International Conference on Engineering, Project, and Production Management

Conference Proceedings

26-28 November 2014
Protea Marine Hotel,
Port Elizabeth,
South Africa

Scientific Chairs
Jolanta Tamosaitiene
Kriengsak Panuwatwanich
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President of EPPM-Association
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THE 2014 (5TH) INTERNATIONAL CONFERENCE ON ENGINEERING, PROJECT, AND PRODUCTION MANAGEMENT

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26-28 November 2014
Protea Marine Hotel, Port Elizabeth, South Africa
FOREWORD

The Department of Construction Management, Nelson Mandela Metropolitan University, is delighted to host the 5th Conference of the Association of Engineering, Project, and Production Management in South Africa in 2014. Given that South Africa is a developing country, is on the verge of major infrastructure development, and the role of production in the economy, the conference is of particular importance.

A range of thanks are due to the Organising Committee, Scientific Chairs, Scientific Committee, editors of the proceedings, keynote speakers, international community in the form of the authors of the papers, Mr Mark Abrey, the conference website Administrator, and Mrs Mariana Botes, the conference secretary.

John Smallwood
Conference Chair
EDITORIAL

Current technological advancement has enabled the ability of various elements within an engineering system to be seamlessly integrated to achieve enhanced efficiency. However, the increased complexity inherent in the intricacy of such integrated system means the current industrial problems can become far more complex. Solving these problems will require the understanding of how various elements within the system interact. The nature of this problem-solving exercise often demands well-developed approaches utilizing the nexus of cross-disciplinary knowledge to address the heterogeneity of the various elements encapsulated in the system.

The 5th International Conference on Engineering, Project, and Production Management (EPPM) addresses the importance of such knowledge nexus and in so doing provides a platform for the discussion of innovative research and practice and creative cross-breeding of multidisciplinary fields of engineering and management. The conference hosts theoretical discussions, data analysis, case studies, and industrial practices in the form of research papers, which provides a great opportunity for researchers, engineers, managers, students, and practitioners to present and discuss current and emerging research issues, problems, questions, findings, and new developments.

The proceedings of the conference this year include 38 papers that have been carefully selected through a rigorous double-blind review process. These papers address theories and applications of engineering management, project management and production management as well as the integration of these areas. The papers also present a wide range both traditional and novel methodologies utilized to help answer some very important research questions that, in turn, helps advance the knowledge in the fields. In recognizing an outstanding contribution to the knowledge, the Best Paper Award is given to the paper with exceptional quality agreed upon by the selection panel.

The Editors wish to express their sincere gratitude to all authors, member of the international scientific committees, members of the international advisory board and the local organizing committee for their effort and support. It is their selfless contribution that makes this conference a success.

Jolanta Tamosaitiene, Kriengsak Panuwatwanich, and Nobuo Mishima
Scientific Chairs

Chien-Ho Ko
President of EPPM-Association
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Jolanta Tamosaitiene – Scientific Chair
Kriengsak Panuwatwanich – Scientific Chair
Nobuo Mishima – Scientific Chair
Chien-Ho Ko – President of EPPM-Association

ORGANISING COMMITTEE’S DECLARATION

All the papers in these conference proceedings were double-blind reviewed by members of the International Scientific Committee. This process entailed detailed reading of the papers, reporting of comments to authors, modification of papers by authors, and re-evaluation of revised papers to ensure quality of the content.
PEER REVIEW PROCESS

A rigorous two-stage peer review process was applied to this conference to maintain and assure the quality of the conference proceedings. In the first stage, submitted abstracts were evaluated by Scientific Chairs in terms of:

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

Authors, whose abstracts were tentatively accepted in the first stage, were requested to submit full papers for further review. Each paper was reviewed by no less than two acknowledged experts in the field with unidentified reviewers’ comments. Authors were requested to submit their revised papers noting and addressing reviewers’ comments. Evidence was required relative to the action taken by authors regarding the comments received. These resubmitted and revised papers were re-reviewed again in terms of:

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

In the second review stage, authors were provided with additional comments and requested to submit their revisions. The final accepted decision was rendered when Scientific Chairs confirmed that all reviewers’ comments were appropriately responded to, having been double peer-reviewed for publication. At no stage was any member of the Scientific Chairs and International Scientific Committee involved in the review process related to their own authored or co-authored papers.

The role of the Scientific Chairs was to ensure that the final accepted papers incorporated the reviewers’ comments and arrange the papers into the final sequence as captured on the CD-ROM. Of the 69 abstracts originally received, only 38 papers were finally accepted for presentation at the conference and inclusion in these proceedings, representing a rejection rate of 45%.
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Department of Construction Management

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for tomorrow

EPPM

Association of Engineering, Project, and Production Management
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Keynote 1: *Quality Costing and Lessons Learnt on Projects*
**Hannelie Nel**
British Inspecting Engineers Ltd., South Africa

Keynote 2: *Airport Gate Scheduling*
**Erwin Pesch**
University of Siegen, Germany
PAPERS
Facilities Management: Physical Built Environmental Factors that Influence User Performance in an Office Building

Asad Jalal Sindhu\textsuperscript{1} and Kassim Gidado\textsuperscript{2}

Abstract

In a generic sense, all services and core products are delivered to the users in a manmade space called ‘facility’ that serves the organization to deliver its core business objectives. Effective, efficient and comfortable working environment improves quality of life, wellbeing and perceived satisfaction of the user which improves performance to achieving the organisation’s goal. The appropriate configuration of the built environmental factors of a facility helps create a pleasant indoor environment and therefore have influential characteristics to dominate user’s productivity and performance.

It is evident that quality of the built environmental factors will encourage users’ healthy working style and improve uses’ wellbeing. Facilities Management of an office building is an integrated approach that maintains, improves and adapts the built environment to support the primary business objectives of the organization. It is about managing user perceived satisfaction and includes the desire to provide a pleasant experience for the users of the facility in order to improve performance. In an organisation (SMEs\textsuperscript{3} in the UK), the role of the manipulation of the nature of the facility is one of the primary objectives of a facilities manager for improved user’s performance and consequently the overall organizational performance. This research paper therefore aims to identify the key built environmental factors that influence the office building users towards improving their performance in a business enterprise. Quantitative research methodology has been adopted using questionnaires survey tool for this paper. The built environmental factors have been measured by the user on the basis of quality, their perceived satisfaction and the effect on their performance to establish a ranking order of significance.

Keywords: Facilities management, users’ performance, office building, built environment.

