and Hao (2014) explains use of prefab components as the most effective approach to minimize waste generation during construction activity.

Due to the industrialized nature of this technique, shortage of skilled labour to meet market demands is not an issue anymore (Nadim and Goulding, 2009). Prefab method of construction is totally independent of inclement weather and hence there is no delay in project completion due to unpredictable weather conditions (Bell, 2009). Factory setting facilitates easy and close supervision of materials and craftsmanship. As most of the work is carried out in factory, there is less need of material handling at project site and hence the management of construction site becomes a lot easier (Gibb, 1999).

Prefab buildings can be tested by prototyping their models, this facilitates the forecasting of building's response to natural disasters especially the earthquakes (Gibb, 1999). Ngowi et al., (2005) believe that prefab is a resource-efficient technology and it is equally beneficial for all types of building construction as well as infrastructure projects.

Issues with Prefab System

In spite of various recognized benefits of prefab technology, it is observed that uptake of this technology is low in many countries or the use of prefab is not as wide spread as its benefits (Shahzad, 2011). This low uptake is generally associated with the high cost of transportation and requirement of carnage for lifting large size prefab components and modules (Gibb, 2003,

MBIE, 2013). Longer project lead time required for ordering and manufacturing of prefab components before the construction activity starts also hinders the likeliness of adopting prefab construction approach (Shahzad and Mbachu, 2011). Another reason that makes prefab unpopular for residential purpose is standardisation of design and lack of flexibility to make any changes in design after the project commencement (Goodier, 2007).

Bell (2009) investigated the socio-cultural perspective of prefab uptake and documented that misperceptions exits about this technology based on cultural issues and the social stigma attached to it, due to bad experiences in the past. These bad experiences are mainly related to the quality of prefabricated buildings, especially the poor quality housing construction of post-world war reconstruction process, labelled prefab as of poor quality and temporary   nature.

Major benefits of prefab like cost savings, time savings and high quality of components are associated with the repetitive nature of manufacturing process and standardization of components, which is in contrast with the requirement of a large number of clients. Shahzad and Mbachu (2012) observe that building owners doesn't like standardization of design, they rather prefer bespoke designs which allows them to make changes to suite their lifestyle throughout the design and initial construction stages. The conventional building approach offers this flexibility and also allows room for more proactive change management, whereas the prefab approach usually limits the extent of the owner's changes to the standard designs; else, the outcomes in terms of costs, speed and wastage will be less desirable when compared to the corresponding outcomes for the conventional system (Scofield and Potangaroa, 2009).

In some cases contractors and sub-contractors are reluctant to adopt this method of construction as they will have to change the way they have been doing their job. In addition to this the requirement of upfront capital to establish specialized prefab factories also hinder the adoption of this technology (Szwarc, 2013). Page (2012) observes that construction industry is inclining towards the use prefab and the use of this technology is likely to grow in future with more understanding of its benefits.

Prefab vs Conventional Construction

Prefab technology has many benefits over and above the conventional construction methods. Gibb (1999) explains how the manufacturing process taking place in factory makes prefab superior over other construction methods. Building panels, components and pods are manufactured in factories, with the use of high tech manufacturing machines making the process quick. The overall duration of project also reduces due to the parallel construction activities taking place at site and off-site. In addition to this, the components manufactured in factories are ready to be installed at project site and this further shortens the duration of site works.

The optimised use of construction material in factories reduces the project cost and also minimizes the waste generation (MBI, 2010). As most of the manufacturing takes place in factories and material is stored in storage, there is less likelihood of material being damaged. Prefab technology is environment friendly because less dust, noise and waste is generated during the construction works (Luo, 2008). Construction workers at project sites are vulnerable to health and safety hazard as they are exposed to extreme weather conditions; temperature, rain and winds. There is also a potential of being injured due to falls and other

site risks. Whereas, prefab factories provide a safe workplace (BlismasPasquire and Gibb, 2006).

Challenges for Prefab Uptake

To improve the uptake of prefab technology, there is a need to encourage its application by addressing the barriers which are hindering the adoption of this construction technique. This is not possible until the benefits of prefab technology are fully appreciated by the construction industry and clients (Shahzad, 2011). In this regard, one of the most challenging task would be to create awareness of prefab benefits among the project stakeholders to create an environment where prefab is accepted as a useful construction technique (Bell, 2009). Ian Page and Norman (2014) suggest that builders can perform this task by gradually introducing parts of prefab in conventional construction process and celebrating the performance efficiency gains of prefab application. Builders can also play a role by instructing the sub-contractors to use prefab technology (Szwarc, 2013).

Requirement of training is also recognised as an important challenge by Ian Page and Norman (2014). They highlighted the need of skilled labour required to manufacture high tech prefab components with complex interfaces. Coming up with design options which can ease the transportation of prefab components is also very critical to cut down the cost of transportation, as in some cases high cost involved in transportation of large sized prefab components neutralises the cost savings achievable with the use of prefab (Kelly, 2009).

RESEARCH METHODOLOGY

Case study research method is adopted for this research, this method is recognized to be useful when data samples and participants are selected based on their relevance to the subject issue and how well they represent the target population (Cooper, 1995). Information about cost, time and prefab content of completed commercial building projects provided the data for this study. Where some of the information was missing or incomplete for a specific building, the project manager for that building was contacted for the missing information. This is another reason of selecting case study research method, as it allows the flexibility of extracting required information from project records, making direct observations on the project and interviewing the project stakeholders (Cooper and Schindler, 2006).

Investigations were focused on exploring the performance efficiency of projects in terms of cost and time savings that could be achieved by the use of prefab components and panels in a building. 30 light to medium commercial buildings were randomly selected to be investigated. These buildings are located in Auckland region and have been completed in last 12 months.

With no pre-defined sampling frame for the study, information on the prefab buildings was obtained by online keyword searches by convenience sampling (Cooper and Emory, 1995) for the study. The construction companies were randomly accessed to request the cost and time data of recently completed commercial buildings. The key information acquired for all the buildings included: Initial cost estimates, final cost of project on completion, estimated project duration, actual duration of project, percentage cost of prefab components, gross floor area (GFA) and number of floors etc.

Data Analysis

The proportion of prefab content for a building was computed by finding out the percentage

cost of prefab components out of total project cost, hence the percentage prefab cost reflects the percentage prefab content in a particular building. Cost performance for each building was computed as quotient of initial cost estimate and final project cost (Eq. 1).

$$CP = \left(\frac{ICE}{AC}\right)_{\%}$$

(Eq. 1)

Where:

CP   =   Cost Performance

ICE   =   Initial Cost Estimate

AC   =   Actual Cost

Similarly, the time performance for each building was computed as quotient of initial time estimate and actual completion time (Eq. 2).

$$TP = \left(\frac{ITE}{AT}\right)$$

(Eq. 2)

Where:

TP   =   Time Performance

ITE   =   Initial Time Estimate

AT   =   Actual Time

Hypothesis Testing

It is recommended to ascribe some level of confidence in the formulation of hypothesis or theory generated from the limited samples (Cooper and Schindler, 2006, Mbachu, 2006).

This is done by reliability tests or statistical tests of significance. The statistical tests of significance, which informed the third objective of the study, therefore proceeded with a null hypothesis which assumed that there is no significant relationship between estimated and actual cost and time performance for the range of prefab content. The alternative hypothesis assumed that significant correlation exists between estimated and actual cost performance data for the range of prefab content data. The hypothesis testing was conducted separately for the observed cost and time performance. Typical procedure for the cost performance is defined as follows:

H_0:   There is no significant correlation between estimated and actual cost performance data for the range of prefab content data.

The alternative hypothesis was formulated as follows:

H_a: Significant correlation exists between estimated and actual cost performance data for the range of prefab content data

Acceptance condition: Accept H_0 if t-value is less than the value of t-crtitical.

Rejection condition: Reject H_0 if the t-value is equal or lower than the value of t-critical; accept the alternative hypothesis instead.

The above hypothesis tests were replicated for time performance.

RESULTS AND DISCUSSION

First two objectives of this study pivots on determining whether or not a relationship exists between prefab content and performance of project in terms of cost and time. For this purpose cost performance and time performance of each of the building included in

the study was computed against the percentage prefab content. Cost performance of building projects was measured by comparing the difference between initial cost estimates and actual project cost (Eq. 1).

Similarly time performance of case study building projects was computed by comparing the difference between the initial estimate of project duration and actual project duration (Eq.   2).

Of all the buildings investigated in this study, fourteen buildings were constructed mainly using panelised prefab with complementary onsite construction, six buildings were constructed using a mix of modular and panelised prefab with complementary onsite construction, Another six buildings were constructed using conventional construction methods with a small proportion of prefab frames and components and only four buildings were fully modular with complementary onsite construction.

Table 1. Shows the percentage cost performance and percentage time performance for each of the investigated building.

Data analysis yield that significant relationship exist between the proportion of prefab content in commercial buildings and their computed cost performance. Cost performance of all the case study projects was analysed against the proportion of prefab content for each building (Figure 1). Analysis reveal an increasing trend i.e. cost performance of commercial building projects improves with the increase in percentage content of prefab employed in the construction process. The breakdown of this relationship shown 40% - 70% improvement in cost performance with the application of 30% - 50% prefab content, 70% - 80% cost performance is observed when content of prefab is between 50% - 70% of the total project and 100% or more cost performance is achieved with the application of prefab in the range of 70% - 90%. The exponential trend between the prefab content and cost performance suggest that 77% prefab content in commercial buildings can result in 100% or more cost performance.

Table 1: Cost and Time Performance of Commercial Buildings

Project No.	% Prefab Content	Time performance			Cost performance		
		Estimated Duration (Weeks)	Actual Duration (Weeks)	%age Time Performance	Estimated Cost ($)	Actual Cost ($)	%age Cost Performance
1	30%	24	48	50%	315000	750000	42%
2	38%	28	52	54%	303750	675000	45%
3	45%	32	48	67%	533400	889000	60%
4	50%	24	35	69%	513500	790000	65%
5	52%	32	46	70%	902300	1289000	70%
6	50%	40	57	70%	1101175	1550950	71%
7	55%	37	52	70%	1264201	1755835	72%
8	59%	28	38	75%	1213758	1685775	72%
9	58%	36	52	70%	1137231	1557850	73%
10	67%	24	31	77%	925558.7	1250755	74%
11	63%	24	27	89%	610500	825000	74%
12	65%	40	47	85%	1463126	1950835	75%
13	68%	40	46	88%	1886250	2515000	75%
14	55%	48	67	72%	2090000	2750000	76%
15	66%	36	40	90%	1862592	2450779	76%
16	70%	32	37	86%	1178566	1550745	76%
17	64%	48	64	75%	1710646	2250850	76%
18	60%	40	46	88%	1689305	2165775	78%
19	67%	36	42	86%	1443441	1850565	78%
20	70%	48	60	80%	2176975	2755665	79%

21	70%	48	54	90%	3450511	3750555	92%
22	65%	36	45	80%	2751750	3057500	90%
23	75%	40	42	95%	2850950	2850950	100%
24	72%	40	42	95%	2891760	2950775	98%
25	75%	24	22	109%	918750	875000	105%
26	70%	56	57	98%	3053435	2775850	110%
27	85%	40	32	125%	3631470	3157800	115%
28	88%	24	19	126%	1121000	950000	118%
29	80%	40	34	119%	2588796	2157330	120%
30	90%	36	28	129%	4200924	3500770	120%
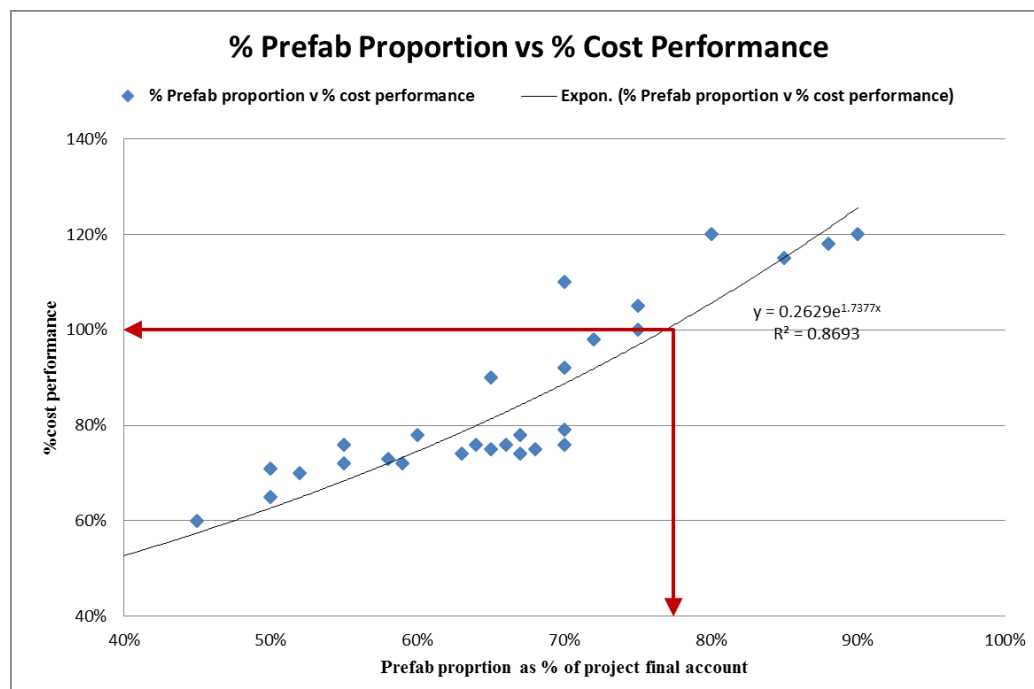
Figure 1: Prefab Content vs Cost Performance of Commercial Buildings

The time performance computed for all the buildings was analysed against their prefab content (Figure 2). The analysis of performance show that a significant relationship exists between the percentage prefab content and resulting time performance. 30% - 50% application of prefab content has shown an improvement of time performance between 50% - 70%, whereas 50% - 70% prefab content has shown time performance improvement between 70% - 100% and with the application of 70% - 90% prefab content 100% or more

cost performance has been noticed. With the application of 74% prefab content in commercial buildings, 100% or more time efficiency can be achieved.

The findings of this study are in agreement with the previous studies, that use of prefab has many beneficial aspects including saving in building completion cost and the duration required to complete the building project (Egan, 1998, BlismasPasquire and Gibb, 2006, Page and Norman, 2014).
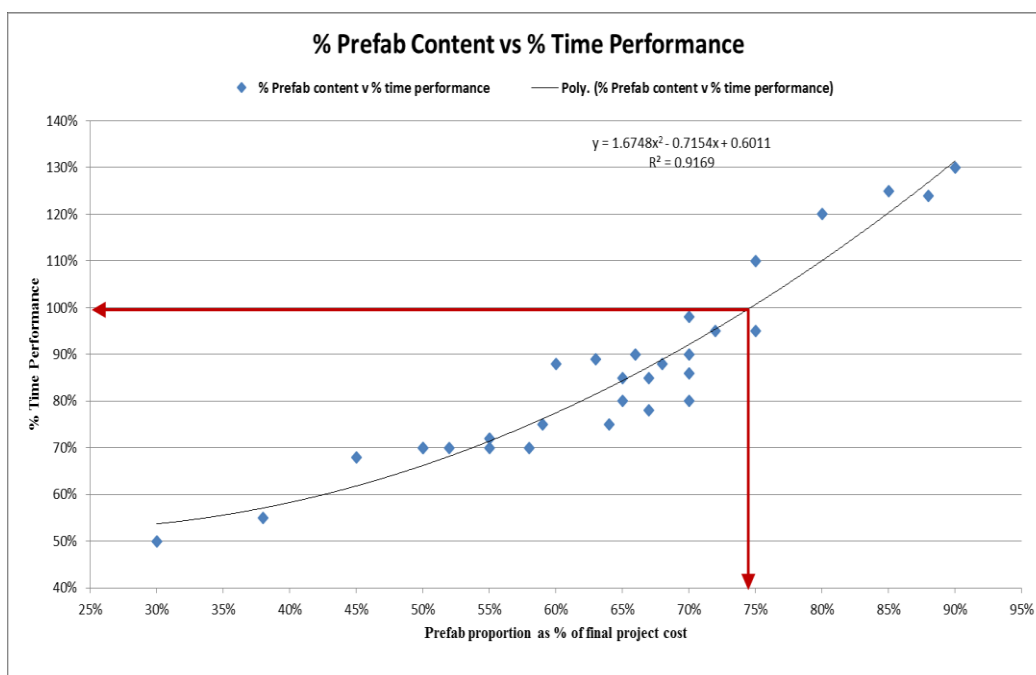
Figure 2: Prefab Content vs Timet Performance of Commercial Buildings
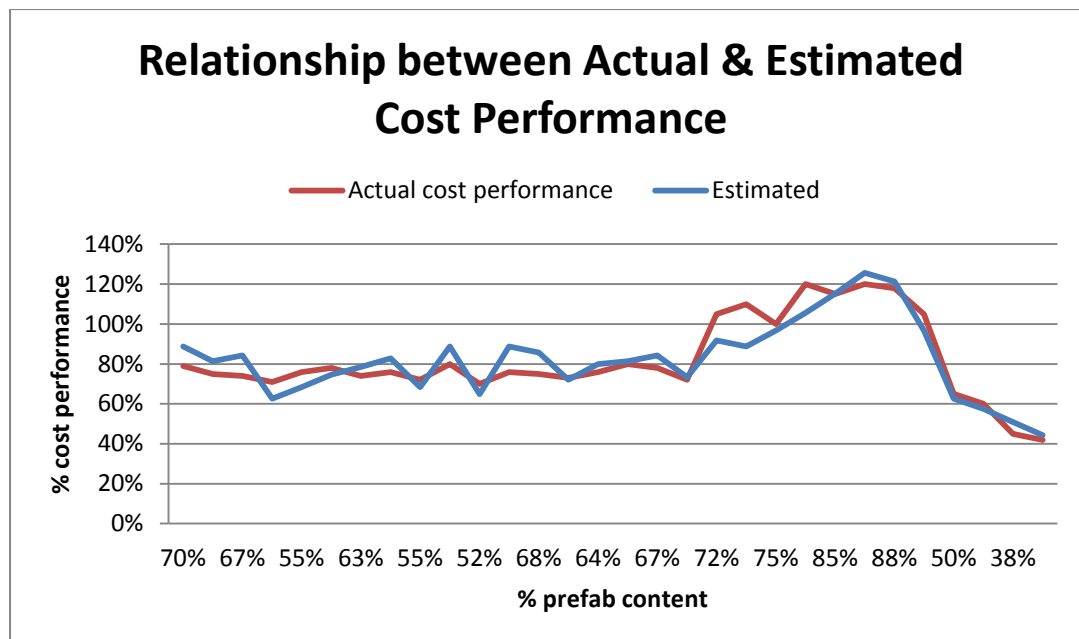
Figure 3: Relationship between Actual and Estimated Cost Performance

Figure 3 shows the relationship between the estimated and actual cost performance. The observed relationship was analysed to test the null hypothesis using t-value test. As the observed 't-value' (7.755) was greater than the value of 't-critical' (2.04522). Therefore null hypothesis stating that there is no significant correlation between estimated and actual cost performance data for the range of prefab content was rejected and alternate hypothesis stating that significant correlation exists between estimated and actual cost performance data for the range of prefab content data was accepted.