Introduction

This research paper briefly introduces the facility (facility in the context of this paper is an office building of an SME), facilities management (functionality/operations mechanism) and the built environmental factors (BEFs) that influence users’ perceived satisfaction and performance. Literature search regarding the office building, employee’s performance, facility management have been carried out to develop an understanding of the relationship between the users and the facility to identify the key BEFs of the facility in an organisational environment. A questionnaire survey has been conducted about the user’s perceived satisfaction towards the BEFs and how these factors affect their performance.

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\textsuperscript{3} Small to medium business enterprises in the United Kingdom
This paper produced a hierarchical list of the built environmental factors established through the questionnaire survey. Targeted participant of this research were users (employees/staff members) of a small to medium business enterprise using office buildings located and operating within the United Kingdom (UK).

COBE and BCO (2005), Codinhoto (2008) and Oseland (2004) have used quantitative methods to study the BEFs affecting users of various facilities. This paper adopts the same quantitative approach. A questionnaires survey had been designed to initially confirm the built environmental factors identified through the literature review. Physical work environment satisfaction questionnaire (PWESQ) and post occupancy evaluation (POE) methods have been used to develop the questionnaire. The questionnaires were sent out using link of an online survey tool (Survey Monkey™) and respondents were asked to answer the questions online. Respondents are the professional office users identified through Facilities Management Association (FMA) and Interserve Plc, UK. 144 responses were received and analysed using Statistical Package for the Social Sciences (SPSS).

**Literature Review**

**Facility as an Active Support to the Business**

Frontczak et al (2012) states that the contemporary users of the built environment spend 90% of their lives indoors, which leaves a very serious impact on user’s well-being and their working performance. In a facility, comfortable working environment plays a vital role to improve efficiency, workability, quality of life, wellbeing and level of satisfaction of a user. A facility serves a common purpose which is provision of work space and the services. Facility is a space where users perform and carry out their routine work activities for operational purposes towards achieving organisational core businesses objectives. As a hosting venue these are developed to fulfil the user’s needs, administer plans and to coordinate the corporate activities. A facility is a workspace where the processing actions related to the organisation of the business such as information, planning, filing, designing, analysing, supervising, deciding and broadcasting and communications take place, (Arora, 1980 quoted by Kamarulzaman et al, 2011). It provides work space and services to satisfy users’ demands and needs in an office building setting, (Tiwari et al, 2010) and Seeley (1995). Generically, it serves the organisation as an active support to promote their business, financially enhances the value, quality and the use of the land provides neighbourhood surrounding, and on commercial scale municipal surroundings, (Callaway et al, 2008). Most office buildings are used for a specific purpose to promote the image of the business (external expression), and as a medium of relations to other business communities and to support effective and improved internal communication CABE (2005).

Most office buildings in the UK are influenced by the North American construction style which has been argued by a number of researchers as not user oriented and have a very low level of user control over the indoor environment. The user’s perception towards buildings has been changed and the buildings are not only use for working place but as a meeting point, Kok and Jennen (2012). Modern office buildings are trendy equipped with new technology. They have become more complex and this new wave demands organisations to pay more considerations to the users of the facility and to the ever changing information technology, IFMA (2012).

A facility provides suitable space with the help of facilities management to make the experience and working activities of the users as smooth as possible.
The Facilities Management (FM)

Facility management is the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities and user comforts. 1960 is the year when the term facilities ‘management (FM) was used for the very first time Wiggins (2011:1). Facilities management reflects the organisations nature and purpose of the businesses. It is an integrated approach to operating, maintaining, improving and adopting the facility and the infrastructure of an organisation in order to create an environment that supports the primary objective of the organisation, Price et al (2001). It plays a central role in the maintenance and operation of a facility, Alexander (2007). It encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes and the technology.

Better user performance the facility is attainable with better facilities management system. It is not just the design, layout of the office building which can impact the user performance but the way office building is managed also have its role to play, Haynes (2011) quotes Clements-Croome (2003). Facilities Management can be classed as a quality control department in the facility, an integrated approach to maintaining, improving and adapting the built environment to accurately reflect and to directly support the primary business objectives of the organization. It is about managing users and their perceived satisfaction with an intention and desire to provide them a pleasant experience to gain an improved performance. It is the management of people and the facility, making available resources useful and utilizing them properly, ensuring to make user’s experience unique by providing services excellence and making organization’s image encouraging and constructive for users and the community.

Impact of Built Environment on a Facility User

CABE and BCO (2005) suggest that the performance measurement of both office building and their users can improve the management process, resource allocations, decision making, better regulations and legislative oversight and accountability. Facilities Management is a management of interaction between user and the facility, and control over the BEFs can leave positive or negative impact on user’s which ultimately reflects in the organisational performance, (IFMA). In the facility built environmental factors (BEFs) create indoor environment, and better indoor environment encourage users healthy working style and improve their performance.

Along with physical BEFs there are some non-physical built environmental factors which can be influential on user’s performance and cannot be ignored such as, climate change or global warming, gender, culture, religion, etc. Stenberg (1995) Redman et al (2009) Wang et al (2008) consider that there is a variation of affects depending on the socio-demographic role of the user such as age, qualification or marital status etc, Ajala (2012), Lagoudi et al (1996). The most important non-physical BEFs are, new legislation, political/organisational pressure groups, climate change, motivation, relationship with higher management, moral, health and safety, social, self-actualisation, gender, age, religion, sick building syndrome (SBS), etc., Butt et al (2013), Redman et al (2011) and Wang et al (2008). These non-physical environmental factors of a facility are beyond the scope of this paper, therefore will not be discussed any further.

Physical Built Environmental Factors in an Office Building
Healthy working environment encourages healthy working style and reduces absenteeism at work. In a manmade built environment comfortable working environment plays a vital role to improve efficiency, workability, quality of life, wellbeing and level of satisfaction of a user, Fanger (2000). The indoor environmental quality (IEQ) has a major and positive impact on the performance of the office workers, Fanger (2001), and the IEQ should be acceptable to all the users in the office building, Frontczak et al (2011), Dorgan and Dorgan (2005) and Ajala (2012). As stated earlier, an office building user spends almost half of their life at their work place, therefore, it is vital to keep a user satisfied with the indoor environmental quality (IEQ), Frontczak et al (2011), Dorgan and Dorgan (2005) and Ajala (2012). The built environmental factors make the indoor environment usable and to support users functional tasks. BEFs can be divided into four major factors, i.e., aesthetics, ambient, ergonomics, and services, Codinhoto et al (2009), Danielson and Bodin (2009). Chuck and Jeong (2012) add fabric (quality, durability, materials) into this list. Therefore, the major BEFs are; aesthetics (colour, art, layout, design), fabric (façade, surface, quality, durability, materials, lighting, acoustics, temperature, humidity), ambient (acoustic level, noise, air, lighting), ergonomics (furniture layout, IT station, hot desks, offices dimensions, shapes, lay out), and the services (operation, maintenance, accessibility, management, cleanliness, decontamination), Chuck and Jeong (2012), Codinhoto et al (2009), Munirathinam et al (2011), Vischer (2008). Instead of using BEFs, Leaman and Bordass (2000) use the term ‘the killer variables’. The killer variables have a serious influence on user’s perceived satisfaction and performance in an office building and the overall system in the facility. They have identified five variables:

1. perceived comfort and control over personal environment
2. response towards the needs, including comfort
3. ventilation types
4. workgroups and the layout and space plan
5. design (durability, quality, materials used)

**Questionnaire Survey**

Comfortable working environment plays a vital role to improve users’ efficiency, workability, quality of life, the wellbeing and level of user’s perceived satisfaction. Users’ satisfaction and experience towards the services provided at work is a growing area of interest amongst the employers, Vischer (2008). The questions asked in this survey were related to the user’s personal experience and their perceived satisfaction with the services. This questionnaire survey had a very good response from the industry and many facilities management organisations have shown their interest in the research findings. A hierarchical list of the key BEFs has been established. This is shown in Table presented in the end of this paper. As adopted from Gidado and Akeleere (2003) and Frontczak (2011), the Severity Index formula has been used for ranking the BEFs, i.e.,

\[
S.I = \sum R_w \frac{W}{R_t}
\]