Similar test was replicated for time performance, which also resulted in rejection of null hypothesis and acceptance of alternate hypothesis

CONCLUSION

The study has successfully established the fact that proportion of prefab content has a significant relationship with the cost performance and time performance of the project. The study has quantified the benefits of employing prefab technology in light to medium commercial building projects by concluding that 77% prefab content in light to medium commercial buildings can result in 100% or more cost performance and similarly 74% prefab content can result in 100% or more time performance.

Findings of this study are likely to encourage the uptake of prefab technology in construction process. However, factors other than prefab content might be responsible for the cost and time performance such as quality of project management, site characteristics, procurement strategies etc. are recommended for further investigations.

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Profiling and mitigating risks in construction contracts

PROFILING AND MITIGATING RISKS IN CONSTRUCTION CONTRACTS

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ABSTRACT

Multiple risks are present in all construction contracts. During the bid process the contractor has to identify the different risk factors inherent in each prospective project. The identifiable risk factors will have differing impacts on profit margins and contingencies allowed for in the tender bids. Currently in New Zealand, there is little or no information on how to profile and respond appropriately to construction contract risks. This could lead to contractors overcompensating for risks or leaving themselves dangerously exposed through inadequate response. This study aimed to establish the leading contractual risk factors in the New Zealand construction industry, their risk profiles and mitigating measures. The research was based on qualitative and quantitative information garnered from practitioners in the New Zealand construction industry. Descriptive statistics and multi-attribute techniques were used in the data analysis. Results highlighted 21 risk factors which were segregated into 6 broad categories in diminishing levels of significance as follows: Site conditions, main contractor, pricing, subcontractor, external and client- related risks. Putting tags and conditions to risky price items or aspects of the tender bids, and transferring the risks onto other parties were analysed as the two most effective out of the 5 key risk mitigation measures identified in the study. Being cautious of the priority risk factors and application of the identified most effective risk mitigation measures could guide contractors and the project team to more appropriately budget for and respond to risks thereby ensuring more satisfactory project outcomes.

Keywords: Construction contracts, construction risks, risk management, risk profiling, risk response deployment, tendering risks.

INTRODUCTION

Risk or uncertainty is a detrimental reality in the construction industry. Not appreciating risk and accounting for it can be very costly to all stakeholders involved in risky decision making in relation to construction contracts.

While it is true that risk is present in every undertaking, the construction industry itself is especially risk prone due to the fact that construction projects are one off projects with many features that make them unique to most industries. Lengthy construction periods and time pressures, complexity and a very competitive market give rise to so many risks which must be responded to (Zou et al., 2007). Globally, extensive research has been carried out into construction risks, and several risk

factors have been identified (Yean Yng Ling & Liu, 2005; Marcus & David, 2012; Rowe, 1977). However, little research has been carried out on construction risks in the New Zealand context (Mbachu, 2011).

Despite it being risk endemic the construction industry has a poor reputation for structured and formalised risk analysis when compared with other industries such as insurance or finance (Laryea & Hughes, 2008). This shows that there is a crucial need for the industry and in particular contractors to have an appreciation of the risks they face and the underpinning factors through having a framework in place for risk analysis and response deployment. The risk of failure in construction businesses suggests that construction companies are not successfully accounting and allowing for risk (Oyewobi, Ibrahim, & Ganiyu, 2012). Within New Zealand we have not been immune to this either, with high profile business failures such as the recent liquidation of Mainzeal.

Contractors have several tools at their disposal for allowing for and managing the risks they may face. Much of this is done through the application of contingency margins to effectively price out the risk. Smith & Bohn (1999) posit a concise way to think of the contractor's contingency as their estimated value of the extraordinary risks they will encounter in a project. Other approaches at the contractor's disposal include avoiding the risk or transferring the risk to other stakeholders involved in the project. There are several models for pricing risks; however several empirical studies (Laryea & Hughes, 2011; Mochtar & Arditi, 2001) have shown that they are rarely used in practice. Instead the industry appears to largely rely on experience and intuition (Larim et al., 2012).

This study aimed to fill a knowledge gap in the literature by examining and ascertaining the specific risk factors experienced in the New Zealand Construction industry. The study also examined how New Zealand contractors are dealing with the identified risks and the impact of the risks on their businesses. Risk profiles of survey participants in the New Zealand construction sector were evaluated in terms of the frequency of occurrence and impact of the identified risk factors to their profit margins.

The overall aim is to develop a risk response deployment framework for profiling, pricing and responding to risks present in construction contracts. Providing a clear and concise risk response approach for New Zealand would be of a great benefit to contractors within New Zealand.

LITERATURE REVIEW

The following subsections will focus on highlighting the key terms and definitions associated with contract tendering, risk in context, risk analysis, risk response deployment method and pricing of contractual risks. Gaps in the existing literature are identified at the end, with an indication of how this study will contribute to narrowing the gaps.

Tendering in construction

Construction industry in most countries is an extremely competitive industry typified with high risks and low profit margins when compared with other sectors of the economy. (Mochtar & Arditi, 2001). Tendering is the popular means by which a company secures work and the price they put forward in the tender is the only instrument for earning revenue. This sets the backdrop as to why it is so important to consider risks in construction contracts as the optimum mark-up needs to be achieved to increase chances of being successful.

Since the lowest price is generally the one accepted in the competitive tender process,

especially for government contracts (Nutakor, 2007), the onus is then on the prospective contractor to deliver as low a bid as possible. This consequently shapes the treatment of risk and attitude to how they price it. With the above in mind when tendering it is critical to identify the optimum mark-up for the project as this increases the contractor's chances of being successful and winning the tender (Yean Yng Ling & Liu, 2005).

Defining 'risk'

A multitude of definitions for risk exists; however they all make the same fundamental point that risk is an unwanted effect or uncertainty that can affect project objectives. Risk is inherent in all construction projects and as such it can never be fully eliminated, although as a best case it can be managed effectively to limit and mitigate the impacts on expected project outcomes (Nieto-Morote & Ruz-Vila, 2011). Risk can be seen as the potential for unwanted or negative consequences of an event or activity (Rowe, 1977). The Australia and New Zealand standard (AS/NZS) 31000 (Australia, 2009) defines risk as the effect of uncertainty on objectives.

In the context of this study, risk and uncertainty are synonymous; each reflects the opportunity that is also embodied in uncertainty.

Benefits of risk analysis

Risk analysis is conducted to show what will happen if the project does not proceed according to plan. It acts as a warning system to alert the organisation to risks and uncertainties in the project's external landscape. It therefore assists in capturing all feasible options and helps to analyse various outcomes of any decision (Ahmet & Önder, 2003).

It has to be shown that there are benefits for undertaking risk analysis. Existing research shows that there is a relationship between successful risk identification and project success. For instance, Baloi & Price (2003) conclude that there is a logical relationship between adopting effective risk management strategies and project success since risks are assessed based on their potential impact on the objectives of the project.

Risk response deployment methods

Many formal models exist for assessing and pricing of project risks at the tender stage. Laryea & Hughes (2008) identify sixty models in their study on the pricing of risks in tender bids. These range from experience-based rule of thumb to formalised stochastic processes.

For the most part practitioners rely on their experience and intuition to allow for risks during the tendering phase. More flexible models have been suggested by Laryea & Hughes (2011) and Mbachu (2011), which are more practicable and simple to use by contractors. Additionally a straight margin on risk approach will often not work as contractors need to price their bids below this level to ensure they remain competitive.

Popular contractual risk factors

Several studies have focused on risk identification in the construction sector (Marcus & David, 2012). Ling (2005) identify five risk factors that seemed to be common cross the globe:

- Risks due to the nature of the work.

- Risks due to current workload / the desire of the company to have the project.

- Risks due to the need for work.

- Risks due to reliability or unreliability of a company's pricing approach.

- Risks based on the perceived competitiveness of other bids.

Pricing risks in construction tenders

Most risk pricing models in existence operate on the basis of applying a contingency margin once the level of risk has been identified. There is little research to support that there is systematic pricing of risks in the construction industry (Laryea & Hughes, 2008). In practice there is often a systematic undercutting of the identified risk so that contractors could stay competitive (Mbachu, 2011). The models for pricing risks generally do not take into account the realities of the market and specific needs of the contractor such as the desire to win the job or outbid competitors, or the expectation of more profitable future contracts following successful completion of the job at hand (Mbachu, 2011).

Existing knowledge gap

There is little research on the subject matter of contractual tendering risks in New Zealand. Also there is a lack of practical risk response deployment method that contractors could use. The literature is therefore lacking in terms of the knowledge of how contractors move from their understanding of risk factors to then setting a price (Laryea & Hughes, 2011). According to Smith & Bohn (1999), most risk and contingency studies has tended to focus on purely theoretical and analytical models for determining the level of risks in a contract. These models generally describe a set-loading of a fixed percentage contingency to cover risks. This study aimed to establish what the leading contractual risk factors are in the New Zealand construction industry, their risk

profiles, and holistic risk response deployment strategies for addressing the risks.

RESEARCH OBJECTIVES

The key objectives of this study are as follows.

1. To identify key risks that contractors in New Zealand construction industry encounter when pricing tenders.

2. To investigate the impact of the identified risk factors on contractor's profit margins and their occurrence frequencies.

3. To evaluate appropriate risk response deployment measures for addressing the identified risks. This involved undertaking a study of frequency and scale of risk negating measures.

RESEARCH METHOD

Research approach

A descriptive research method was adopted as observation technique (through opinion survey) was used as the primary data collection method (Mbachu, 2011). This involved questionnaire survey of stakeholders in the industry including contractors, quantity surveyors and project managers. A qualitative scoping study was first conducted amongst convenience samples of the stakeholders through purposive sampling. This helped to identify risk factors and mitigation measures specific to the New Zealand context. In the questionnaire survey, respondents were then asked to rate the relative levels of impact of the identified risk factors as well as relative levels of effectiveness of the identified risk mitigation measures.

Scope and limitations

The target population consisted of consultants, subcontractors and main contractors. These industry role players came from different sectors of the industry including commercial construction, interiors, civil construction and residential works within New Zealand.

Limitations of the study that were encountered included limited direct access to contractors, subcontractors and consultants. There are of course other stakeholders that affect risk but this study chose to focus on those groups described above. The respondents were largely Wellington based. Poor response rate has always been an issue in the construction industry, which limited the intention to have representative views from the various sampling frames.

Data sources

It was originally intended to utilise membership directories of the New Zealand Institute of Quantity Surveyors (NZIQS) (for quantity surveyors), New Zealand Institute of Building (NZIOB) (for consultants), the Registered Master Builders Federation (RMBF), and Specialist Trades Contractors Federation of New Zealand (STCFNZ) (for contractors and subcontractors, respectively). However due to difficulties inherent in obtaining membership directories from organisations due to privacy concerns, the surveys were administered through email circulars dispatched by the secretariats of the various trade and professional organisations.

Data analysis

Descriptive statistics were used in the data analysis. This involved computation of statistical measures of central tendency - mean, median and mode – as well as measures of dispersion – variance and standard deviation. This helped to understand the mean ratings for each group and the variances in opinions. The SPSS package was also used to carry out

Spearman Rank correlations across multiple variables.

Relative Significance Index (RSI) values computed from the data helped to rank-order the factors according to their risk levels. Overall, the research data gathering and analysis drew from the recommendations of authors such as Mbachu (2011) and Elhag et al. (2005). Elhag et al. (2005) present a mathetical model for computing the RSI as shown in Equation 1.

$$SI = \left(\sum_{i=1}^{5} w_i \times f_i \right) \times \frac{100\%}{n}$$
(1)

Where:

i : Represents the ratings 1-5 from the questionnaire

f_i : The frequency of responses

n : The number of total responses

w_i : The weight for each rating (ranging from 1 to 5 on a 5-point Likert rating scale).

RESULTS AND DISCUSSIONS

Survey responses

One hundred and eighteen responses were received by the cut-off date out of which only thirty six were found usable. This represented a usable response rate of 31%. Discarded responses did not meet the quality criteria set for feedback. This included responses from inexperienced people (years of experience less than 2 years, including interns/ trainees (30%), incomplete surveys (20%) and responses from people that do not have the experience and expertise to make meaningful inputs (49%).

Respondent demographic profiles

Slightly over half of respondents (53%) have more than 20 years of experience in the construction industry. A quarter of the respondents have between 10 and 20 years of experience. Only 8% of respondents have 2-5 years of experience in the construction industry. The general experience level of the survey participants therefore added to the quality of the feedback received.

In terms of scale of projects involved in, majority (56%) indicated that they were involved in projects that were in scale up to $1 million, which is the small to medium scale projects that subcontracts fall into.

In terms of the class of projects involved, majority (70%) chose commercial construction and civil construction works, which were in range of $1m -$5m, and $5m-$10m projects, respectively. Only a small portion (30%) was involved in larger projects worth more than $10 million. Responses in relation to these demographic profiles were fairly representative of the largely Wellington-based industry role players and showed a lack of major construction work currently taking place in Wellington.

In terms of which fields respondents came from, commercial and civil construction shared about a quarter of the responses each. Majority of the remaining responses came from the commercial interiors and refurbishment sector.

Concerning the nature of role played, responses were fairly evenly distributed between directors (22%), construction managers (22%), quantity surveyors (22%) and subcontractor (31%), with little responses (3%) coming from consultants. Significant responses from directors, construction managers and quantity surveyors added breadth and quality to the feedback received.

Contractual risks faced by contractors during tendering

Respondents were asked to rate some identified risk factors in terms of their relative levels of significance. 21 individual risk factors were identified. Through thematic analysis, the risk factors were segregated into 7 broad categories as shown in Table 1.

Unforeseen site conditions were identified as the 2nd greatest risk factor from all of those identified. Wong & Hui (2006) corroborated this finding by concluding that difficulty and uncertainties around site conditions constitute one of the inflating factors to contractors' pricing in competitive tendering.

Programming risks in terms of timeframes that are too tight to achieve satisfactory completion of a project were identified as the main risk in both this category and overall. The pressure to complete a project on time is often immense, especially when costly liquidated damages are involved, which add an additional dimension in terms of financial costs and risks. Additionally the availability of key inputs such as material and labour was identified as the third most significant risk factor. This is consistent with findings in other studies such as Marcus & David (2012) and Mbachu (2011) which highlighted significant risks associated with acute shortage of skilled tradespeople. Overall project related risks were identified as one of the major risks groups, having risk components with overall rankings of 1st, 3rd, 5th and 7th in the overall risk rankings.

Table 1 shows that pricing risks comprise experience and capability of estimating team, poor design and documentation, and insufficient time given to price the work (with overall ranking of 9th, 11th and 13th). It should be noted that Karim et al. (2012) study of Indonesian contractors identified design or documentation errors as the major risk factors

confronting contractors. Overall the pricing risks were identified as mid-ranking risks, suggesting that risks around initial pricing is not the major concern of most contractors, probably because many look up to variations to make up envisaged profit on a job (Mbachu, 2011).

Unreasonable expectations by the client was identified as a significant risk and ranked as the 6th most significant set of risks. This suggests that architects or consultants are possibly not doing enough to educate their clients on realistic expectations from the project team. Respondents had stronger feeling towards risks associated with working with difficult clients. The financial viability of the client was

perceived as the third most risky factor within this subgroup.

Surprisingly, finance related risks factors received very low rating by the respondents. These results were at variance with the findings of Marcus & David (2012) which identified subcomponent risk factors within this group, particularly, interest rates on bank loans and overdraft facilities issues as significant risks for contractors. Perhaps, this could be because the majority of the respondents being subcontractors did not depend on bank loans and overdraft for project financing. Mbachu (2011) noted that most subcontractors do not meet the stringent conditions for bank loans.

Table 1: Contractual risk factors impacting on tendering

Risk factors	Significance level rating					Total	Mean	Category Rank	Overall Rank
	1 %	2 %	3 %	4 %	5 %				
Site risks									
a) Inclement weather	8%	33%	28%	22%	8%	36	2.89	2	16
b) Unforeseen site conditions	0%	14%	36%	36%	14%	36	3.50	1	2
Project related risks									
c) Buildability issues such as complex site details or new methods that are unfamiliar	3%	11%	53%	25%	8%	36	3.25	4	7
d) Availability of key inputs such as labour, material or equipment	3%	14%	33%	36%	14%	36	3.44	2	3
e) Programme risks due to required delivery timeframes	0%	6%	22%	50%	22%	36	3.89	1	1
f) The ability or productivity of Subcontractors	0%	17%	39%	39%	6%	36	3.33	3	5

Pricing risks

g) insufficient time given to price the work	8%	31%	19%	33%	8%	36	3.03	3	13
h) Poor design & documentation	3%	25%	42%	22%	8%	36	3.08	2	11
i) Experience & competency of the estimating team	3%	28%	28%	36%	6%	36	3.14	1	9

Risks within your own organisation

j) Concerns around skill or competence of project team within your organisation	23%	31%	20%	23%	3%	35	2.51	2	19
k) current workload, i.e. taking on too many projects at one time	11%	25%	22%	33%	8%	36	3.03	1	12

Client related risks

l) unreasonable expectations of the client	0%	11%	50%	36%	3%	36	3.31	1	6
m) perceived risks that may arise as a result of dealing with a particular client	0%	28%	28%	42%	3%	36	3.19	2	8
n) Concerns around the financial viability of the client	17%	25%	14%	19%	25%	36	3.11	3	10
o) Perceived risks that may arise as a result of dealing with a particular Architect or consultant	6%	33%	28%	31%	3%	36	2.92	4	15

Finance related risks

p) interest rate changes	40%	31%	29%	0%	0%	35	1.89	3	21
q) Banks calling up or limiting overdraft facilities	39%	31%	17%	11%	3%	36	2.08	2	20
r) Possible cash flow risks, e.g. due to staging	9%	36%	26%	20%	9%	35	2.83	1	17

External risks

s) General market conditions	0%	33%	39%	28%	0%	36	2.94	2	14
t) Shortages of skilled labour	0%	17%	36%	36%	11%	36	3.42	1	4
u) Compliance risks, e.g. H&SE Act.	17%	25%	31%	28%	0%	36	2.69	3	18

Relative levels of significance of the broad risk categories

Survey respondents were asked to rate the broad areas of risks in accordance with their relative levels of significance. Table 2 shows the results of the analysis. Site related risks received the highest mean rating of 3.31, emerging as the most significant risk category. This was followed by main contractor related risks. Surprisingly, client related risks received the lowest level of significance rating. As majority of the respondents were subcontractors, the ranking of the significance levels of the broad risk categories could be different if main contractors were the majority; main contractors have been known to prioritise client related risks as the most significant set of risks impacting on tendering price (Karim et al., 2012; Wong & Hui, 2006). Perhaps, the result may not be surprising after all, if main contractors are seen as 'clients' of the subcontractors, given the high significance rating of main contractor related risks by the respondents.   Usually, in the traditional procurement system which dominates procurement system in New Zealand (Mbachu, 2011), subcontractors have contractual relations only with the main contractors, and therefore are shielded from direct influences of the client-related risks.

Table 2: Relative levels of significance of the broad categories of contractual risks

| Broad categories of the contractual risks | Significance level rating | | | | | | | |
	1 %	2 %	3 %	4 %	5 %	Total	Mean	Rank
Site risks	0%	14%	47%	28%	8%	36	3.31	1
Main contractor related risks	6%	17%	36%	36%	6%	36	3.19	2
Pricing risks	0%	28%	39%	25%	8%	36	3.14	3
Subcontractor related risks	3%	19%	47%	25%	6%	36	3.11	4.5
External risks	3%	22%	42%	28%	6%	36	3.11	4.5
Client related risks	3%	36%	39%	11%	11%	36	2.92	6

Risk mitigation strategies

Respondents were asked to rate identified risk mitigation strategies in terms of the frequency with which they use them in practice. Putting tags and conditions to overly risky price items or some aspects of the tender bids for which the respondents were not prepared to accept was the most frequently used risk mitigation method. This result is in agreement with similar findings by Laryea & Hughes (2011) to the end that, in the bidding process, contractors mainly

dealt with unwanted risks through the addition of tags and conditions.

  The 2nd most popular means of mitigating risk is to transfer the risk onto other parties. The use of these first two methods of mitigation allows the tenderer to keep their bid competitive by not requiring a contingency sum to cover the risks. The inclusion of contingency sums is only the 3rd most readily used risk mitigation strategy. This contrasts with its prominence in the literature as the most widely used risk mitigation measure (Marcus & David; 2012; Elhag et al., 2005).

Table 3: Risk mitigation strategies

| | Frequency of use (low to high) | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | | | |
Risk mitigation measure	%	%	%	%	%	Total	Mean	Rank
Putting tags and conditions to risky price items or aspects of the tender bids	3%	8%	17%	42%	31%	36	3.89	1
Transferring the risks onto other parties	9%	22%	33%	19%	11%	36	3.03	2
Lump sum adjustments to margin to cover identified risks	8%	33%	17%	39%	3%	36	2.94	3
Taking protective measures against risks such as liquidated damages	20%	36%	17%	14%	11%	36	2.60	4
Strategic withdrawal from the tendering by pricing uncompetitively	17%	42%	25%	11%	6%	36	2.47	5

Freely given feedback by respondents

Respondents were asked to comment generally about the topic, especially as regards to further risk factors they face while tendering for contract jobs. The following are the most recurring feedback received. They relate to issues around compliance, contract administration, construction management, costing and foreign exchange.

1. Health & Safety is a big issue. Inductions are required on site as well as a regular update meeting. This time never seems to be factored in to the schedule or pricing.
2. Environmental compliance is an issue. Costs and delay involved in guarding against pollution such as noise, dust and spills, even run-off/ sediment control are huge, often beyond the risk

contingency added at the tendering stage.

3. Cultural issues, such as protection of heritage trusts or endangered species.
4. Very onerous special conditions of contract, e.g. contractors bond, unrealistic LD's.
5. High deductible on Principal's Contract Works policy, under NZIA conditions.
6. Transfer of information between tender take-off and work on site. E.g. quantity is measured as 2.7m sheets, but ordered as 2.4m incurring more waste and labour.
7. Incorrect assumptions: Actual site method being different from tender assumptions, causing a change of method or losses if ignored.
8. Incompetence, especially on the part of the subcontractors and the supervisory team.
9. Poor productivity of internal resources compared to that allowed in tender build up.
10. Ambiguity between Drawings, specification and basis for payment.
11. Subcontractor workload and prior commitments - having to get another subby at a higher cost.
12. Variations notification to client/engineer - timely notification within contract specified timeframes.
13. Delay as a result of H&S incident.
14. Cost fluctuation resulting from instability in the foreign exchange rates (especially where offshore content cost is significant).
15. Our biggest risk is when a clear error has been made in the contract documentation by the consultants or architects and they then refer to an "all capturing" clause to make the contractor do the work. Generally the contractor has priced the job competitively to win the work at a fair margin and assumes the contract

documents to be right. Lumps of contingency are not included to cover consultants' errors.

CONCLUSIONS

This paper has explored the leading contractual risk factors in the New Zealand construction industry, their risk profiles and mitigating measures. Results highlighted 21 risk factors which were segregated into 6 broad categories in diminishing levels of significance as follows: Site conditions, main contractor, pricing, subcontractor, external and client- related risks. The most risky factors under the broad categories comprise, respectively, unforeseen site conditions, poor project management, inexperience or incompetent estimating team, work overload arising from taking on too many contracts at the same time, shortage of skilled labour, and clients' unreasonable expectations.

Putting tags and conditions to risky price items or aspects of the tender bids, and transferring the risks onto other parties were analysed as the two most effective out of the 5 key risk mitigation measures identified in the study. Being cautious of the priority risk factors and implementation of the identified most effective risk mitigation measures could guide contractors and the project team to more appropriately budget for and respond to risk thereby ensuring more satisfactory project outcomes.

The findings of the study are fraught with a number of shortcomings which may limit their generalisation or application in a wider context beyond the study scope. These comprised poor responses which were not representative of the various sampling frames for the study, and exclusion of feedback from important stakeholders such as clients. Furthermore the responses were heavily biased to the favour of subcontractors who constituted the majority of

the respondents. Notwithstanding the shortcomings, the findings have provided useful starting points for further debate and more detailed investigations into the subject matter.

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Influence of socio-economic conditions on building costs in New Zealand

INFLUENCE OF SOCIO-ECONOMIC CONDITIONS ON BUILDING COSTS IN NEW ZEALAND

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ABSTRACT

Building cost trends are influenced by some socio-economic factors (SEFs) which are external to project environment. However, in practice, estimators of building costs only focus on immediate project cost variables. Influence of SEFs on cost estimates and underpinning variables is scarcely considered. This may be due to a gap in the knowledge of which SEFs significantly influence building costs and extent of the influences. This study aimed to bridge this knowledge gap by examining time series trends in key socio-economic indicators (SEIs) and building costs with a view to ascertaining which SEIs significantly influenced annual changes in building costs over a 12 year period – 2001 to 2013. The study adopted archival research method. Data were sourced from Rawlinsons construction handbooks and databases maintained by the Reserve Bank and the Statistics New Zealand. Analyses were by the SPSS time series modelling and Student T tests. Results showed that out of 18 SEIs analysed in the study, only 11 were reliable influencers of building cost trend over the study period. Annual changes in house prices were found to be the most significant influencer of building cost trend, followed by changes in the producer price index (PPI) and consumer price index (CPI). 7 SEIs, which were considered as key influencers of building costs in previous studies were found to have no significant influence on building costs. Notable among these were capital goods price index (GPI), labour cost index (LCI). It was argued that unaddressed multi-collinearity issues in previous studies and the tendency to base forecasts on pattern recognition rather than on the outcome of stochastic analysis, might be responsible for the contrasts found in this study. Overall, it was recommended that construction cost estimators should monitor future movements in the identified 11 SEIs to gain understanding of correlational effects on building cost estimate over a given forecast horizon for a project. This would minimize forecast risks and ensure more reliable cost estimation.

Keywords: Building costs, socio-economic indicators, time series modelling, trend analysis, regression analysis.

INTRODUCTION

With the exception of the period of global financial crisis (GFC), building costs have been known globally to always increase at a far greater pace than any other asset group. For instance, the Department of Building and Housing (DBH, 2008) reports that the period 2001-2007 was marked by increases in

residential and non-residential building costs, which were more than double the increase in the consumer price index (CPI) inflation and all other sectors' capital goods prices. Similarly, the American Institute of Steel Construction (AISC, 2014) observes that Construction costs have escalated significantly over the past five years with the square footage cost of non-residential buildings increasing by a rate greater than the 19.4% increase of the CPI.

Attempts by building economists, property analysts and other property experts to forecast increases in building costs or gain understanding of the key drivers have been unreliable. This is evident in a lot of forecasts that turned out to be significantly different from the actual results. For instance, Federal Reserve Bank of New York (2000) notes "that analysts seeking evidence of future directions of socio-economic trends often focus on the movements of a single indicator, whereas simple statistical tests reveal that such indicators, used in isolation have very limited predictive power" (p.1). Perhaps this may explain the finding by the Reserve Bank of New Zealand (2013) that only 28% of the predicted market shifts were on target, while 72% proved unreliable. Worse still, many forecasts or trend analyses are 'quasi-quantitative' in the sense that quantitative approach may be used to explore the trends, but inference of correlations is often qualitative – i.e. by pattern recognition, which involves visual inspection of apparent trends (Stewart, 2001). Only in few instances are statistical tests of significance carried out to assess whether the apparent correlations are real or by chance variations. A lot more improvement could have been made if stochastic analysis were undertaken to examine the measure of confidence implicit in the forecasts.

Drawing upon classical and Keynesian economics (Vitez, 2014), we understand that trends in building costs – and in deed for all goods and services - are influenced by supply

and demand forces that shape market conditions and directions. The market demand and supply conditions are in turn influenced by layers of other factors which are underpinned by micro- and macro- economic conditions (Reserve Bank of New Zealand, 2013). The first layer or immediate set of factors influencing building costs comprises increases in the key building cost components. The Organisation for Economic Cooperation and Development (OECD) (2013) identifies the key components of building cost (to the building owner) as comprising building development cost, land cost and land improvement cost. The building development costs comprise materials, labour, preliminaries and general (P&G), contractor's overhead, risk and profit margins, and consultants' fees.

In practice, estimators of building costs only focus on immediate project cost variables. After estimating the cost of building works from underlying cost components, allowances are made for cost increases over the project period and for variations to the contract. Rawlinson's (2013) puts the building works contingency for variations to the contract as being in the range of 3 – 10%. Additional allowance is made for total project contingency, in addition to building works contingency. The latter is usually in the range of 10 to 20%, depending on the perceived risk profile of the project (Hendrickson, 2008).

In estimating the building costs, the influence of the socio-economic factors (SEFs) on the cost estimate and its underpinning variables is scarcely considered. Stewart (2001) argues that one of the effective ways of improving reliability of forecasts is to limit the amount of information used to a small number of really important cues. In the context of this research, Stewart's (2001) recommendation could be applicable, whereby estimate or forecast of building costs could be reliably made if based on a limited number of really important SEIs. But the question is which SEIs are really

important in terms of influencing future directions of building costs? There is a knowledge gap here, as few studies have looked at which SEFs significantly influence building costs and the extent of the influences.

Research aim and objectives

This study aimed to bridge existing knowledge gap by examining time series trends in some socio-economic indicators (SEIs) and the corresponding trends in some building construction costs and to analyse any cause-and-effect relationship with a view to ascertaining which SEIs significantly influence observed annual changes in the building costs over a 12 year period – 2001 to 2013. The specific objectives of the study were as follows:

1. To analyse annual percentage changes in building costs and the corresponding changes in the socio-economic indicators within the delineated study period 2001-2013.
2. To regress the annual percentage changes in the building costs against corresponding changes in the SEIs and to examine the relative levels of influence of the SEIs on the observed annual changes in the building costs over the study period.
3. To test the levels of significance of any observed influences of the SEIs and to use these as a basis for prioritising the SEIs, as well as for segregating them into significant and non-significant groups, where applicable.

Components and drivers of building cost

The Department of Building and Housing (DBH, 2008) segregates total building development cost into materials, project management and overhead, labour and council fees and levies. A six year (i.e. 2001 – 2007)

trend analysis of the building cost increases for residential and non-residential buildings in New Zealand by the Department of Building and Housing (DBH, 2008) shows 42.5% increase in residential building costs over the period. The cost increase was found to be underpinned by materials (39.2%), project management and overhead (30.7%), labour (15.3%) and council fees and levies (14.8%).

From a broader perspective, Turner Construction (2014) sees increases in construction costs as being driven by various socio-economic and market factors including constrained availability of labour, stability in commodity prices and competition in the market. Turner Construction (2014) further notes the failure to take into account wider socio-economic and market factors such as labour rates, productivity, material prices and competitive conditions of the marketplace as the shortcomings in published indicators of building costs and price trends. Turner Construction's (2014) observation suggests that the factors shaping the magnitude and direction of the building cost trend are in layers, which range from primary to tertiary influence factors. The primary influence factors comprise the building cost components. The building cost components are in turn influenced by factors in the project environment such as the project characteristics and the actions or omissions of the key role players in the project development cycle. Next is the set of factors operating at the industry level, such as the level of competition, skills and productivity, as well as property market dynamics such as the level of investment in property development, level of demand for building, and property market cycle. Underpinning the secondary layers is the set of macro- and macro- economic factors, socio-cultural, political and legislative influences, as well as global dynamics. The Reserve Bank of New Zealand (2013) sees these tertiary influence factors as socio-economic dynamics which movements are

captured through changes in the socio-economic indicators (SEIs).

The above conceptual schema helps to understand the raft of factors influencing trends in building cost and shows that basing future estimates of building costs on the primary or immediate building cost components alone will prove unreliable since the building cost components themselves are influenced by the secondary influence factors. But then, the solution does not lie on an understanding of the secondary factors alone, since they are in turn influenced by the next lower layer of tertiary level factors. A more strategic approach should focus on the root drivers comprising the tertiary factors. With the SEIs being the metrics for assessing shifts in the tertiary factors (Reserve Bank of New Zealand, 2013), more reliable building cost estimate and forecast could be made by examining how the annual building cost changes move with corresponding annual changes in the influential SEIs. This study will focus on establishing the influential SEIs and their relative levels of influence on the building cost trend over the study period.

Socio-economic indicators (SEIs)

As the name implies, socio-economic indicators (SEIs) are indexes for reporting on the annual or quarterly changes in the socio-economic trends in the country (Statistic New Zealand, 2013). Several SEIs exist for several purposes that include political, socio-cultural, economic, statutory, statistical and research. Barnes (2014) argues that of all SEIs, three are the most important:

-        Gross domestic product (GDP); this measures economic growth or recession,
-        Consumer Price Index (CPI); this measures rate of inflation;
-        Unemployment rate; this measures rate of unemployment.