Where: \(R_w\) = number of respondents; \(W\) = weighting or points assigned; \(R_t\) = total number of responses obtained for the variable. Likert scale considered for measure of severity is: no effect = 1, low effect = 2, medium effect = 3, high effect = 4, critical effect = 5
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type</th>
<th>Built Environmental Factors</th>
<th>Response %</th>
<th>Response Count</th>
<th>Skipped</th>
<th>Severit y Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Ix. BEFs</td>
<td>Suitable level of lighting to perform your routine activities</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.94</td>
</tr>
<tr>
<td>30</td>
<td>Ix. BEFs</td>
<td>Air quality (emission of gases, outdoor pollution, dust in the air, moisture etc.)</td>
<td>75</td>
<td>108</td>
<td>36</td>
<td>3.93</td>
</tr>
<tr>
<td>29</td>
<td>Ix. BEFs</td>
<td>Fresh air circulation at your work place</td>
<td>75.69</td>
<td>109</td>
<td>35</td>
<td>3.92</td>
</tr>
<tr>
<td>43</td>
<td>Ix. BEFs</td>
<td>Overall cleaning and maintenance of the communal facilities and the area</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.92</td>
</tr>
<tr>
<td>31</td>
<td>Ix. BEFs</td>
<td>Poor ventilation system in the office</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.88</td>
</tr>
<tr>
<td>39</td>
<td>Ix. BEFs</td>
<td>Communications system to report a fault regarding these factors</td>
<td>75.69</td>
<td>109</td>
<td>35</td>
<td>3.85</td>
</tr>
<tr>
<td>32</td>
<td>Ix. BEFs</td>
<td>Poor management and maintenance</td>
<td>75.69</td>
<td>109</td>
<td>35</td>
<td>3.84</td>
</tr>
<tr>
<td>4</td>
<td>Ex. BEFs</td>
<td>Traveling time to your work place</td>
<td>85.42</td>
<td>123</td>
<td>21</td>
<td>3.76</td>
</tr>
<tr>
<td>24</td>
<td>Ix. BEFs</td>
<td>Furniture suitable, adjustable, rearrange able, re-organisable (in terms of layout and design flexibility in the space)</td>
<td>80.56</td>
<td>116</td>
<td>28</td>
<td>3.76</td>
</tr>
<tr>
<td>35</td>
<td>Ix. BEFs</td>
<td>Lighting provided in your office</td>
<td>75.69</td>
<td>109</td>
<td>35</td>
<td>3.75</td>
</tr>
<tr>
<td>5</td>
<td>Ex. BEFs</td>
<td>Traveling cost to your work place</td>
<td>84.03</td>
<td>121</td>
<td>23</td>
<td>3.73</td>
</tr>
<tr>
<td>26</td>
<td>Ix. BEFs</td>
<td>Individual control over temperature regarding settings/adjusting its level</td>
<td>75.69</td>
<td>109</td>
<td>35</td>
<td>3.73</td>
</tr>
<tr>
<td>22</td>
<td>Ix. BEFs</td>
<td>Lay out/setting/ design is suitable to perform day to day activity</td>
<td>81.94</td>
<td>118</td>
<td>26</td>
<td>3.72</td>
</tr>
<tr>
<td>25</td>
<td>Ix. BEFs</td>
<td>Central heating and air circulation system (HVAC) in your office</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.72</td>
</tr>
<tr>
<td>33</td>
<td>Ix. BEFs</td>
<td>Natural lighting in your office</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.69</td>
</tr>
<tr>
<td>46</td>
<td>Ix. BEFs</td>
<td>Solving the maintenance issues</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.67</td>
</tr>
<tr>
<td>47</td>
<td>Ix. BEFs</td>
<td>Response handling (response time to rectify the maintenance issues)</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.67</td>
</tr>
<tr>
<td>17</td>
<td>Ex. BEFs</td>
<td>Building design is suitable for the organisational purpose</td>
<td>86.11</td>
<td>124</td>
<td>20</td>
<td>3.65</td>
</tr>
<tr>
<td>23</td>
<td>Ix. BEFs</td>
<td>Enough storage space for your working tools and equipment</td>
<td>81.94</td>
<td>118</td>
<td>26</td>
<td>3.64</td>
</tr>
<tr>
<td>34</td>
<td>Ix. BEFs</td>
<td>Artificial lighting in your office</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.64</td>
</tr>
<tr>
<td>28</td>
<td>Ix. BEFs</td>
<td>Odours in the air</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.62</td>
</tr>
<tr>
<td>36</td>
<td>Ix. BEFs</td>
<td>Individual control over lighting</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.59</td>
</tr>
<tr>
<td>42</td>
<td>Ix. BEFs</td>
<td>Provision of tea, coffee, refreshments, etc.</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.53</td>
</tr>
<tr>
<td>44</td>
<td>Ix. BEFs</td>
<td>Provision of security services</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.47</td>
</tr>
<tr>
<td>37</td>
<td>Ix. BEFs</td>
<td>Individual control over opening a window to get the natural light</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.39</td>
</tr>
<tr>
<td>7</td>
<td>Ex. BEFs</td>
<td>Parking space for the building users</td>
<td>82.64</td>
<td>119</td>
<td>25</td>
<td>3.36</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Type</td>
<td>Built Environmental Factors</td>
<td>Response %</td>
<td>Resp. Count</td>
<td>Severity Index</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Ix. BEFs</td>
<td>Break out areas</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.35</td>
</tr>
<tr>
<td>48</td>
<td>Ix. BEFs</td>
<td>Acoustics in break out areas (less noisy)</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.33</td>
</tr>
<tr>
<td>9</td>
<td>Ex. BEFs</td>
<td>Traveling/wait time (waiting time for transport to get to your work)</td>
<td>84.03</td>
<td>121</td>
<td>23</td>
<td>3.31</td>
</tr>
<tr>
<td>18</td>
<td>Ex. BEFs</td>
<td>Building facade and shading is suitable to cope with climatic changes</td>
<td>85.42</td>
<td>123</td>
<td>21</td>
<td>3.3</td>
</tr>
<tr>
<td>41</td>
<td>Ix. BEFs</td>
<td>Quality of products and services provided in the break out areas</td>
<td>77.08</td>
<td>111</td>
<td>33</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>Ex. BEFs</td>
<td>Accessibility to public transport</td>
<td>84.72</td>
<td>122</td>
<td>22</td>
<td>3.29</td>
</tr>
<tr>
<td>27</td>
<td>Ix. BEFs</td>
<td>Individual control over opening/operating windows</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>3.22</td>
</tr>
<tr>
<td>21</td>
<td>Ix. BEFs</td>
<td>Internal Way-finding (to find a room/office) is easy</td>
<td>81.25</td>
<td>117</td>
<td>27</td>
<td>3.21</td>
</tr>
<tr>
<td>10</td>
<td>Ex. BEFs</td>
<td>Noisy (outside traffic and other noise pollution of the area)</td>
<td>84.72</td>
<td>122</td>
<td>22</td>
<td>3.19</td>
</tr>
<tr>
<td>13</td>
<td>Ex. BEFs</td>
<td>Represent the main business of the organisation</td>
<td>86.11</td>
<td>124</td>
<td>20</td>
<td>3.19</td>
</tr>
<tr>
<td>19</td>
<td>Ix. BEFs</td>
<td>Internal layout represent the organisation’s culture and values</td>
<td>81.94</td>
<td>118</td>
<td>26</td>
<td>3.19</td>
</tr>
<tr>
<td>12</td>
<td>Ex. BEFs</td>
<td>Represent the organisation’s culture and values</td>
<td>85.42</td>
<td>123</td>
<td>21</td>
<td>3.11</td>
</tr>
<tr>
<td>11</td>
<td>Ex. BEFs</td>
<td>Outside view (roads, streets, civic centre, etc.)</td>
<td>84.72</td>
<td>122</td>
<td>22</td>
<td>3.1</td>
</tr>
<tr>
<td>8</td>
<td>Ex. BEFs</td>
<td>Outside view (surroundings: nature, horticulture, etc.)</td>
<td>84.03</td>
<td>121</td>
<td>23</td>
<td>3.07</td>
</tr>
<tr>
<td>6</td>
<td>Ex. BEFs</td>
<td>Way-finding to the building</td>
<td>83.33</td>
<td>120</td>
<td>24</td>
<td>3.04</td>
</tr>
<tr>
<td>1</td>
<td>Ex. BEFs</td>
<td>Accessible to local amenities</td>
<td>84.72</td>
<td>122</td>
<td>22</td>
<td>3.01</td>
</tr>
<tr>
<td>16</td>
<td>Ex. BEFs</td>
<td>Colour and design of the facade is a depiction of your organisation</td>
<td>86.11</td>
<td>124</td>
<td>20</td>
<td>2.95</td>
</tr>
<tr>
<td>20</td>
<td>Ix. BEFs</td>
<td>Colour scheme used inside the building matches the colour of the organisation</td>
<td>81.94</td>
<td>118</td>
<td>26</td>
<td>2.94</td>
</tr>
<tr>
<td>15</td>
<td>Ex. BEFs</td>
<td>Aesthetically perfect design</td>
<td>86.11</td>
<td>124</td>
<td>20</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>Ex. BEFs</td>
<td>In the middle of city centre</td>
<td>84.03</td>
<td>121</td>
<td>23</td>
<td>2.84</td>
</tr>
<tr>
<td>14</td>
<td>Ex. BEFs</td>
<td>Office building as an iconic symbol for the community and culture</td>
<td>86.81</td>
<td>125</td>
<td>19</td>
<td>2.84</td>
</tr>
<tr>
<td>45</td>
<td>Ix. BEFs</td>
<td>Provision of games/equipment for physical activities in the break out area</td>
<td>76.39</td>
<td>110</td>
<td>34</td>
<td>2.77</td>
</tr>
</tbody>
</table>

Ex. BEFs: External expression of an office building

Ix. BEFs: Internal Expression of the an office building
**BEFs: Built environmental factors**

Total No of respondents: 144

**Discussion**

Literature review identifies almost 48 BEFs in a facility (Sr. No. 1 to 48) as shown in Table 1. An attempt has been made through a questionnaire survey to show the BEFs on a significance scale according to the user’s perceived satisfaction and experience. Questions asked in this survey were related to the user’s personal experience and their perceived satisfaction with the services. This questionnaire survey had a very good response from the industry and many facilities management organisations have shown their interest in the research findings. Generally, the questions related to indoor environment fetched higher score as compare to other built environmental factors. Previous studies suggested that the satisfaction and performance are critically influenced by the indoor built environmental factors; for example lighting (natural or artificial), HVAC, storage and privacy, external view through the window, etc., Codinhoto et al (2008), Sundstrom et al (1996), Voordt (2004), Unzeitig and Madhavi (2005). As stated earlier this questionnaire was divided into two sections (i) external expressions (Ex. BEFs) and (ii) internal expressions (Ix. BEFs). Table 1 shows that on the severity index scale external built environmental factors have also gained ranking amongst the top 20 ranking based on the users perceived satisfaction and their experience. The Table 1 shows that Ix. BEFs are not the only key factors that affect the users’ perceived satisfaction and performance, but also the Ex. BEFs, time and the cost of traveling to the work place in particular.