Barnes' (2014) argument hinges on the fact that governments and the reserve banks base their fiscal and monetary policies largely on the changes in these indicators relative to established benchmarks. The fiscal and monetary policies in turn affect the decisions, choices and operations in the main stream economy.

Generally in the construction industry, changes in the GDP impact on building costs when they stimulate or decrease the volume of building activities in a given period. Barnes (2014) and the Bureau of Economic Analysis (2014) present wider implication of the GDP that shapes future directions of the economy, monetary policies and fiscal policies, and by implication, future trends in building costs. This relates to the Real GDP value and the economic inferences that could be drawn from it. Bureau of Economic Analysis (2014) reports that globally, the general consensus is that annual Real GDP growth rate of 2.5 – 3.5% is the range of best overall economic benefit: enough to provide for corporate profit and jobs growth, yet moderate enough to not trigger concerns for inflation and the application of macro prudential monetary policies. Barnes (2014) argues that if the economy is just coming out of recession, it is Ok for the GDP to grow to 6-8% range for a specific timeframe without the need to tighten macro-prudential policies. Barnes (2014) reports that investors look for the long-term rate to stay near the 3% growth level for the overall best economic stability that fosters long term planning and economic growth. Bureau of Economic Analysis (2014) defines an economic recession as the condition of two consecutive quarters of negative GDP growth.

The above knowledge of the Real GDP figure compared to the 2.5-3.5% post-recession range or 6-8% recession range has interesting implication for future building cost directions, which estimators or predictors of building costs

should be aware of. This means that if the Real GDP figure falls below the ranges, fiscal and monetary policies are likely to be formulated to stimulate economic growth and hence portend future increase in building activities and higher building cost trends. The reverse is the case for Real GDP figures above the two ranges. This also aligns with the inflation growth range of 2.5-.35% which most national governments and reserve banks use as the litmus test for applying or relaxing fiscal and monetary policies (Reserve Bank of New Zealand, 2014). This knowledge is essential and should be taken into account while estimating or predicting building costs over any given period.

RESEARCH METHOD

Method

The study examined trends in some socio-economic indicators and building cost data with a view to ascertaining whether or not significant correlations exist between the two datasets as a basis for prioritising the significant correlates of the building cost trends. The research required historical data on building costs and socio-economic indices over a given period. Archival research was therefore the appropriate research method for the study based on the recommendations of Cooper and Schindler (2006) and Zikmund et al. (2009).

Source and units of analysis for the building costs

The cost information for the various building types in 3 main cities of New Zealand - Auckland, Christchurch and Wellington - over the trend period 2001 to 2013 was sourced from Rawlinsons construction handbooks (15th to 28th editions) (Rawlinsons, 2013). The handbooks provided ranges of base building cost per square metre of gross floor area ($/m2) of each building variant in the main cities delineated for the study. The 15 major types and 41 sub-types of the buildings involved in the study are shown in Table 1. For each year, the representative samples of the base building costs of all the building types across the 3 cities were averaged to provide a representative building cost for the trend analysis.

Table 1: Main and sub-types of buildings for which cost data was available

	Major types	Sub-types	No of sub-types
1	Administrative, civic	Administrative	4
		Civic	
		Authorities	
		Post offices	
2	Banks	Banks	1
3	Educational	Primary	3
		Secondary	
		Tertiary	
4	Entertainment	Cinemas & theatres	4
		Production	
		Grandstands	
		Aquaria	
5	Healthcare	Hospitals	1
6	Hospitality	Bars, liquor outlets	3

		Hotels	
		Motels	
7	Industrial	Factories & warehouses	5
		Big sheds	
		Cold stores	
		Workshops	
		Fuel storage installations	
8	Offices	Offices	1
9	Parking	Integral	2
		Open area	
10	Primary industry	research laboratories	2
		Meatworks	
11	Sports facilities	Clubhouses & gymnasia	4
		Squash courts	
		Swimming pools	
		Tennis/ netball courts	
12	Residential	House	4
		Multi units: low rise	
		Multi units: high rise	
		Retirement village units	
13	Devotional	Places of worship	2
		Halls	
14	Retail	Suburban	2
		City	
15	Miscellaneous	Commercial	3
		Toilet facilities	
		Rural buildings	
	Total number of sub-types:		41

Sources and units of analysis for the socio-economic indicators

Information on socio-economic indicators was sourced from the Reserve Bank of New Zealand (RBNZ, 2013) and the Statistic New Zealand (StatsNZ, 2013). Units for the indicators comprise index values, dollar amounts, numbers or rates (i.e. percentages). The focus was on construction sector data, except where no such data were available for the period. The following socio-economic indicators were found in the RBNZ and StatsNZ databases:

1) Real gross domestic product (GDP),
3) Capital goods price index (CGPI),
4) Consumer price index (CPI),
5) Producer price index (input prices, construction sector),
6) Productivity index (multifactor),
7) Building consents issued,
8) Number of buildings constructed or renovated,
9) Value of buildings constructed or renovated,
10) Population of New Zealand,
11) Labour cost index,
12) Mortgage interest rate,
13) Business lending rate,
14) Small medium enterprises (SME) overdraft rate,

15) Exchange rate - real trade weighted index (TWI),
16) Energy price index,
17) Unemployment rate,
18) Employment rate (full time equivalent, construction sector),
19) House prices.

The values of the indicators were in most cases, reported each quarter of the year. On the other hand, the building cost data were only for June of each year. To align with the building costs for which data were available only in June of each year, the annual values of the SEIs used in the study were for the June quarter. It should be noted that several other SEIs exist such as net migration, government spending, and consumer and business confidence. However, these were not included in the analysis due to unavailability of consistent information over the study period.

Method of data analysis

Time series modelling (Australian Bureau of Statistics, ABS, 2013), correlation analysis (Averkamp, 2013), and regression analysis (Cooper and Schindler, 2006) have been identified as the most appropriate methods for analysing historical data for trend movements, correlations and inter-relationships/ cause-and-effect relationships, respectively. The appropriateness of the methods was also underscored by the research aim which primarily was to examine trends in the socio-economic indicators and the building cost data, as well as to ascertain whether or not significant correlations existed between the two data sets as a basis for prioritising and identifying the socio-economic indicators which correlated significantly with the building cost trends.

Rather than perform individual correlation, regression and time series analysis on the research data, the SPSS Time Series Expert Modeler was used. This provided an integrated analysis involving all three analytical functions in addition to a validation analysis which was based on advanced statistical tests of significance. This was more so that the individual correlation, regression and time series analysis required prior knowledge of the nature of the data distribution and the correct variant of the regression and time series model that would best fit the data distribution. Furthermore, regression analysis in a standalone procedure is often constrained by data distribution characteristics that violate the traditional assumptions of normality and non-serial correlation of lagged error terms (IBM, 2013). Statsoft (2014) argues that the SPSS Time Series Expert Modeler function uses both exponential smoothing and Autoregressive and Moving Average (ARMA) techniques to solve inherent problems that would ordinarily violate underlying assumptions of normality and serial correlation of error terms, and therefore is able to provide more reliable results. It does this through data transformation techniques such as corrections for outlier effects, residual errors, serial correlation, multi-collinearity and heteroskedasticity. The Federal Reserve Bank of New York (2000) also recommends this approach by observing that autoregression is the appropriate technique to use when there is a need to gain understanding of which variables are key drivers that shape movements in a particular socio-economic trend, with the autoregression involving a regression of the observed trend dependent variables against corresponding trends in the suspected list of underpinning (independent) variables.

In the analysis, the p-value associated with the Student t test score helped to more accurately determine the extent to which each independent variable was a statistically significant contributor to the observed values of the dependent variables – and hence was used to identify the key socio-economic indicators having significant influence on the trends of the building costs observed during the delineated period – 2001 – 2013.

RESULTS AND DISCUSSIONS

Ttrends in the SEIs and building costs

The first objective of this study was to analyse annual percentage changes in building costs and the corresponding changes in the socio-economic indicators within the delineated study period 2001-2013. Building cost data ($/m2 of gross floor area) for the period were compiled from Rawlinsons construction handbook. Data on the eighteen SEIs were compiled from the Reserve Bank and Statistics New Zealand databases. Table 2 presents the raw data, while Table 3 shows the annual percentage figures. Owing to differences in the units of the variables, percentage annual change values were computed as a common denominator and used in the analysis.

Table 2: Data on building costs and socio-economic indices 2000-2013

Year	Building cost ($/m2)	GDP (const)	CGPI (const)	CPI	Producer Price Index (input)	Productivity Index (Multifactor)	Building Consent issued ($ million)	Building number	Building value ($million)	NZ Population change	Labour cost index	Mortgage Interest rate (%)	Business lending rate (%)	SME Overdraft rate (%)	Exchange rate (Real TWI 14)	Energy Price Index	Unemployment rate	FTE employee (const) (000)	House prices (% change)
2000	1072	1185	1020	849	611	1028		67338	6254	22600	785	8.04	7.39	9.62	51.75	1135	6.3%	79	-1.1%
2001	1104	1144	1059	876	659	956	1603	62163	6215	22700	800	7.83	7.64	8.92	49.63	1215	5.4%	77	1.1%
2002	1138	1217	1074	900	670	964	1939	68085	7105	68000	814	7.28	7.09	9.03	57.26	1217	5.3%	89	8.9%
2003	1218	1382	1081	913	678	1026	2210	75666	8292	78800	832	7.31	7.18	8.73	62.91	1167	4.8%	90	17.1%
2004	1326	1559	1121	935	702	1045	2653	83161	10146	60300	847	7.05	6.59	9.33	65.97	1294	4.2%	107	21.2%
2005	1431	1624	1154	962	749	1014	2717	77474	10838	46300	870	7.55	7.82	10.41	73.52	1505	3.8%	111	13.1%
2006	1540	1676	1194	1000	820	993	2753	76856	10981	50700	902	7.85	8.31	11.07	64.53	1989	3.7%	119	10.4%
2007	1618	1855	1227	1020	880	1028	3063	77905	11771	43700	938	8.12	8.63	11.82	75.89	1779	3.7%	131	13.4%
2008	1691	1738	1265	1061	936	1083	2849	71441	11684	40600	973	8.69	9.26	12.41	70.25	2483	4.0%	131	-4.4%
2009	1727	1620	1317	1081	970	983	2355	56343	9829	46900	1000	7.51	5.81	9.88	63.68	1904	6.0%	131	-3.1%
2010	1600	1741	1309	1099	985	1022	2382	56205	9608	52000	1013	6.57	5.90	9.85	69.58	2046	6.9%	109	3.1%
2011	1625	1533	1314	1157	1023	1063	2052	51273	8637	37400	1037	6.26	6.10	10.00	75.40	2234	6.5%	112	0.7%
2012	1663	1592	1327	1168	1038	1106	2448	52574	9246	27900	1064	5.94	6.04	10.10	74.62	2373	6.8%	118	4.0%
2013	1754	1837	1337	1176	1049	1153	3035	55730	11063	38000	1085	5.55	5.49	9.61	75.62	2306	6.4%	128	8.7%

Table 3: Annual percentage changes in the building costs and the socio-economic indicators 2001-2013

Year	Building cost	GDP (const)	CGPI (const)	CPI	Producer Price Index (input)	Productivity Index (Multifactor)	Building Consent issued	Building number	Building value	NZ Population	Labour cost index	Mortgage Interest rate	Business lending rate	SME Overdraft rate	Exchange rate (Real TWI 14)	Energy Price Index	Unemployment rate	FTE employee (const)	House prices % change
2001	2.7%	-3.5%	3.8%	3.2%	7.7%	-7.0%	2.9%	-7.7%	-0.6%	0.6%	1.9%	-2.6%	3.4%	-7.3%	-4.1%	7.1%	5.4%	-2.6%	1.1%
2002	3.0%	6.4%	1.4%	2.8%	1.8%	0.8%	7.8%	9.5%	14.3%	1.8%	1.8%	-7.0%	-7.2%	1.2%	15.4%	0.1%	5.3%	13.0%	8.9%
2003	7.1%	13.6%	0.7%	1.5%	1.2%	6.4%	7.9%	11.1%	16.7%	2.0%	2.2%	0.4%	1.3%	-3.3%	9.9%	-4.1%	4.8%	1.3%	17.1%
2004	8.6%	12.8%	3.7%	2.4%	3.5%	1.9%	0.8%	9.9%	22.4%	1.5%	1.8%	-3.6%	-8.2%	6.9%	4.9%	10.9%	4.2%	15.7%	21.2%
2005	8.2%	4.2%	2.9%	2.8%	6.6%	-3.0%	-3.4%	-6.8%	6.8%	1.1%	2.7%	7.1%	18.7%	11.6%	11.4%	16.3%	3.8%	3.3%	13.1%
2006	7.5%	3.2%	3.5%	4.0%	9.5%	-2.1%	0.1%	-0.8%	1.3%	1.2%	3.6%	4.0%	6.3%	6.3%	-12.2%	32.1%	3.7%	7.4%	10.4%
2007	5.0%	10.7%	2.8%	2.0%	7.3%	3.5%	3.2%	1.4%	7.2%	1.1%	4.1%	3.4%	3.9%	6.8%	17.6%	-10.5%	3.7%	8.9%	13.4%
2008	4.5%	-6.3%	3.1%	4.0%	6.4%	5.4%	-2.1%	-8.3%	-0.7%	1.0%	3.7%	7.0%	7.3%	5.0%	-7.4%	39.6%	4.0%	0.0%	-4.4%
2009	1.4%	-6.8%	4.1%	1.9%	3.6%	-9.2%	1.8%	-21.1%	-15.9%	1.1%	2.8%	-13.6%	-37.3%	-20.4%	-9.4%	-23.3%	6.0%	-0.3%	-3.1%
2010	-6.6%	7.5%	-0.6%	1.7%	1.6%	4.0%	-2.8%	-0.2%	-2.3%	1.2%	1.3%	-12.5%	1.5%	-0.3%	9.3%	7.5%	6.9%	-19.7%	3.1%
2011	1.6%	-11.9%	0.4%	5.3%	3.8%	4.0%	-1.6%	-8.8%	-10.1%	0.9%	2.4%	-4.7%	3.4%	1.5%	8.4%	9.2%	6.5%	2.6%	0.7%
2012	2.4%	3.8%	1.0%	1.0%	1.5%	4.0%	2.4%	2.5%	7.1%	0.6%	2.6%	-5.1%	-1.0%	1.0%	-1.0%	6.3%	6.8%	5.1%	4.0%
2013	5.8%	15.4%	0.8%	0.7%	1.1%	4.3%	8.8%	6.0%	19.6%	0.9%	2.0%	-6.6%	-9.1%	-4.9%	1.3%	-2.8%	6.4%	7.5%	8.7%

Relative levels of influence of the SEIs on the building cost trend

The second objective of the study was to regress the annual percentage changes in the building costs (as dependent variables) against corresponding changes in the SEIs. The aim was to examine the relative levels of influence of the SEIs on the observed annual changes in the building costs over the study period. The third objective aimed to test the levels of significance of any observed influences of the SEIs and to use these as a basis for prioritising the SEIs, as well as for segregating them into significant and non-significant groups. To achieve these objectives, the annual percentage changes in the building costs and SEIs were subjected to integrated time series modelling and multivariate regression analysis using the multivariate autoregressive integrated moving average (ARIMA) function of the SPSS Expert Modeler. Outputs of the analysis are presented in Table 4.

Table 4: Socio-economic indicators as significant and non-significant correlates of building costs based on p-values of t-test results

	Socio-economic indicators (SEIs)	[a]R-est	[b]Std error	t-value	P-value	[c]Remarks
1	House Prices	0.451	0.034	13.19	.00004	
2	Producer Price Index (PPI) (input, construction)	0.572	0.060	9.53	.00022	
3	Consumer Price Index (CPI)	0.482	0.053	9.18	.00026	
4	Productivity Index (Multifactor)	-2.831	0.374	-7.57	.00064	
5	Building Consents Issued	2.759	0.385	7.17	.00082	
6	Exchange Rate (Real TWI 14)	-0.235	0.033	-7.14	.00084	Significant correlates
7	Real GDP (construction)	2.491	0.396	6.30	.00148	
8	Unemployment Rate	-0.158	0.027	-5.85	.00206	
9	Mortgage Interest Rate	-0.167	0.034	-4.97	.00422	
10	SME Bank Overdraft Rate	0.168	0.034	4.94	.00432	
11	Business Lending Rate	0.167	0.036	4.67	.00550	
12	Capital Goods Price Index (CGPI) (construction)	0.280	0.10962	2.554279	0.051	
13	Labour Cost Index (construction)	0.290	0.113535	2.554279	0.051	
14	Energy Price Index	0.54	0.212739	2.538321	0.052	
15	Building Numbers	2.831	1.135978	2.492389	0.055	Non-significant
16	Employment Rate (FTE, construction)	0.68	0.27445	2.477682	0.056	
17	Building Value	0.35	0.144533	2.421585	0.06	
18	NZ population	0.56	0.255596	2.190958	0.08	

[a]*R-est: Estimate regression coefficient;* [b]*Std error: Standard error of estimate.*
[c]*Remarks: 'Significant correlate': SEI with p-value > 0.05 (alpha); 'Non-significant correlate': SEI with p-value < 0.05.*

Table 4 shows the ARIMA model estimate regression coefficient (*R-est*) of each SEI as independent parameter used in estimating trends in the annual changes in the building costs over the study period. The regression coefficients indicated relative levels of influence on the building cost trends. However, IBM (2013) cautions against the use of the estimate coefficients as a basis for determining cause-and-effect relationship between dependent and independent variables, since other effects such as sensitivity to randomness, outlier effects, serial correlation, heteroskedasticity, multi-collinearity and residual errors, could distort the result.. Expert Modeler tool addresses all but residual errors through in-built autocorrelation, sensitivity analysis and smoothing functions. However, it reports the residual errors in the form of standard error of estimate ('*Std error*').