![Figure 1. A conceptual model of user's perceived satisfaction mechanism](image)

**Conclusion**

This paper has achieved three main goals; a list of 48 BEFs as shown in Table 1. This list of BEFs could be useful for analysing physical work environment satisfaction (PWES) and post occupancy evaluation (POE). It presents the top 10 most critical BEFs. This paper has also established that researchers and the facilities managers overlook the external BEFs. However, based on the questionnaire data this paper identified critical external BEFs that cannot be overlooked by the facilities managers at the time of decisions making about the
facility. The ranking of the BEFs may be limited to UK, but the identified key factors should apply beyond the UK as long as it is within an office environment.

References
The Chartered Association of Building Engineers (CABE) and British Council for Office Buildings (BCO) (2005), ‘the impact of Building Design on Business Performance, Commission for Architecture and Built Environment and the British Council for Offices.
Influence Factors on Cost and Time Overruns in Mozambicans Construction Projects: Preliminary Findings

Elisa Atália Daniel Muianga¹, Ariovaldo Denis Granja², and Joyce Andrade Ruiz³

Abstract

Cost and time overruns are typical problems in many construction projects. In Mozambique, the underlying causes related to this issue are not well understood. This study is a first attempt to determine the influence factors of cost and time overruns in this context. This ongoing research aims to categorize the influence factors that contribute to the occurrence of cost and time overruns, and to establish their criticality in Mozambican construction projects. A survey has been designed to collect preliminary data from construction managers in Mozambique, seeking to find out the critical influence factors related to cost and time overruns. Results will provide perceptions and guidance into the managerial needs of practitioners to overcome typical cost and time overruns in Mozambicans construction projects.

Keywords: Cost overrun, time overrun, delay, construction, Mozambique

Introduction

Cost and time overruns are common problems occurring in construction projects. Several studies conducted on causes and factors of cost and time overruns in construction projects have been published and cover a large geographical and contextual diversity. There are several studies on this topic, however only a small number of these investigations sought to categorize and classify these factors, in order to provide a more holistic understanding of the subject. Specifically in Mozambique, no studies were available showing the specific causes of cost and time overruns in construction projects.

This ongoing research aims to identify the influence of cost and time influence factors that best fit in the Mozambican context through regional analysis of other published studies. For this purpose, a Systematic Literature Review (SLR) about costs and time overruns in construction projects was performed to find categories and respective influencing factors for this problem. From these factors, pre-questionnaire survey was applied to seek the causes which may serve as the basis for a larger study in Mozambique.

This study represents the first step in determining cost and time overruns and related influence factors. The results will provide the first basis for obtaining the critical factors in construction projects in Mozambique. To deepen the discussion on theoretical models and methods to avoid cost and time overruns is beyond the scope of this paper. For a

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comprehensive overview of constraint project scheduling and related discussion based on
time and cost, please refer to Brucker et al. (1999).

Research Method

SLR is rooted on the evidence based paradigm (Kitchenham et al. 2009), so “the best
evidences” of any topic are sought by means of literature searching. In this research, the
selected databases were Scopus, Science direct and Web of Knowledge. Initially, 92 studies
were obtained through SLR. Factors were obtained, which were evaluated and grouped into
categories according to their content (Table 1). These factors were the basis for the
development of the pre-questionnaire survey.

The first stage of the research was based on the SLR method. The SLR is a secondary
study, which means to identify, evaluate and interpret the available primary research in
relevant studies for a specific research question (Kitchenham et al. 2009). The objective of an
SLR is to extract specific details of published articles relevant to the topic (Brereton et al.
2007). It was intended to collect information and integrate available research evidence with
expertise (Kitchenham et al. 2009).

In the second stage, a survey questionnaire was prepared to examine the factors that affect
cost and time overruns in Mozambique. This instrument was validated using a preliminary
test to know whether it was possible to apply it to a wider sample. The survey questionnaire
is usually applied when there is a need to get opinions from a group of people on a particular
subject. This method requires a statistical analysis to evaluate the results. The application of a
questionnaire is seen as a very useful tool for reducing costs and time on research (Martins;
Ribeiro, 2011).

In the studies analyzed, cost and time overruns were defined as follows:

- The difference between the original cost and the cost at completion (Avotos, 1983);
- Time overrun is the time to complete work after the date specified in the contract (Ramanathan; Nakayana; Idrus, 2012).

From 92 studies of SLR, some of them have made proposals for categorization in relation
to the main factors triggering cost and time overruns, which are described in the form of its
determinants (e.g. González et al, 2013; Long et al., 2004; Assaf; Al-khalil; Al-hazmi , 1995;
Le-hoai et al., 2008; Sugiharto; Hampson, 2003). In this research, 11 new categories were
proposed for the sake of grouping the factors according to the SLR (Table 1). The literature effort, 697 factors were identified and, because there are factors
that may have different terminology in different studies, they were stratified to homogenize
the best grouping factors within the 11 categories. Therefore, classifications performed
reduced the number of factors of 697 to 95 factors distributed into categories. These factors
were the basis for designing the pre-questionnaire.

The pre-questionnaire was designed seeking to obtain evidences in relation to the factors
and the level of importance, which managers could choose for each factor in relation to cost
and time overruns. The importance of factors varied between not relevant, minor relevance,
moderately relevant, relevant and very relevant (Table 2).
The pre-questionnaire analysis was separate in factors groups. The relevant averages of one factor were calculated following the attributed values 0-4 for the categories of "not relevant" to "very relevant", and then calculated a weighted average. For instance, if everyone answered "Not relevant", average relevance is 0, and if all answered "very relevant", average relevance is 4. The influence in cost and time were also examined. For each factor, the interviewee would have to choose which factor was more influential in relation to overruns.

The pre-questionnaire data were then descriptively analyzed. Only factors that reached their relevance greater or equal 2.5 were considered and presented in Table 2. This filtering process allowed to reduce and apply only moderate relevant factors to the final questionnaire for the sake of providing a less extensive questionnaire and easiness of comprehension to respondents.

**Results and Discussion**

Table 1 presents the 11 categories and their respective determinants that provide the grouping from the SLR synthesis. The determinants represent groups of causes within the same context.