To guard against the residual error effect, Statsoft (2014) suggests the use of the Student t value; this computes the estimate regression coefficient as a unit of the 'Std error' (i.e. t-value = *R-est ÷ Std error*). The t-value gives a more accurate indication of the level of influence of a particular SEI on the building cost trend than the regression coefficeint. It was therefore used to prioritise the SEIs in terms of their relative levels of influence on the observed building cost trends. The signs of the regression coefficient helped to segregate the SEIs into positive influencers (or 'escalators') and negative influencers (or 'de-escalators). Thus, an SEI is said to escalate positive changes in building cost trend if its coefficient is positive; otherwise, it is a de-escalator, meaning that changes in its value over time has opposite effect on corresponding changes in the building cost.

Significant and non-significant SEIs

Part of the third objective was to test the levels of significance of any observed influences of the SEIs. With the t-value being a more reliable indicator of the level of influence (Statsoft, 2014), the *p-value* corresponding to the absolute *t-value* of each SEI (i.e. │t-value│) was used as the test statistic in a step-wise test of significance. The p-value served as the basis for accepting or rejecting the null hypothesis which assumed that no SEI had a significant influence on the building cost trend or that any observed influence was by chance variations. At the 5% level of significance, an SEI was non-significant if its p-value was equal to or more than 0.05 alpha level of the test.

The SEIs were prioritised or rank-ordered based on their absolute t-values as indicators of relative levels of influence on the building cost trends, with 1 being the most influential (i.e. the SEI with the highest absolute t-value). P-value of 0.05 was used as a threshold for segregating the SEIs into significant and non-significant influencers or correlates, as shown in Table 3.

Table 4 shows that out of the 18 SEIs involved in the study, only 11 were found to be significant influencers of the building cost trend in New Zealand. House price factor, with the highest t-value of 13.19 was the most influential SEI. This result is not a surprise, given the exorbitant house prices in New Zealand in recent years, which are steeply eroding housing affordability in the country, especially in Auckland and Canterbury regions. Perhaps, the findings of the Productivity Commission (2012) could explain the link between house prices and building cost trends. The Commission noted that "the sharp rise in house prices in New Zealand during the 2000s reflected a number of cumulative demand-side factors against a degree of stickiness in housing supply" (p.1). The factors included credit growth, low interest rate and property investment, much of which fuelled effective demand for housing without a corresponding increase in supply leading to acute supply

shortage. The supply shortage in turn pushed up prices of building cost components, including materials and profit margins. The recent move by the local and national governments to free-up underutilise land for affordable and third sector housing (Housing New Zealand, HNZ, 2013) was aimed at stimulating supply, in the hope that supply shortage may be reduced and the flow on effect might reduce building costs and house prices and increase housing affordability levels.

It is surprising that some SEIs such as capital goods price index (CGPI), labour cost index (LCI) and population were not among the significant influencers of building cost trend over the study period. This is in contrast with the findings of a number of authors who see these SEIs as key contributors to increase in building costs. For instance, Statistics New Zealand (StatsNZ, 2014) observes that increases in residential building prices were contributed by increases in GPI, LCI and other factors such as contractor margins. Rider Levett Bucknall (RLB) (2013) reported weak outlook for non-residential building activities over the period in addition to little growth in building consents. With the CGPI providing information on the change in the general price level of fixed capital assets, perhaps, the RLB (2013) report might explain why this SEI was not a key contributor to the building cost trend over the study period.

From a statistical analysis point of view, another explanation could because the non-significant SEIs had multi-collinearity relationships among themselves, which reduced their specific influences on building cost trends. Statsoft (2014) explains that 'multi-collinearity' arises where an independent variable in the regression analysis has serial correlations with other independent variables, causing any correlation with the dependent variable unreliable or viewed as chance variation. This is more so that the SPSS Expert Modeler tool

used in the analysis deals with multi-collinearity distortions only in the cause-and-effect relationship between the independent variables and the dependent variable, and not among the independent variables (IBM, 2013).

This result may have far reaching implications in the forecasting circles; it might point to the fact that the 7 SEIs which were found to be correlates of building cost trends in earlier studies might be based on pattern recognition rather than on the outcome of stochastic analysis or tests of significance. Stewart (2001) notes the distorting influences in forecasts involving multiple variables as key contributor to forecast errors and warns against making conclusions on time series and correlations based on pattern recognition alone. The Federal Researve Bank of New York (2000) sees this as a problem with many forecasters. Locally, Ranchhod (2003) examines the inflation and interest rate forecasting performance of the Reserve Bank of New Zealand, the National Bank of New Zealand and the New Zealand Institute of Economic Research (NZIER) and finds significant forecast errors; the author concludes that "all of the forecasters examined have tended to over-predict the level of interest rates" (p.1).

CONCLUSION

This study has examined time series trends in some socio-economic indicators (SEIs) and the corresponding trends in some building construction costs. Through the analysis of cause-and-effect relationship, it has investigated the SEIs which significantly influence observed annual changes in the building costs over a 12 year period – 2001 to 2013. Results showed that out of 18 SEIs analysed in the study, only 11 were reliable influencers of building cost trend over the study period. Annual changes in house prices were

found to be the most significant influencer of building cost trend, followed by changes in the producer price index (PPI) and consumer price index (CPI). SEIs having the least significant effect comprised business lending rate, SME bank overdraft rate and mortgage interest rate. Surprisingly, 7 SEIs, which were considered as key influencers of building costs in previous studies were found to have no significant influence on building costs within the study period. Notable among these were capital goods price index (GPI), labour cost index (LCI). It was argued that unaddressed multi-collinearity issues in previous studies and the tendency to base forecasts on pattern recognition rather than on the outcome of stochastic analysis and tests of significance might be responsible for the contrasts found in this study. Overall, it was recommended that construction cost estimators should monitor future movements in the identified 11 SEIs to gain understanding of correlational effects on building cost estimate over a given forecast horizon for a project. This would minimize forecast risks and ensure more reliable cost estimation.

ACKNOWLEDGEMENTS

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SECTION V

INDUSTRY COLLABORATION RESEARCH

5.1 NZIQS – MASSEY COLLABORATION RESEARCH

O'BRIEN, P., MBACHU, J. and LOMAX, S.

Current and future challenges facing New Zealand quantity surveyors: Priority issues and potential solutions

CURRENT AND FUTURE CHALLENGES FACING NEW ZEALAND QUANTITY SURVEYORS: PRIORITY ISSUES AND POTENTIAL SOLUTIONS

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ABSTRACT

This paper explores some of the key challenges New Zealand Quantity Surveyors currently face and some potential measures to address them. Through a pilot survey of 110 experienced and practising quantity surveyors, key challenges at the pre-contract, construction and post-construction phases were identified. Respondents were also asked to identify key challenges in the evolving and widening role of Quantity Surveyors in the future. The survey feedback was analysed using content analysis.

The paper poses some research questions and proffers potential solutions to the challenges at each building development phase based on the survey findings. It also addresses some of the future challenges identified in the survey. The aim is not to present definitive lists of challenges and solutions facing practitioners, but to provide a starting point for more detailed research investigations into the subject. Based on the challenges identified in this paper, it is hoped that the research community will be in a position to initiate research projects aimed at exploring these challenges in greater detail and

hence offer solutions that could be of benefit to practitioners and the industry as a whole.

Keywords: Construction, construction economics, cost management, project management, quantity surveying.

1. INTRODUCTION

Quantity Surveyors (QS) have traditionally overseen the financial and contractual administration of construction projects, ensuring that the preliminary cost estimates advised at the outset of any project are monitored and adjusted as the project is developed from design through tendering to construction and close-out (Baloyi & Price, 2003; Elhag et al., 2005) In their position as the custodian of the 'project purse strings' of the multi-million dollar investment in the construction industry, QS perform a vital role (Mbachu, 2011). Depending on the efficiency level and effectiveness with which they perform this role, it is arguable that the construction industry's ability to contribute to the economic and social development of the

country can be impaired or improved (Ling, 2005; Hanna, 2007).

On account of several factors, the efficiency and effectiveness of the QS performance can be severely constrained. Research that looks at the challenges QS face and identifies the appropriate measures to address these challenges can therefore be crucial for supporting improved performance which will in turn likely contribute to improved performance of the wider construction industry. The same could be said of many of the industries participants.

In the light of there being little or no local research in this area, the intention of this paper is to identify some of the key challenges New Zealand QS face and suggest some measures for addressing the challenges as, it is hoped, a stimulus for further and more thorough research. As noted earlier, the challenges were initially identified through a pilot survey of practising quantity surveyors. Relevance of the key challenges and the appropriateness of the suggested solutions would need to be validated through a thorough research programme. The research community is encouraged, indeed challenged, to initiate research projects aimed at exploring these issues in greater detail and proposing solutions that would be of benefit to quantity surveyors, other practitioners and the industry as a whole.

Research objectives

The key objective of this paper is to provide answers to the following research questions:

1. What are the current and future challenges facing quantity surveyors in New Zealand?

2. What potential solutions exist for addressing the challenges?

3. Which of these challenges and solutions are worthy of further detailed empirical investigation?

2. RESEARCH METHOD

Data gathering

Empirical data for the research was obtained through personal interviews conducted over a three year period (from March 2012 to October 2014). The interviewees were experienced quantity surveyors based in Auckland, Christchurch, Wellington, and the sub-regions of these cities. The interviewees were selected through purposive sampling technique. This sampling approach is recommended (Patton, 1990; Morse, 1991; Cooper and Schindler, 2006) as the most appropriate for the nature and purpose of the study, particularly given that the aim was to obtain a qualitative foundation for the design of a more representative and quantitative study. In addition, it allowed the engagement of interviewees who could give authoritative feedback on the subject matter, who were knowledgeable about the issues being investigated through their current involvement in the building development process, and "who were articulate, reflective and willing to share with the interviewers" (Coyne, 1997, p. 624). Interviewees were recruited through the researchers' network and contacts.

Data analysis

At the end of the interviews, feedback was analysed using content analysis (Patton, 1990). This enabled the researchers to identify recurring concepts or themes in the feedback and responses. Frequency count was used to identify and prioritise the concepts based on the

number of mentions by interviewees (Tronchim, 2006).

3. RESULTS AND DISCUSSIONS

3.1 Survey responses

Usable responses were received from 110 survey participants over the period. These were each interviewees who met the quality criteria set for respondents and who were available to participate in the annual window for data collection. The demographic profiles demonstrated that feedback was received from quantity surveyors from different backgrounds, positions and locations.

3.2 Demographic profiles of the respondents

Of the responses, 40%, 32% and 26% were from the Auckland, Christchurch and Wellington regions, respectively. The balance (2%) came from Southland. Geographically, the majority of the responses were from the Auckland region (which of itself is no surprise given the relative population of each of these regions).

In terms of industry role, majority of the interviewees were contractor quantity surveyors (52%); others were consultant quantity surveyors (45%), and quantity surveyors who worked in other areas such as property development (2%) and banks (1%).

Professional memberships of the interviewees comprised the New Zealand Institute of Quantity Surveyors (NZIQS) (49%), the Royal Institution of Chartered Surveyors (RICS) (42%), and 'other' category, namely, the International Association of Cost Engineers (9%). A number of participants held membership of two or more professional bodies.

In terms of status in their respective professional associations, majority (82%) were full members, with 35% of these holding Fellow or Registered Quantity Surveyor status. The balance (18%) held Associate/ Graduate/ Affiliate membership status. To meet the quality criteria, feedback from student members was not canvassed.

In terms of experience, the majority (60%) had over 20 years' experience. Only 4% had less than 10 years' experience. Feedback from those having less than 5 years' experience was not included in the analysed data.

The positions of the interviewees within their respective organisations ranged from director / principal partner (51%), senior cost manager / consultant (40%), and intermediate positions (9%). Again, feedback from juniors / interns was not canvassed.

The rich demographic profiles of the respondents added to the quality of the responses received.

3.3 Current and future challenges facing quantity surveyors

Unsurprisingly, given the dynamic environment of the industry and the seemingly continual evolution of the quantity surveyor's role (, the challenges faced by quantity surveyors in New Zealand are multi-faceted. Content analysis of the feedback offered by interviewees showed that the challenges could be broadly aggregated into four categories:

- Current challenges relating to the core technical role of the QSs.

- Future challenges relating to evolving professional roles, in particular specialist services.

- Stakeholder related challenges (being the acts/ omissions of all other participants in the construction process including clients, architects, engineers, Building Consent Authorities, suppliers, subcontractors, etc.)

- External challenges arising from broader factors including;

    o Local industry and market conditions, including the boom and bust cycles, skill shortage and the level of competition;

    o macro- & micro-economic trends, including exchange rates, interest rates, taxation, insurance and credit finance;

    o technological advances;

    o statutory/ legal compliance issues;

    o socio-cultural issues; and

    o global dynamics.

These categories or 'clusters' provide hotspots for research investigations, looking at how the role of the quantity surveyor is influenced by these dynamics.

Each cluster is explored in greater detail in later sections.
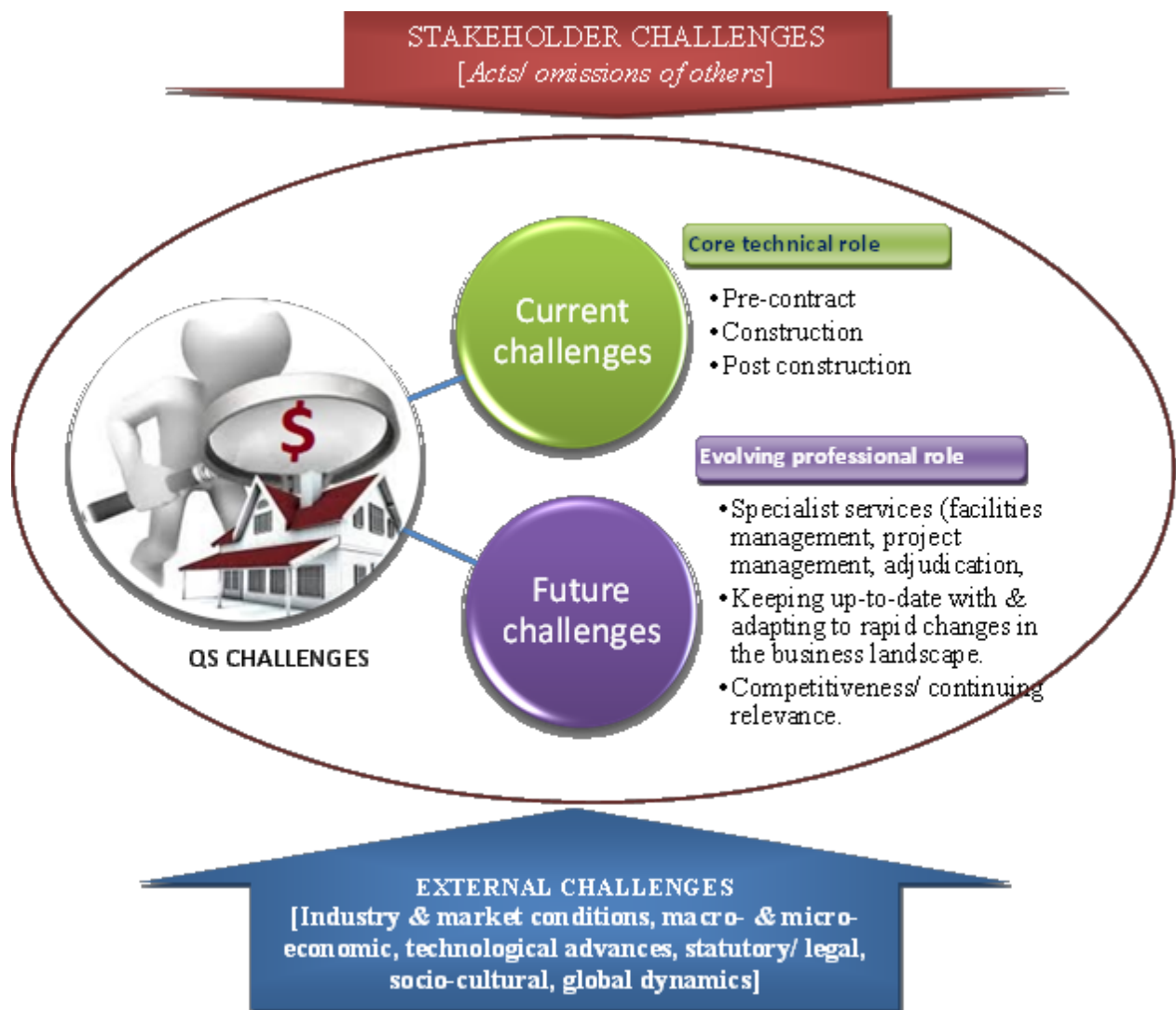
Figure 1: Current and future challenges of the quantity surveyo