<table>
<thead>
<tr>
<th>Category</th>
<th>Determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Governmental relations</strong></td>
<td>Factors related to licenses, laws, governmental bureaucratic procedures.</td>
</tr>
<tr>
<td><strong>Contractual issues</strong></td>
<td>Factors related to obligations of contracts, contractual constraints, inadequate contracts.</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>Factors related to supervision, leadership, relation between different parties in project.</td>
</tr>
<tr>
<td><strong>Management</strong></td>
<td>Factors relating to the resource management and development, communication, coordination of work.</td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td>Factors related to unreasonable constraints to owner, funding shortage.</td>
</tr>
<tr>
<td><strong>Design and documentation</strong></td>
<td>Factors related to quality of project, delays related to problems with project design and documentation work.</td>
</tr>
<tr>
<td><strong>Schedule and control</strong></td>
<td>Factors related to planning, scheduling and commitment.</td>
</tr>
<tr>
<td><strong>Scope changes</strong></td>
<td>Factors related to change orders and rework, repair and modification of the initial scope.</td>
</tr>
<tr>
<td><strong>Environment and economy</strong></td>
<td>Factors related to social, environmental and economic effects.</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>Factors related to shortages of materials, fluctuations in the price of materials, lack of assessment in relation to location and local suppliers.</td>
</tr>
<tr>
<td><strong>Labor and equipment</strong></td>
<td>Factors related to performance skills of the workforce, job instructions, constructions, methods, tools and equipment.</td>
</tr>
</tbody>
</table>

After the pre-questionnaire design, a pretest and a pilot survey were designed mainly to check the accuracy of the instrument for data collection. The questionnaire was sent by email for 10 project managers of major construction firms in Mozambique. Hundred percent of the questionnaires returned. The interviewees understood all the formulated questions and suggested that the number of factors should be reduced to make the process easier.
Using statistical analysis, the values of importance also were considered in a severity index and calculated from the percentage sum of evaluation indices important and very important. Then the relevance average equal or greater than 2.5 was applied, resulting in 53 relevant factors to be included in the final questionnaire.

Table 2. Categories (11) and related cost and time overruns factors (53) in construction projects and citations

<table>
<thead>
<tr>
<th>Categories</th>
<th>Factors</th>
<th>Nr (%)</th>
<th>Mir (%)</th>
<th>Mor (%)</th>
<th>R (%)</th>
<th>Vr (%)</th>
<th>Ra (%)</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td>Delay in delivering material to construction sites</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>70</td>
<td>3.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Monopoly of materials by some suppliers and escalation of materials prices</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>60</td>
<td>30</td>
<td>3.2</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Types of construction materials availability at the local market,</td>
<td>0</td>
<td>10</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>2.8</td>
<td>T/C</td>
</tr>
<tr>
<td><strong>Environment and economy</strong></td>
<td>Problem with imported materials</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>60</td>
<td>20</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Using inadequate specification by international consultant</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>20</td>
<td>20</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Transportation delays</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>20</td>
<td>20</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td><strong>Labor and equipment</strong></td>
<td>Low productivity, Poor work execution, Shortage of laborers</td>
<td>0</td>
<td>10</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Mistakes occurrence during the construction stage</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>30</td>
<td>20</td>
<td>2.7</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Equipment unavailability and failure</td>
<td>0</td>
<td>10</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>2.7</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Poor technical performance</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>10</td>
<td>30</td>
<td>2.7</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Construction cost underestimation</td>
<td>0</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>10</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Lack of engineering experience</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>60</td>
<td>10</td>
<td>2.7</td>
<td>T/C</td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td>Methods of payments for completed work</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>90</td>
<td>3.8</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Acceleration costs</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>3.2</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Monthly payment difficulties from agencies</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>2.5</td>
<td>T/C</td>
</tr>
<tr>
<td><strong>Design and documentation</strong></td>
<td>Delayed payments on contracts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>4</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Financial problem, funds and associated auxiliaries not ready</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>70</td>
<td>3.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Cash flow problem/cash problem during construction</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>70</td>
<td>3.6</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Change design</td>
<td>0</td>
<td>0</td>
<td>11.1</td>
<td>44.4</td>
<td>44.4</td>
<td>3.3</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Errors and omission in design, incomplete drawings, inappropriate design</td>
<td>0</td>
<td>11.1</td>
<td>11.1</td>
<td>11.1</td>
<td>66.7</td>
<td>3.3</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Delay in preparation and approval</td>
<td>11.1</td>
<td>0</td>
<td>33.3</td>
<td>33.3</td>
<td>22.2</td>
<td>2.6</td>
<td>T/C</td>
</tr>
<tr>
<td>Category</td>
<td>Issue</td>
<td>Score1</td>
<td>Score2</td>
<td>Score3</td>
<td>Score4</td>
<td>Score5</td>
<td>Score6</td>
<td>T/C</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Management</td>
<td>Poor site management</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>3.0</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Unreasonable estimation and adjustment of the project cost</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>20</td>
<td>50</td>
<td>3.2</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>No practical use of the earned value management system</td>
<td>10</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>50</td>
<td>3.0</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Lack of cost planning/monitoring during pre and post contract stage</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>60</td>
<td>3.3</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Shortage of subcontractors and specialist firms</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>3.0</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Poor communication and coordination between parties</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>2.5</td>
<td>T/C</td>
</tr>
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<td></td>
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<td>0</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>3.2</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Lack of control of time and cost inputs</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>70</td>
<td>3.4</td>
<td>T/C</td>
</tr>
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<td>Organization</td>
<td>Conflict among project’s participants, major disputes and negotiations</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>2.6</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Consequences of decision making</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>60</td>
<td>10</td>
<td>2.8</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Lack of knowledge, experience and bad leadership</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>30</td>
<td>50</td>
<td>3.3</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Problem with subcontractor and relation between different subcontractors schedules in the execution of the project</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>60</td>
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<td>T</td>
</tr>
<tr>
<td>Schedule and control</td>
<td>Change schedule</td>
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<td>10</td>
<td>0</td>
<td>40</td>
<td>50</td>
<td>3.3</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>Lack of commitment</td>
<td>0</td>
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<td>40</td>
<td>10</td>
<td>40</td>
<td>2.8</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>No supervision method and Incapable inspectors</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>2.9</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Stoppages because of work being rejected by consultant</td>
<td>0</td>
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<td>10</td>
<td>60</td>
<td>20</td>
<td>2.9</td>
<td>T/C</td>
</tr>
<tr>
<td></td>
<td>The distance between each project site posed challenges in logistic planning to distribute resources</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>2.7</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>Ineffective planning and scheduling</td>
<td>0</td>
<td>22.2</td>
<td>0</td>
<td>11.1</td>
<td>66.7</td>
<td>3.2</td>
<td>T</td>
</tr>
<tr>
<td>Governmental relations</td>
<td>Bureaucracy in bidding</td>
<td>0</td>
<td>20</td>
<td>30</td>
<td>10</td>
<td>40</td>
<td>2.7</td>
<td>T/C</td>
</tr>
<tr>
<td>Contractual issues</td>
<td>Aggressive competition at tender stage</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>60</td>
<td>30</td>
<td>3.2</td>
<td>T/C</td>
</tr>
</tbody>
</table>
Conflicts between contract documents
Unrealistic contract durations
Contractor selection methods
Lowest bid price
Insufficient time for preparation of contract documents
Underestimation of time for completion of projects
Scope changes
Scope and specifications changes, changes interests, lack of clarity in project scope
Frequency variations, change orders
Rework, repairs and repetition of work
Additional works, extra work, increase in scope of the work