3.3.1   *Current challenges relating to core technical role*

A number of the current challenges facing quantity surveyors relating to the professions'

core technical role in the construction processes are articulated in Figure 2 below.
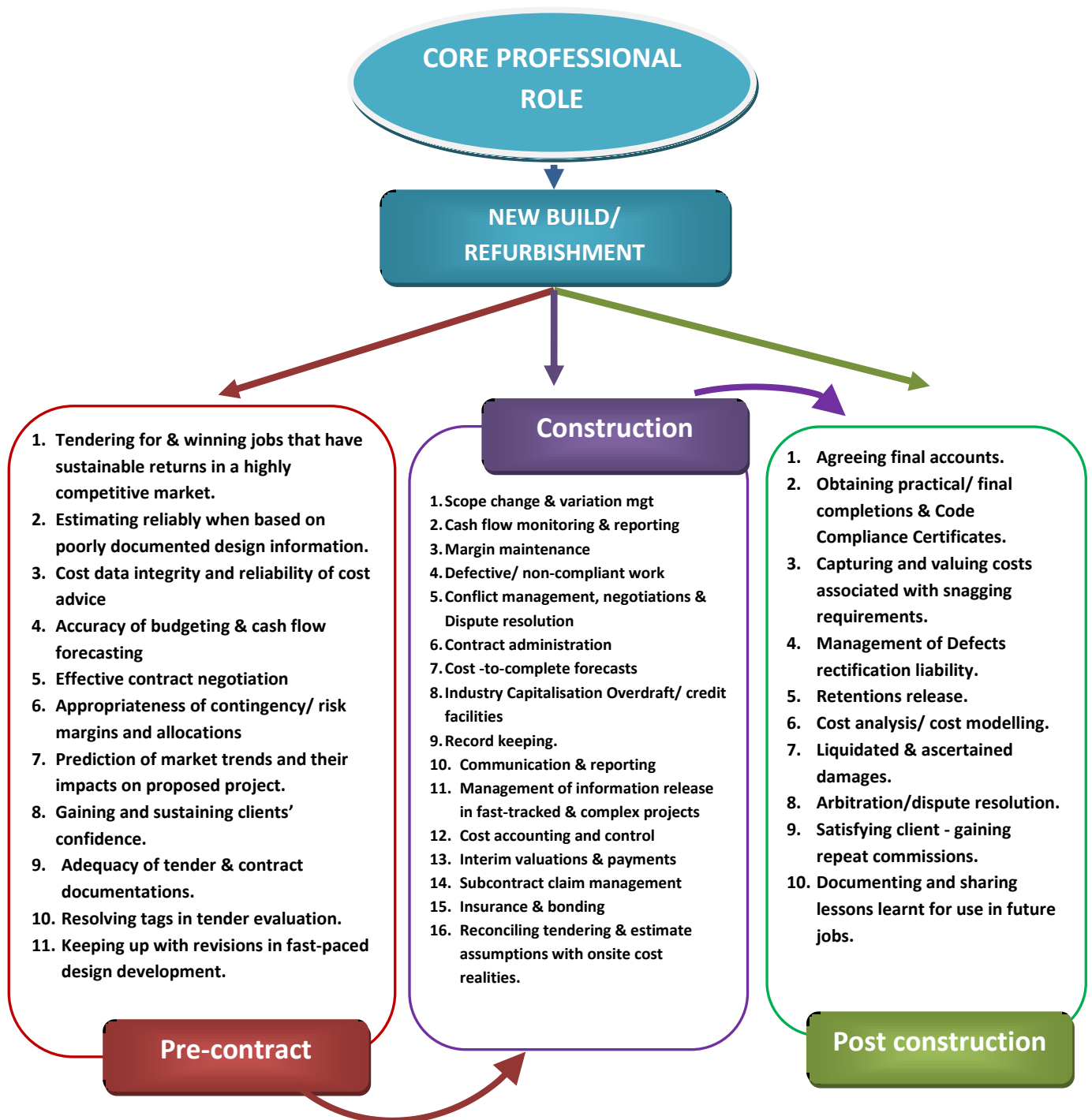
Figure 2: Broad categories of current challenges faced by the quantity surveyor

− Preparing budgets and cash flow forecasts

The key challenges at this phase are set out in figure 2.

3.3.1.1 Key challenges at the pre-contract phase

The pilot survey identified pre-contract challenges faced by quantity surveyors in the following areas of the services / duties which are performed at the pre-contract phase (either for a client or for a contractor involved in design and build or construction phase contracting.)

- − Preliminary cost advice

- − Investment appraisal/ feasibility studies

- − Cost planning and cost checking

- − Value management/ value engineering

- − Advising on contract strategies and procurement systems

- − Estimating contract price for use in benchmarking tenders

- − Preparing tender documents and inviting tenderers

- − Negotiating contract prices and preparing contract documents

Key pre-contract phase research questions and suggested solutions

Figure 3 highlights those questions and issues that quantity surveying profession would like the research community to address in relation to the challenges faced at the pre-contract phase of construction projects. The challenges have been broadly grouped into those faced by client engaged quantity surveyors and those engaged by construction contractors together with possible solutions put forward as suggested areas for further investigation of their effectiveness. The identification of alternative, cost effective solutions by the research community is considered paramount.

In addition the research community is challenged to explore and identify other issues occurring at this phase of the construction process, together with identifying suitable solutions.
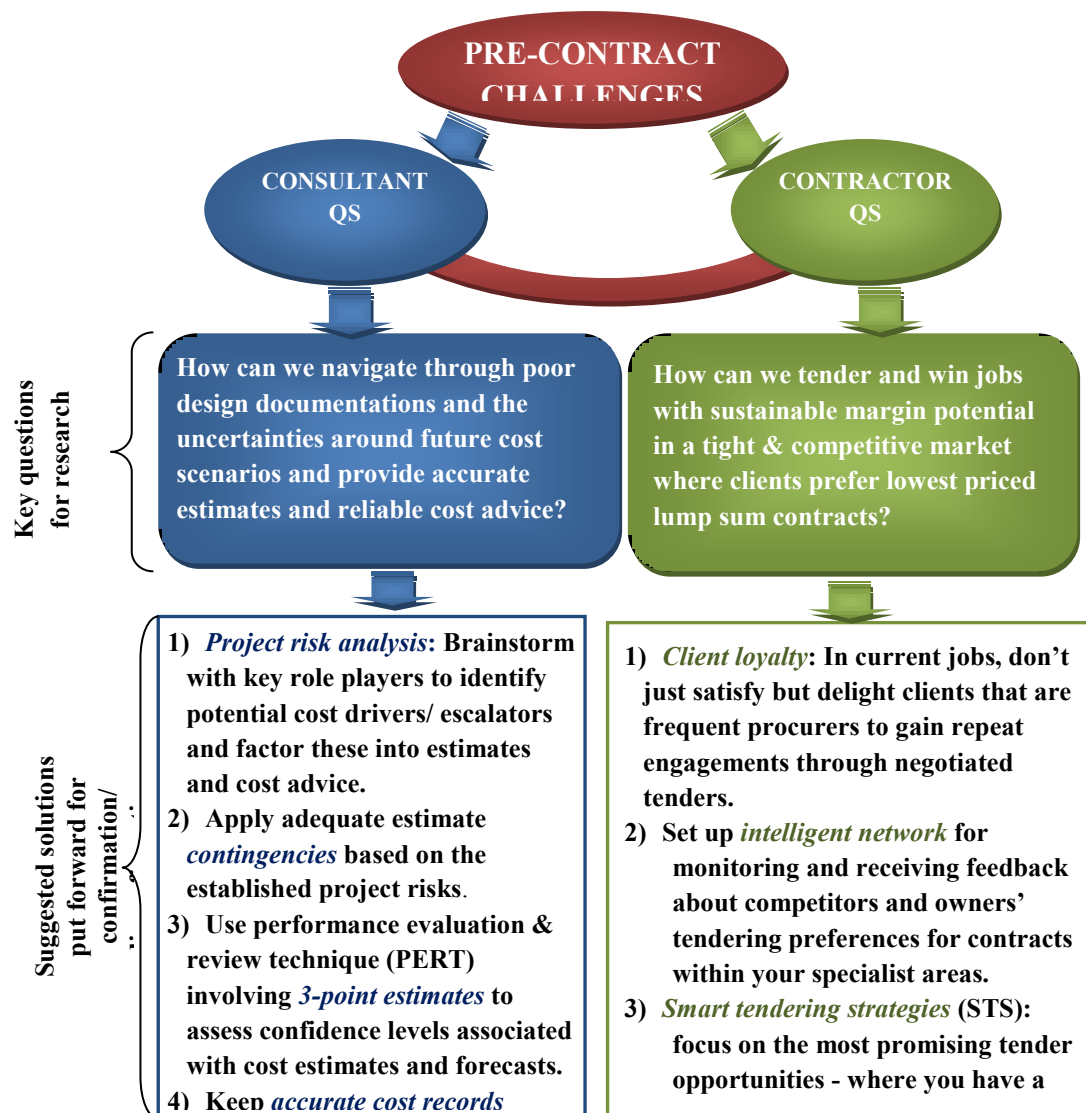
Figure 3: Key research questions and tentative solutions on pre-contract QS challenges for further research investigations

Background to the key challenges at the pre-contract phase

The most critical pre-contract phase challenges relate to the quality of the design documentation, and clients' preference for the

lump sum fixed price contract and lowest cost conforming bid. These two challenges were seen by the majority of the quantity surveyors interviewed in the course of this preliminary study as major contributing factors to the other

challenges faced in this and the remaining phases of the construction project process. The key issues highlighted by the interviewees are discussed in the following subsections.

Quality of design documentation

The outcome of the pilot survey suggests that poor quality of design documentation – both drawings and specifications – is one of the key challenges faced by consultant and contractor quantity surveyors. Concerns raised included:

- Design drawings and specifications being in conflict, containing errors or lacking sufficient details for accurate cost advice to be provided, measurements and pricing to be carried out, and for realistic, bona fide tenders to be submitted.

- Buildability issues – designs too complex or fraught with constructability problems, arising mainly from a lack of understanding of the way in which buildings are constructed in practice and contractors' approaches to construction.

- Designs not complying with Building Code, with the risks of non-compliance passed on to the contractors and tenderers

- Designs and design assumptions not aligned with specific site conditions and restrictions. Designers are accused of often replicating designs without doing adequate site investigations and ensuring that the designs fully address unique site issues. Ultimately, risks are passed on to the contractors and tenderers with the usual caveat that "the tenderer should visit the site to ascertain the site characteristics and any other issues that may affect cost and will be deemed to have allowed for

the cost of dealing with these in the tender", yet doing so may make the tender uncompetitive.

Clients' preference for lump sum fixed price contracts and lowest cost conforming bid

The view of the pilot participants is that New Zealand construction clients, especially public sector clients, prefer lump sum fixed price contracts, an open and competitive tendering process and operate a lowest cost conforming bid procurement award process. In tandem, many clients seek to transfer as much risks as possible to the contractor, yet their preferred contract and procurement strategies arguably do not provide commensurate reward to the contractor for shouldering the bulk of the risks. It is perceived that these clients' and their financiers' preferences cause a lot of issue for the construction industry and its service providers, including quantity surveyors.

Open/ competitive tendering is very expensive, involves a lot of paper work, is time consuming and offers limited chances of tendering success. It is often joked that the project is awarded to the tenderer who makes the biggest mistake!

Tenderers invest significant resource and effort in preparing and submitting tenders, which is wasted if they fail to win the tenders, often with no feedback as to why they lost the tender. The 'successful' contractor may not be successful in the true sense of the word, because nature of the contract and lowest cost conforming bid do not allow room for sustainable margins on a project.

For the contractor quantity surveyor, the quandary is margin - too much margin will likely mean that the job will not be won in the first instance; too little margin may win the job but could result in cash flow problems which if

experienced on other projects, can result in more significant and terminal issues.

3.3.1.2 Key challenges at the construction phase

The pilot survey identified Construction phase challenges faced by quantity surveyors in the following areas of the services / duties which are performed at this phase.

- Contract administration.

- Financial management of the project, including:

    o Interim valuations and payments

    o Monitoring, and exercising cost control over the project

    o Forecasting costs to complete and preparing financial statements

    o Final account preparation and agreement

- Evaluating and settling claims, including subcontract claim management.

- Settlement of payment disputes and giving expert evidence in arbitrations and disputes.

The key challenges identified at this phase are set out at Figure 2 above.

Key construction phase research questions and solutions

Figure 4 highlights those questions and issues that quantity surveying profession would like the research community to address in relation to the challenges faced at the construction phase of projects. It also presents possible solutions to these challenges. Research is needed to validate the relevance of these and identify any other challenges together with recommending alternative, cost effective solutions through a process of further investigation.

CONSTRUCTION PHASE CHALLENGES

CONSULTANT | CONTRACTOR

Contractor's claims & payment entitlements | **Achieving decent margin**

Research questions

Amidst the prevalence of poor communication and documentation, how do we carry out proper evaluations & provide impartial cost advice on contractor's contractual entitlements which may be in | **How do we make sustainable margins on lump sum fixed price contracts won on lowest cost conforming bid, in situations where a client is quick to dispute claimed amounts within payment schedules, and where taking any formal DR steps results in reputational damage or removal**

Suggested solutions put forward for confirmation/

1) Promote partnering agreement which focuses on trust, transparency and win-win outcomes for parties.
2) Leverage negotiation & conflict management skills to resolve all cost-driven conflicts of interests and disagreements before they become full blown disputes that require arbitration, adjudication or litigation.
3) Use effective communication system to bring everybody on the same page in terms of contractual responsibilities, decisions, requirements and expectations.

1) Adopt lean construction principles (LCP), last planner methodology (LPM) and waste minimisation to reduce all forms of construction waste and costs.
2) Ensure effective & continuous tracking of expenditure against budget and follow up early decisions against any over spending.
3) Recommend closer supervision of the subcontractors' work to ensure quality, cost and schedule performance and minimise defective work and cost and time overruns.
4) Ensure that all variation orders are captured and signed off and that costs & time implications are agreed upon prior to onsite implementation.
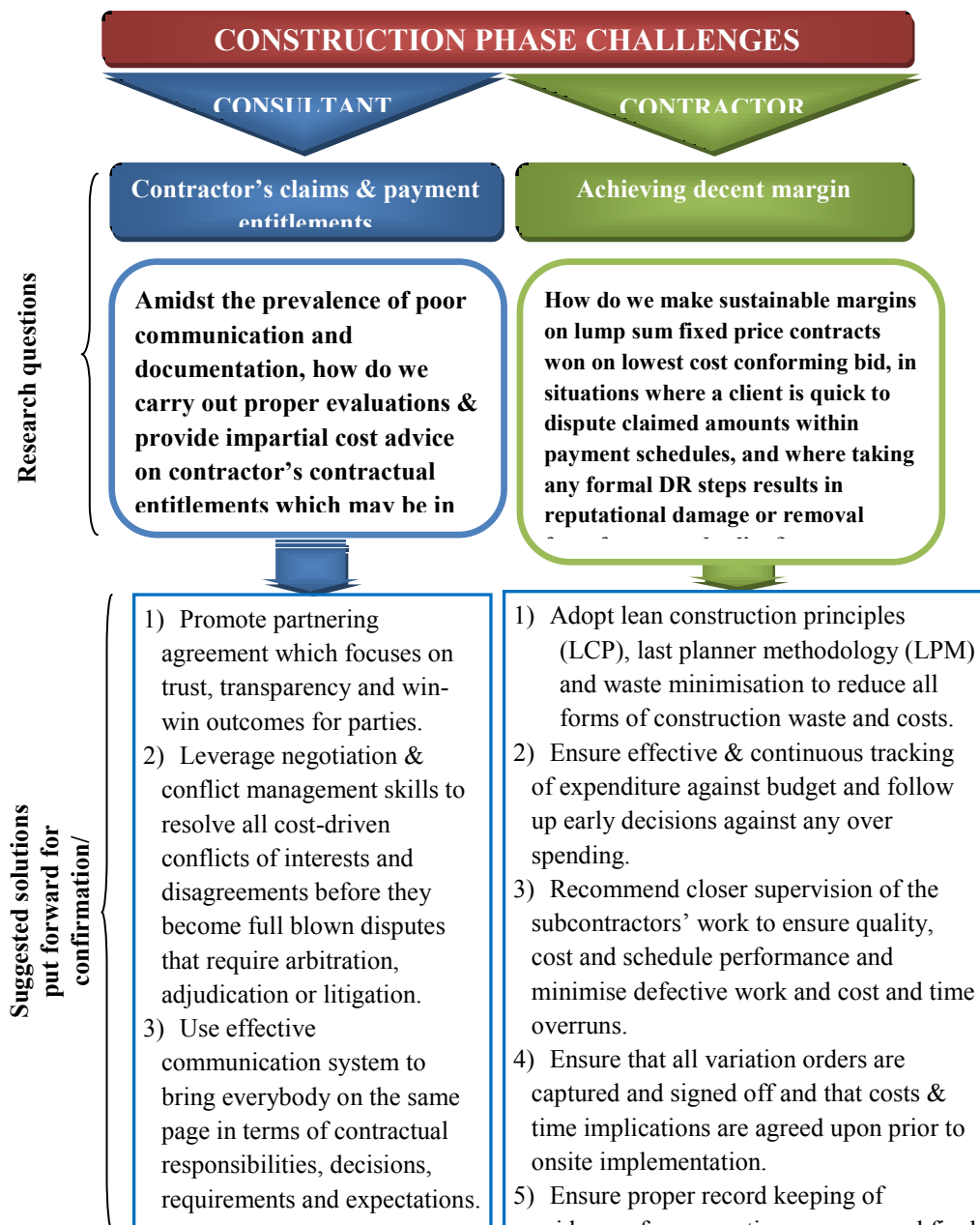5) Ensure proper record keeping of

Figure 4: Key questions and tentative solutions on construction phase challenges for further investigation

3.3.1.3 Key challenges at the post-construction phase

The pilot survey identified post-construction phase challenges faced by quantity surveyors in the following areas of services / duties which are performed at this phase.