<table>
<thead>
<tr>
<th>Factors and factors</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td></td>
</tr>
<tr>
<td>Delay in delivering material to construction sites</td>
<td>Al-Momani (2000); Aziz (2013b);</td>
</tr>
<tr>
<td>Monopoly of materials by some suppliers and escalation of materials prices</td>
<td>Shane et al. (2009); Rahma et al. (2013b);</td>
</tr>
<tr>
<td>Types of construction materials availability at the local market, problem with imported materials, Shortage and lack in quality of material, inadequate material</td>
<td>Kaming, Peter et al. (1997b); Ogunlana et al. (1996); Koushki; Kartam (2004); Nutakor (2007); Ramanathan et al. (2011).</td>
</tr>
<tr>
<td>Lack of consultant's knowledge of available materials</td>
<td>Hwang et al. (2013); Enshassi et al. (2010a).</td>
</tr>
<tr>
<td>Using inadequate specification by international consultant</td>
<td>Manavazhi; Adhikari (2002);</td>
</tr>
<tr>
<td><strong>Environment and economy</strong></td>
<td></td>
</tr>
<tr>
<td>Transportation delays</td>
<td></td>
</tr>
<tr>
<td><strong>Labor and equipment</strong></td>
<td></td>
</tr>
<tr>
<td>Low productivity, Poor work execution, Shortage of laborers</td>
<td>Semple et al. (1994); Josephson;</td>
</tr>
<tr>
<td>Mistake occurrence during the construction stage</td>
<td>Hammarlund (1999); Muya et al. (2013);</td>
</tr>
<tr>
<td>Equipment unavailability and failure</td>
<td></td>
</tr>
<tr>
<td>Construction cost underestimation</td>
<td></td>
</tr>
<tr>
<td>Poor technical performance, lack of skills</td>
<td>Frimpong et al. (2003)</td>
</tr>
<tr>
<td>Lack of engineering experience</td>
<td></td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td></td>
</tr>
<tr>
<td>Methods of payments for completed work.</td>
<td></td>
</tr>
<tr>
<td>Acceleration costs.</td>
<td></td>
</tr>
<tr>
<td>Delayed payments on contracts.</td>
<td></td>
</tr>
<tr>
<td>Monthly payment difficulties from agencies</td>
<td>Okpala; Aniekwu (1988); Nega (2008).</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Table 3, factors and their respective references of 92 studies analyzed in SLR are presented.
Financial problem, funds and associated auxiliaries not ready.
Cash flow problem/cash problem during constructions.

Design and documentation
- Change design, changes in drawings, design modifications.
- Delay preparation and approval drawings.
- Conflicts in design between nominated subcontractor, structure, civil and architectural drawings.
- Errors and omission in design, incomplete drawings, inappropriate design.
- Improvements to standard drawings during construction stage.

Management
- Poor site management.
- Unreasonable estimation and adjustment of the project cost.
- No practical use of the earned value management system.
- Lack of cost planning/monitoring during pre and post contract stage.
- Shortage of subcontractors and specialist firms.
- Poor communication and coordination between parties.
- Slowness related to the decision-making process.
- Lack of control time and cost inputs.

Organization
- Conflict among project participants, major disputes and negotiations.
- Consequences of decision making.
- Lack of knowledge, experience and bad leadership.
- Problem with subcontractor and relation between different subcontractors schedules in the execution of the project.

Scheduling and controlling
- Change schedule.
- Lack of commitment.
- No supervision method and Incapable inspectors.
- Stoppages because of work being rejected by consultant
- The distance between each project site posed challenges in logistic planning to distribute resources
- Ineffective planning and scheduling.

Governmental relations
- Bureaucracy in bidding.

Contract
- Aggressive competition at tender stage.
- Conflicts between contract documents.
- Contractor selection methods

Assaf; Al-Hejji (2006); Sweis et al. (2008); Zou et al. (2007);
Rahman et al. (2013a); Rahman et al. (2013b); Shehu et al. (2014).

Love et al. (2010); Olawale; Sun (2010);
Assaf et al. (1995); Potty et al. (2011);
Lo et al. (2006); Aziz (2013a).

Iyer; Jha (2005); Le-Hoai et al. (2008);
Long et al. (2004)
Adnan et al. (2009);

Chan; Kumaraswamy (1997); Chan;
Kumaraswamy (1996);
Lee (2008).

Olawale; Sun (2010); Ogunlana;
Olomolaie (1989),
Iyer; Jha (2006); Mahamid (2013);
Sugiarto; Hampson (2003).

Iyer; Jha (2005); Al-Najjar (2008).

Wang; Yuan (2011).
Iyer; Jha (2006);
Sambasivan; Soon (2007); Assaf et al. (1995); Hamzah et al. (2011);
Pourrostam; Ismail (2012)

Doloi et al. (2012).
Soekiman et al. (2011);
Al-Najjar (2008).
Lo et al. (2006); Mañelele; Muya (2008); Kamanga; Steyn (2013);
Odeh; Battaineh (2002); Elinwa; Buba (1993);
Aziz (2013a).

Iyer; Jha (2005).
Enshassi et al. (2010b).
Fallahnejad (2013).

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Underestimation of time for completion of projects Fugar; Agyakwah-Baah, (2010).

**Changes and scope**
Scope and specifications changes, changes interests, lack of clarity in project scope. Kaliba et al. (2009); Dominic; Smith (2014); Oladapo (2007).
Frequency variations, change orders. Koushki et al. (2005); Rosenfeld (2014).
Rework, repairs and repetition of work. Orangi et al. (2011); Additional works, extra work, increase in scope of the work. Makovšek et al. (2012).