The key challenges identified at this phase are set out at Figure 2 above.

Key post-construction phase research questions and suggested solutions

It was found that both consultant and contractor quantity surveyors shared the same overall challenges at the post-construction phase. The key questions and suggested solutions are summarised in Figure 5.

The research community is again challenged to validate the findings of the pilot study, identify any further challenges experienced in this phase of the project cycle and identify cost effective, sustainable solutions to each of the challenges.
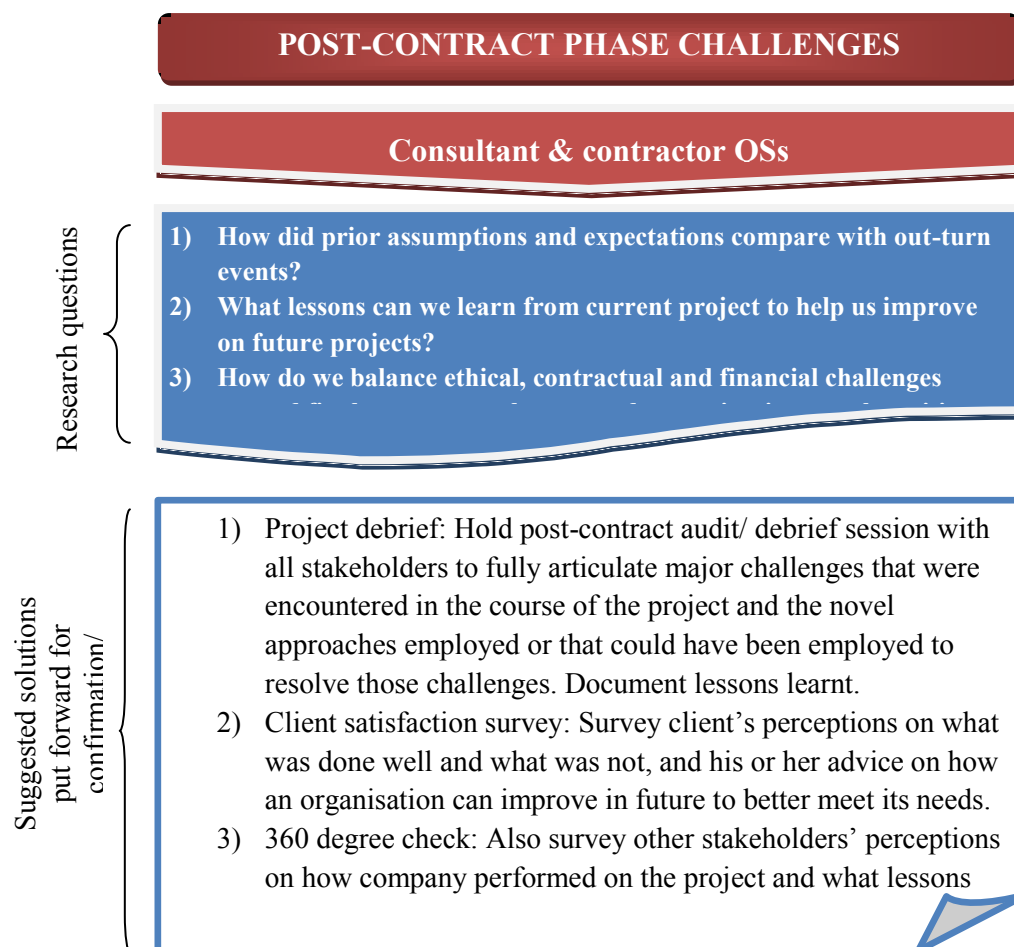
POST-CONTRACT PHASE CHALLENGES

Consultant & contractor OSs

Research questions

1) **How did prior assumptions and expectations compare with out-turn events?**
2) **What lessons can we learn from current project to help us improve on future projects?**
3) **How do we balance ethical, contractual and financial challenges**

Suggested solutions put forward for confirmation/

1) Project debrief: Hold post-contract audit/ debrief session with all stakeholders to fully articulate major challenges that were encountered in the course of the project and the novel approaches employed or that could have been employed to resolve those challenges. Document lessons learnt.
2) Client satisfaction survey: Survey client's perceptions on what was done well and what was not, and his or her advice on how an organisation can improve in future to better meet its needs.
3) 360 degree check: Also survey other stakeholders' perceptions on how company performed on the project and what lessons

Figure 5: Key research questions and tentative solutions on post-contract challenges for further research investigations

4.   FUTURE CHALLENGES

The future challenges facing quantity surveyors mainly emanate from the evolving role of the profession. The distinctive technical role of the quantity surveyor has developed over the years in response to the increasing complexity and diversity of client needs and market demands (Frei et al., 2013). The scope of the quantity surveyor's role has expanded from the measurement and pricing of builder's work to include wider technical and specialist services roles such as the following:

Enhanced technical roles

- Building Economist: concerned with the optimal use of construction

resources and the maximisation of value-for-money solutions;

- Value Engineer: identification and costing of alternative design and construction solutions with a view to recommending the most cost-effective solutions;

- Procurement Consultant: making recommendations for the most appropriate contract procurement strategy arrangements that best meet the needs of the client;

- Cost Manager: responsibility for the forecasting/ budgeting, planning and organising, implementing and monitoring, reporting and controlling project financial spend to ensure that the agreed cost target is met;

- Contracts Administrator: overseeing the contractual administration of the project to ensure compliance with the terms and conditions of the contract, and the wider statutory/ legislative requirements for the project;

- Commercial Manager: management of the overarching commercial aims and objectives of a business.

New and emerging specialist roles

Drawing upon the key base competencies in cost and financial management, procurement, tendering, contract administration, negotiation and conflict management, the quantity surveyor has also been able to take on specialist services roles including the following (Mbachu and Frei, 2012; Frei et al., 2013):

- Project management.
- Facilities management.

- Dispute resolution and expert witness services.
- Property consulting and development services.
- Value engineering and value management.
- Due diligence auditing.
- Investment appraisal, life cycle costing and development Monitoring
- Asset valuation & management.
- Insurance valuation.
- Building surveying and infrastructure audit.

Even a passing look at the progression and widening of the scope of the once distinctive role of the quantity surveyor from the perspectives of consulting, contracting and specialist services, suggests an evolution from being tightly focused on technical aspects of measurement and valuation of building work to wider roles in construction economics, investment appraisal, value management, contract administration, cost/ financial management and dispute resolution.

The flexibility and ability of the quantity surveyor to evolve with changing market demands are keys to the survival and continuing relevance of the profession despite the threats of technological advances and encroachment of other professions into the quantity surveying domain.

That said, it is imperative that we continue to teach and pass on the core skills and base competencies on which this evolution has been founded.

3.3.2 Key challenges for the future

Whilst some are highly specialised, effective performance of these evolving roles requires a broad range of technical, managerial and

generic skills, underpinned by core skills and base competencies complemented by detailed understanding of complimentary subjects which may include economics, business finance, accounting, marketing, communication, ICT, management, construction law, negotiation, conflict management, dispute resolution, human resources management, change and strategic management, land economics, property valuation, risk management, and leadership. Arguably, this means that a quantity surveyor that aspires to be at the top of the game needs to embrace life-long-learning attitude. The modern quantity surveyor needs to upskill through formal and informal education and training in order to broaden his/her skill base and remain abreast of current developments in the broadening field.

Priority research questions and suggested solutions relating to future challenges

Table 1 highlights those questions and issues that quantity surveying profession would like the research community to address in relation to the future challenges faced by the profession. Possible solutions to these challenges are also highlighted. Research is needed to validate the relevance of these and identify any other challenges, as well as recommend alternative, cost effective solutions through a process of further investigation.

Table 1: Priority research questions and potential solutions relating to future challenges faced by quantity surveyors.

Key research questions:
  1. What new and emerging developments are expected to shape future directions in the field of quantity surveying?
  2. What skills and knowledge does the quantity surveyor need to be able to respond more proactively to these developments, maximise the opportunities and minimise inherent threats?
  3. What training programmes or CPDs are required to provide the quantity surveyor with the requisite skills and knowledge for growth and continuous relevance?

Possible solutions:
  1) Building information management (BIM), green building economics (GBE) and computer aided manufacturing (CAM) are the key new and emerging developments that will shape future directions in the field of quantity surveying.
  2) To respond more proactively to these developments, the quantity surveyor needs to broaden his or her skillset to include 5D BIM capability, economics of sustainable design and construction, client relationship management (CRM) and strategic & change management.
  3) To equip the quantity surveyor with the requisite knowledge for growth and continuous relevance, the upskilling and training programmes for the quantity surveyor should be strategically designed to deliver on the above competencies. Short course, in-house training and CPD events can be effectively employed for this purpose.

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4. CONCLUSIONS

This paper has examined the current and future challenges facing quantity surveyors in New Zealand identified through the pilot survey.

Preliminary findings have identified the top challenges in the core technical roles of the consultant and contractor quantity surveyors as well as those of the evolving specialist roles. Key research questions and possible solutions

for addressing the identified challenges have been provided as a catalyst for further validation and expanded research initiatives into the challenges.

Overall, it should be noted that quantity surveying is just one of the integral parts of the built environment supply chain (BESC). A significant proportion of the challenges the profession faces draws from the wider problems of the BESC. Whilst interim solutions have been suggested, holistic and long-lasting solutions to these problems require a coordinated approach that looks at the broader issues of the BESC and the constraints of the external business environment.

It is suggested that a multi-disciplinary and collaborative approach is required to address the problems with a view to finding multi-dimensional solutions. It is in this regard that the collaborative initiative being facilitated through the formation of the annual New Zealand Built Environment Research Symposium (NZBERS) and the hosting of today's series should be acknowledged and encouraged.

Having relayed the issues faced by Quantity Surveyors to the members of the research community here today, we would hope that academic staff and postgraduate students will take up the challenge and design research projects aimed at exploring these matters in greater detail and hence offer solutions that will be of benefit to the industry as a whole.

ACKNOWLEDGMENTS

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SECTION VI

CONCLUDING EDITORIAL

6.1) BUILT ENVIRONMENT RESEARCH AT THE UNIVERSITIES VERSUS INDUSTRY RESEARCH NEEDS: GAPS AND CRITICAL AREAS FOR FUTURE RESEARCH

Introduction

Three recurring questions that underpin the need for the annual series of the NZBERS and the associated Proceedings are:

1) What kind of built environment (BE) research is being carried out in the universities?
2) To what extent does this address the research needs of the New Zealand built environment sector?
3) What gaps exist and which critical need areas should shape future research directions in the universities?

The above questions were offshoots of the concerns raised by Pieter Burghout - BRANZ CEO and Chair of the New Zealand Construction Industry Council (NZCIC) – in his keynote address at the inaugural session of the NZBERS 2011. Pieter remarked that, "*We don't know how much research actually is going on in our sector, and on what*!" This concluding editorial section will attempt to address the questions, based on the outcome of a thematic analysis of the industry priority research needs as highlighted in the Building a Better New Zealand strategic document and the extent to which the research needs have been addressed by current research efforts of the universities. Information on the latter was based on presentations and submissions made at the NZBERS 2014, as well as research information on the universities' websites.

National Science Challenge programmes

The Government's programme of National Science Challenges (NSCs) identifies the industry research needs and dictates the research directions in the New Zealand built environment.

In September 2014, the Government announced a new initiative to develop better housing and urban environments as part of its programme of NSCs. The current programme – National Science Challenge 11 – is titled "Building Better Homes, Towns and Cities". The programme is expected to deliver on five expectations:

- practical solutions to develop smart cities, better transport and healthy urban environments
- solutions to constraints on construction sector productivity and innovation uptake
- innovative materials, processes and devices for the New Zealand construction sector
- better understanding of demographic drivers and consumer preferences in housing
- solutions for cost-effective upgrades to existing building stock

Industry priority research needs

The Building a Better New Zealand (BBNZ) is a joint industry/ government consultation initiative. According to the Science and Innovation Minister Steven Joyce, the aim is to identify a number of important research opportunities for the building sector which will create the knowledge needed to transform the urban environments of New Zealand into:

- more vibrant places to live,

- affordable, well-located houses and buildings that meet the demands of New Zealand's diverse population,
- resilient buildings, cities and communities to change and shocks such as natural disasters.

Through coordinated and collaborative efforts of the Building Research Association of New Zealand (BRANZ), Ministry of Business, Innovation and Employment (MBIE), Construction Strategy Group (CSG) and the Construction Industry Council (CIC), the research strategy for the building and construction industry was formulated to incorporate the requirements of the Government's National Science Challenge 11, the CIC research agenda, and the BRANZ building research and information agenda. The BBNZ research strategy therefore represents the New Zealand built environment research needs.

Figure 1 shows the 2014/2015 Building Levy investment in each of the priority research themes and how this translates to the percentage of total $10.34m investment envelop for the period. The investment budgets could serve as the relative levels of importance the Government, BRANZ and MBIE place on the nine research themes, perhaps due to the amount of earlier investments and research efforts already committed in the research areas, and where the critical need for future research exists.

The figure indicates that Better Buildings and Operating Environment constitute more than 50% of the total investment outlay, with contributions of 29% and 26%, respectively. Better Cities and Communities (i.e. Building Better Cities & Communities), Building Performance (i.e. Maintaining and Improving the Performance of Existing Buildings), and Automations, Industrialisation and New Technologies, constitute the least priority areas

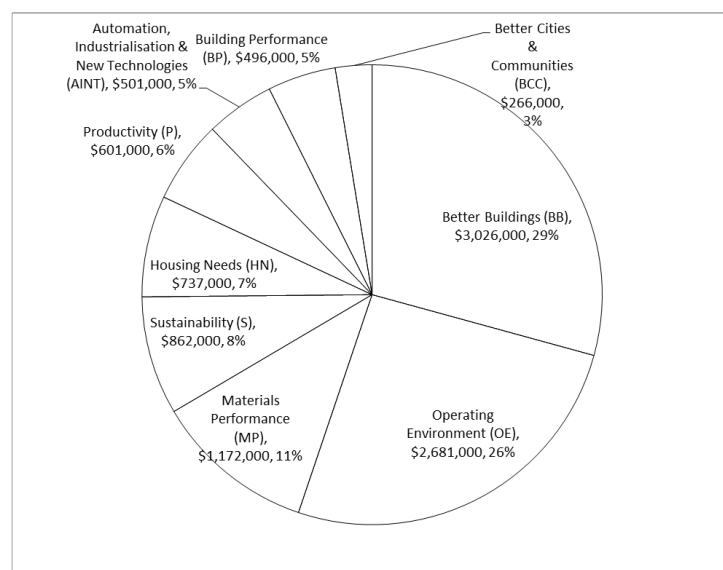with percentage investments of 2.57%, 4.80% and 4.84%, respectively.

Figure 1: 2014/15 investments in the nine research priority themes. [*Source*: BRANZ Building Research Levy Prospectus 2015/2016]

Research in the universities

Section II of this document highlights the recently completed and on-going research in the universities as summarised by the built environment programme directors in their presentations. Sections 111 and 1V give details of some of the research projects as provided by research students and academic staff in their presentations and papers submitted for the symposium.

Information provided in sections II – IV therefore contributes to addressing the question of what the built environment research is being carried out at the universities. Section I featured keynotes from industry chieftains and government functionaries. The purpose of the keynotes was to provide insights into the current and future research needs of the New Zealand construction industry. A cursory look at the information provided in Section I shows that the suggested research needs have been

covered in the research themes included in the Building a Better New Zealand (BBNZ) research strategy document. The nine themes and the required research topics are shown in Table 1 below.

Industry research needs versus universities' research: Gaps and future research focus

The extent to which the research at the universities addresses the identified industry' research needs could be established through cross-tabulation analysis of the research projects reported by the programme directors in their presentations in Section II versus the research themes and topics listed in the BBNZ research strategy document. The cross-tabulation analysis was done in Table 1 and summarised in Table 2.

Priority research needs areas for the future

Future directions for research in the New Zealand built environment should be shaped by the industry's critical research needs areas. The nine research priority themes set in the BBNZ provide indications of the industry's critical research needs areas, being the outcome of a joint industry and government consideration of the 'innovative research and industry good projects' worthy of future Building Research Levy investments.

Future Priority Research Needs Index (FPRNI) could be developed as a framework for prioritising the identified nine research priority areas based on two parameters:

    a) The relative importance attached to a given research theme based on its proportion of the total investment budget. Thus, the higher the proportion, the higher the need for the research theme.

    b) The gap in the current involvement of the universities in the research theme. This gap is taken as 100% minus the % current involvement of the universities in the given research theme - as summarised in Table 1. Thus, the wider the gap, the higher the need for research efforts in a given research theme.

The Future Priority Research Needs Index (FPRNI) is therefore computed as follows:

$$FPRNI_i = \%UniInvolGap_i \times \%BLInvest_i$$

[Eq.1]

Where:

FPRNI$_i$ = Future Priority Research Needs Index for the ith research theme.

%UniInvolvGap$_i$ = % gap in the current involvement of the universities in the research theme (taken as 100% minus % level of current involvement).

% BLInvest$_i$ = % of 2014/2015 Building Levy Investment in the research theme

To enable visual prioritisation of the research themes based on the three parameters of Building Levy investment, % gap in current university level of engagement and the FPRNI scores, the latter were adjusted by re-scaling the scores based on the highest FPRNI score achieved. The analysis carried out in Table 2 shows that score for Operating Environment (i.e. 0.194 or 19.4%) was the highest. Equating this value to 100%, the relative FPRNI scores of other research themes were recomputed.

The adjusted FPRNI scores help to prioritise the nine research themes in terms of their critical levels of need for future research efforts. The results plotted in Figure 2 showed that the universities are mainly involved in the

following research themes as at November 2014:

- Sustainability (94%)
- Automation, Industrialisation & New Technologies (78%)
- Building Performance (78%))

The increasing emphasis placed in these areas by the industry, especially in relation to green building practices, prefabrication and BIM, and weathertightness, respectively, might be the key drivers for more focused involvement of the universities in these areas.

Figure 2 also shows that the following research themes have not received the attention they deserve by the universities in their research efforts; these should therefore dictate future research directions in the built environment:

- Materials Performance (9%)
- Operating Environment (25%)
- Housing Needs (26%).

Perhaps, the exclusive involvement of BRANZ in material and component appraisal – as the only recognised agency for product certification for acceptable solutions under the Building Act – might be responsible for the low competition in the materials performance area. It should be noted that the research themes on Meeting the Housing Needs of all New Zealanders, Building Buildings and Building Better Cities and Communities were recent additions to the Building Research and Information (BRIA) research strategies introduced in 2012. With the recent inclusion of these in the strategic research agenda, there will be more involvement of the universities in the research areas.

Critical research needs for the future
Based on the Future Priority Research Needs Index (FPRNI) scores computed in Table 2 for the nine research priority areas, it could be seen that the three most critical areas for future research focus are as follows:

- Operating Environment,
- Better Buildings and
- Materials Performance.

Perhaps, this result was driven by the recent concerns about the inhibitions of compliance costs on businesses and the legacy of leaky buildings due largely to poor quality performance of the sector. Surprisingly, Sustainability, Building Performance and New Technology research themes were the least in terms of critical research need areas for the future. As earlier indicated, these could be due to the amount of earlier investments and research efforts to date in the research areas.

Conclusions and Caveat
Operating Environment, Better Buildings, and Materials Performance research themes will shape future directions in the built environment research in the New Zealand universities. However, analysis of the extent of universities' involvement in the nine research priority research areas which forms the basis for the Future Priority Research Needs Index (FPRNI) scores should be viewed with caution. As earlier indicated, the analysis was based on the recently completed and on-going research in the universities as summarised from presentations and papers submitted for the NZBERS 2014, as well as additional information sourced from the universities' websites. The information may not be accurate records of existing research projects in the research themes. Also, the industry research needs as articulated in the Building Better New Zealand industry research strategy document were in relation to specific research questions; recently completed and ongoing research projects in the universities do not necessarily address the specific research questions to the degree intended. However, the framework developed here could be good pointers to areas of critical research needs for the future.

Table 1: Extent of universities' involvement in the industry research strategy identified in the Building a Better New Zealand (BBNZ)

	BBNZ strategic research needs: Themes and research topics	Universities involved in the research topics									No	%
	http://www.buildingabetternz.co.nz/cms_show_download.php?id=1	Auckland 1	AUT 2	Canterbury 3	Lincoln 4	Massey 5	Otago 6	Unitec 7	Victoria 8	Waikato 9		
BB	**Better Buildings (BB)**											**49%**
BB1	Resilient buildings	1	1	1	1	1		1	1		7	78%
BB2	Moisture in buildings					1	1	1	1		4	44%
BB3	Indoor air quality (IAQ) & moisture control					1	1	1	1		4	44%
BB4	Ventilation			1		1	1	1	1		5	56%
BB5	Acoustic performance					1			1		2	22%
MP	**Materials Performance (MP)**											**9%**
MP1	Performance of systems/ effects of new materials on existing materials										0	0%
MP2	Performance of new materials in existing systems										0	0%
MP3	Performance of existing materials in new applications										0	0%
MP4	Improving the performance of materials	1		1					1		3	33%
MP5	Product assurance			1							1	11%
BP	**Building Performance (BP)**											**78%**
BP1	Retrofit solutions	1	1	1		1	1	1	1		7	78%
BP2	Building condition	1	1	1		1	1	1	1		7	78%
S	**Sustainability (S)**										0	**94%**
S1	Measuring sustainability	1	1	1	1	1	1	1	1	1	9	100%
S2	New technologies	1	1	1		1	1	1	1	1	8	89%
AINT	**Automation, Industrialisation & New Technologies (AINT)**											**78%**
AINT1	New construction systems and processes	1	1	1		1	1	1	1		7	78%
OE	**Operating Environment (OE)**											**25%**
OE1	Health & safety	1	1	1		1		1	1		6	67%
OE2	Standards and conformance review							1			1	11%
OE3	Building Act/ Building Code			1				1			2	22%
OE4	Export opportunities										0	0%
P	**Productivity (P)**											**42%**
P1	Industry structure	1	1			1		1			4	44%
P2	Productivity measures	1	1			1		1	1		5	56%
P3	Industry processes	1	1			1		1			4	44%
P4	Skills	1	1			1		1	1		5	56%
P5	Technology	1	1	1		1		1	1		6	67%
P6	Client value	1	1			1			1		4	44%
P7	Operating environment					1			1		2	22%
P8	Canterbury rebuild	1		1		1					3	33%
P9	Auckland growth		1								1	11%
HN	**Housing Needs (HN)**											**26%**
HN1	Population change								1		1	11%
HN2	Housing an ageing population					1			1		2	22%
HN3	Housing a diverse population								1	1	2	22%
HN4	Meeting the needs of vulnerable groups										0	0%
HN5	Housing tenure							1	1	1	3	33%
HN6	Housing affordability		1	1		1	1		1	1	6	67%
BCC	**Better Cities & Communities (BCC)**											**46%**
BCC1	Sustainable urban planning				1		1	1	1	1	5	56%
BCC2	Sustainable urban design				1		1	1	1	1	5	56%
BCC3	Sustainable & affordable urban development	1	1		1		1	1	1	1	7	78%
BCC4	Lessons from Christchurch rebuild	1		1	1	1					4	44%
BCC5	Urabn planning & individual property rights						1			1	2	22%
BCC6	Appropriate mix of medium & high density housing						1		1		2	22%

Table 2: Priority research need areas for the future based on building levy investment and extent of universities' current involvement in the industry strategic research themes identified in the Building a Better NZ

	Strategic research theme	[1]% uni involv	[2]BL invest ($ x 10^6)	(%)	[3]% Uni invol gap	[4]FPRNI Actual	[5]Adjusted
1	Operating Environment (OE)	25%	2.681	26%	75%	19.4%	100%
2	Better Buildings (BB)	49%	3.026	29%	51%	15.0%	77%
3	Materials Performance (MP)	9%	1.172	11%	91%	10.3%	53%
4	Housing Needs (HN)	26%	0.737	7%	74%	5.3%	27%
5	Productivity (P)	42%	0.601	6%	58%	3.4%	17%
6	Better Cities & Communities (BCC)	46%	0.266	3%	54%	1.4%	7%
7	Automation, Industrialisation & New Technologies (AINT)	78%	0.501	5%	22%	1.1%	6%
8	Building Performance (BP)	78%	0.496	5%	22%	1.1%	5%
9	Sustainability (S)	94%	0.862	8%	6%	0.5%	2%
	Average involv/ Total invest (x106)	50%	10.34				

1) % uni invol: % of universities involved in the strategic research theme

2) BL invest: Building Levy investment budget for the research theme out of the total amount of $10.34 million earmarked for 2014/2015

3) % uni involv gap: % gap in the current extent of the universities' involvement in the research theme (i.e. 100% - % uni invol)

4) FPRNI: Future Priority Research Need Index score for research theme (= % BL invest x % uni invol gap; see Eq.1)

5) Adjusted %FPRNI: Future Priority Research Need Index score for research theme adjusted as a % of the maximum actual FPRNI
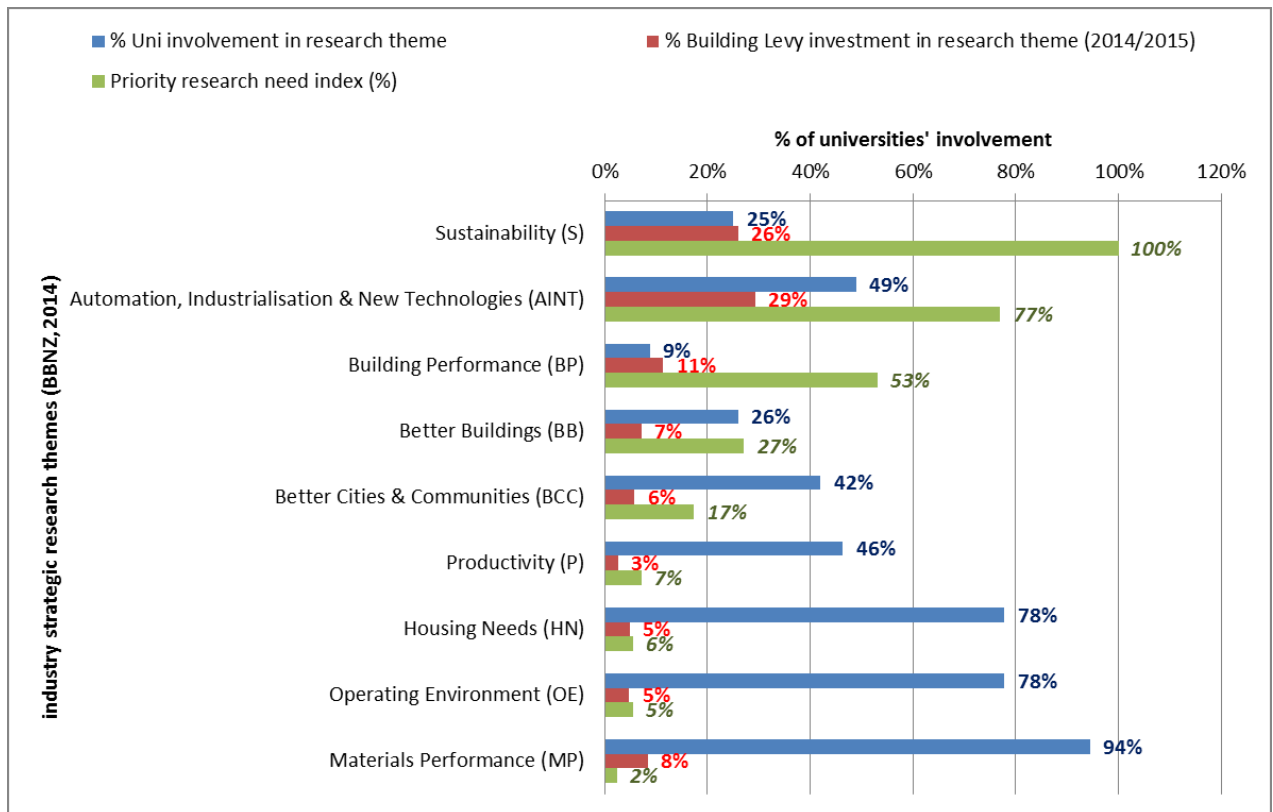
Figure 2: Priority research need areas based on building levy investment and extent of universities' current involvement in the industry strategic research themes identified in the Building a Better NZ

University programme leaders

- Professor Robyn Phipps, Programme Director, Construction, School of Engineering and Advanced Technology, Massey University;
- Professor Suzanne Wilkinson, Programme Director, Engineering Management, Department of Civil & Environmental Engineering, University of Auckland.
- Professor John Tookey, Programme Director, Engineering Project Management, AUT.
- Dr James Rotimi, Programme Coordinator, Master of Engineering Project Management, AUT;
- Associate Professor Linda Kestle, Chair, Research, Faculty of Technology & Built Environment, UNITEC.
- Dr Ricardo Mendoza, Director, Postgraduate Studies, Department of Civil & Natural Resources Engineering, University of Canterbury.
- Dr Fabricio Chicca, Programme Director, Building Science, School of Architecture, Victoria University of Wellington.

Keynote speakers

- Lt Col (rtd) Warren Parke, Chair, Construction Clients Group (CCG).
- Bruce Rogers, President, Northern Chapter, NZIOB.
- Paul O'Brien, Chair, NZIQS Auckland Branch Board; Commercial Manager, Leighs Construction).
- Regan Solomon, Manager, Research, Investigations and Monitoring Unit (RIMU), Auckland Strategy and Research, Auckland Council.
- Professor Paul McDonald, Pro-Vice Chancellor, College of Health, for delivering the Welcome Address on behalf of Steve Maharey (CNZM), Vice Chancellor, Massey University.

Industry Patrons

- Dr Wayne Sharman (Strategic Business Development Manager, BRANZ)
- Kevin Golding (Winstone Wallboards);
- Dr Kevin Walls (Director, Building Code Consultants Ltd).
- Matthew Ensoll, Director, Quantum Meruit Project Management.
- Victoria Troake (Director, Troake Group).
- Gary Caulfield (Director, Construction Cost Consultants)

- Paul O'Brien (Commercial Manager, Leigh Construction; Chair, NZIQS Auckland Branch Board)
- Sam Lomax, Vice Chair, Auckland Branch Board, New Zealand Institute of Quantity Surveyors (NZIQS).

Sponsors:

- Winstone Wallboards (GIB) – thanks to Kevin Walls, Manager, Sustainability.
- Ebert Construction Ltd – thanks to Ron MacDonald, General Manager, Northern.
- Royal Institution of Chartered Surveyors (RICS) Oceania – thanks to Brian Dewil, the Country Manager for Oceania.
- New Zealand Institute of Quantity Surveyors (NZIQS) – thanks to Paul O'Brien and Sam Lomax, the Chair and Vice Chair of the Auckland Branch of the NZIQS, respectively.

Scientific and Technical Committee (S&TC)

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- Dr Vicente Gonzalez, Senior Lecturer and Coordinator, Master of Engineering Studies, Department of Civil and Environmental Engineering, The University of Auckland.
- Garry Miller, Senior Lecturer, Faculty of Engineering, The University of Auckland.
- Dr Fei Ying, Lecturer, Engineering Project Management, AUT.
- Dr Niluka Domingo (Lecturer, Construction, Massey University);
- Temi Egbelakin (Lecturer, Construction, Massey University);
- Naseem Ameer Ali (Senior Lecturer, Construction, Massey University).
- Alice Yan Chang-Richards, Research Fellow, Faculty of Engineering, The University of Auckland
- Dr Mikael Boulic, Lecturer, Construction, Massey University.

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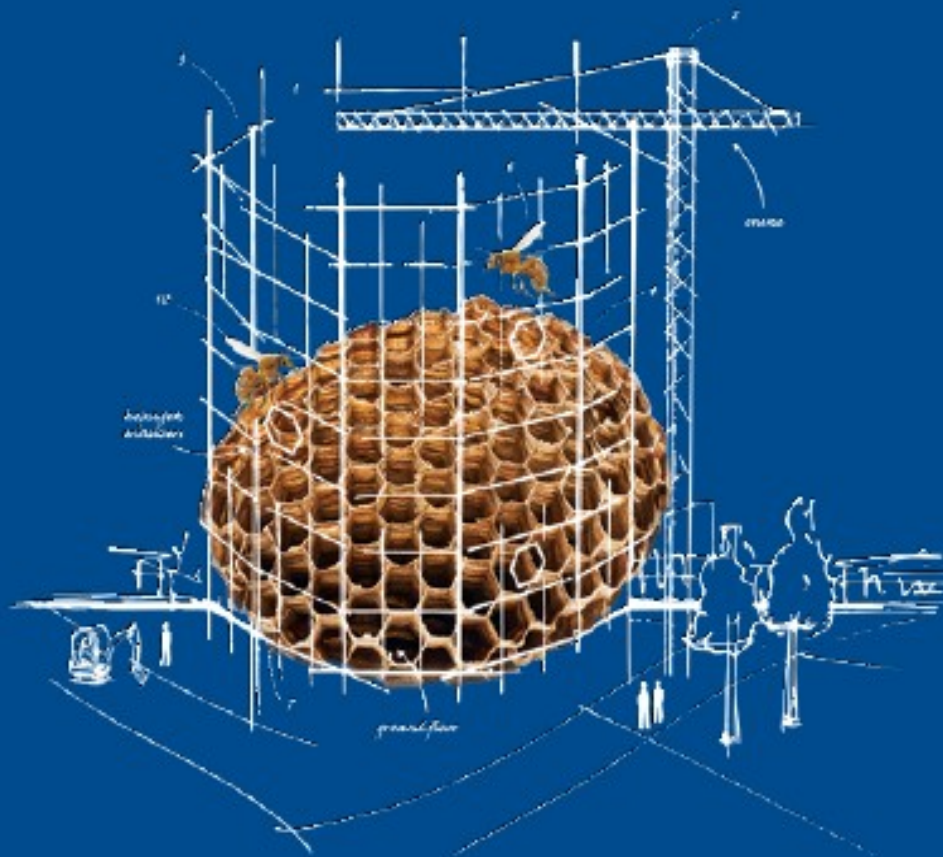## 4th Annual New Zealand Built Environment Research Symposium
[NZBERS 2014]
14 November 2014
Massey University, Albany, New Zealand

Dr Jasper Mbachu
[Editor-in-Chief]

What kind of built environment research is being carried out in the universities? To what extent does this address the research needs of the New Zealand built environment sector?

The NZBERS, through its website and Proceedings, aims to address these questions.
http://construction.massey.ac.nz/nzbers-2014_Proceedings.pdf