**Conclusion**
According to the evidences, avoiding cost and time overruns still poses a huge challenge in construction projects worldwide. This research contributes to better organize evidences of primary research by means of a SLR effort, identifying and categorizing factors that trigger cost and time overruns. Furthermore, this framework further help to identify the most relevant factors accountable in different situations.

This initial data collection effort was mainly intended for validating the data collection instrument. For the sequence of this research, a larger sample will be devised for finding’s generalization purposes.

**Acknowledgements**
Acknowledgements to CAPES for granting the scholarship to one of the authors of this research.

**References**


Deconstruction Project Planning Considering Local Environmental Impacts

Anna Kühlen1, Rebekka Volk2, Julian Stengel3, and Frank Schultmann4

Abstract

At present deconstruction project planning and related research focus mainly on economic issues including costs for equipment, workers and material disposal. Nevertheless, deconstruction of buildings can have major impacts on the local environment in terms of noise, dust and vibrations. Usually these environmental concerns are not included in deconstruction planning. But they can be harmful for humans, animals and the surrounding built environment. Analyses of different deconstruction techniques show major differences in noise, dust and vibrations. To use this potential to mitigate local environmental impacts, principals and deconstruction managers have to perform environmental conscious detailed deconstruction planning. In support of balancing these environmental issues with economic and technical aspects, a multi-criteria decision approach can help in the planning phase. In this paper a combination of the multi-criteria decision analysis methods Analytic Hierarchy Process (AHP) and Multi-Attribute Value Theory (MAVT) is embedded in a system for the planning of deconstruction projects based on deconstruction techniques applied to single building components. The structure of this system is described in detail, encompassing the procedure of modelling the overall planning and decision making process as well as the application of the decision making logic. Expert knowledge and experimental noise, dust and vibration measurements related to different deconstruction techniques form the system database. The system is exemplarily applied to deconstruction planning of a small one-level building. Finally, its possible future practical implementation is addressed.

Keywords: Deconstruction, environmental impacts, multi-criteria, project planning, sustainability.

Introduction

Especially in cities, where space is limited and demographic and economic changes ask for adaptions in the spatial distribution of buildings, deconstruction of buildings becomes increasingly necessary (Shin et al. 2005, Couto and Couto 2007). Deconstruction is the last building life cycle stage, also often called ‘demolition’5 (ISO 22263:2008-01, Thomsen et

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4 Professor, Institute for Industrial Production (IIP), Karlsruhe Institute of Technology, Hertzstr. 16, 76187 Karlsruhe, Germany, Tel: +49-721-60844469, Fax: +49-721-60844682, E-mail: frank.schultmann@kit.edu
5 In this research the term deconstruction is chosen. The terms deconstruction and demolition are used almost synonymously nowadays. Both terms describe the removal of a building/structure. In deconstruction ecologic aspects, such as the recycling of building materials, are explicitly considered. Today regulations
Deconstruction activities are potentially the source of high impacts on the local environment, mainly noise, dust and vibrations (DIN-Standard 2000, Lippok and Korth 2007). These impacts can cause local health hazards (Haltenorth et al. 2007) and can harm the surrounding built environment. The extent of deconstruction related environmental impacts in the form of noise, dust and vibrations highly depends on and varies with applied deconstruction technologies (DIN-Standard 2000, Chen and Li 2006), i.e. a combination of equipment and deconstruction methods, as well as on building characteristics, such as building materials (Kühlen et al. 2014). The building characteristics are fixed by the exiting building. Hence, in planning of deconstruction projects decision on the applied single deconstruction techniques should be included to manage and mitigate local environmental impacts. This approach to manage and mitigate impacts on the local environment in deconstruction project planning becomes recently important. In the future it might become a key aspect of project quality in the course of sustainable development, encompassing an ecologic and social dimension besides the economic dimension.

As building deconstruction has project character, operational project planning tools and methods are applicable for detailed planning on activity-level. Nevertheless, current tools for operational deconstruction project planning manly focus on economic issues and do not explicitly consider local environmental impacts (Haltenorth et al. 2007). Consequently, the integration of local environmental impacts in operational deconstruction project planning and decision making is addressed in this research. First, approaches of operational deconstruction project planning and decision making in recent research are reviewed. Then an approach for multi-criteria decision support is presented, which takes account on environmental impacts in the selection of appropriate deconstruction techniques for the planning of single deconstruction activities.

Recent Research Approaches of Deconstruction Project Planning

In general the deconstruction of buildings is little considered in science and research (Thomsen et al. 2011, Jain et al. 2008). A comprehensive overview of different qualitative and quantitative approaches of current research in the area of deconstruction is given in Xanthopoulos et al. 2012, including deconstruction project planning, besides construction and demolition waste management. The emphasis of this research is on project planning and decision making methods. Hence, studies mainly focusing on the management of deconstruction materials after the actual deconstruction process on site or on ‘design for deconstruction’ at the early design stage of new buildings are excluded in the review of recent research approaches. Only very few approaches allow detailed project planning of the single deconstruction activities using case study-based, quantitative, activity-related data about duration times, costs and resources (Schultmann and Rentz 2002, Seemann 2003, Schultmann 2003). The focus is on economic issues and impacts on the local environment in terms of noise, dust and vibrations are not considered here. Singly on strategic level environmental impacts are occasionally considered in the context of decision making (Kourmpanis et al. 2008a, Kourmpanis et al. 2008b, Chen und Li 2006, Anumba et al. 2003). With the help of methods of multi-criteria decision analysis (MCDA) decisions on the overall deconstruction project are made considering different-scaled, qualitative and quantitative economic and environmental aspects. Decisions are not made on single activities of the overall project and no detailed deconstruction-activity-related data of impacts on the local environment is available.

force the consideration of these ecologic aspects in demolition as well. Hence, the differentiation between these terms is limited.
The review shows that up to now there are very few operational deconstruction planning approaches. These research approaches on operational level do not consider environmental impacts. Furthermore, MCDA methods have proven to be appropriate to make decisions considering diverse different-scaled economic and environmental aspects. Hence, an approach for operational deconstruction planning including multi-criteria decision making on single activities and considering local environmental impacts is developed. The planning approach requires deconstruction-activity-related data of impacts on the local environment. As related data in literature is rarely, data is generated from experimental noise, dust and vibration measurements related to different deconstruction techniques as well as expert knowledge.

**Multi-Criteria Decision Support System for Deconstruction Planning**

In this section a system for the consideration of local environmental impacts in operational deconstruction planning is developed. Multi-criteria decision support is provided for single activities of the deconstruction project plan. The system can support principals and deconstruction managers in performing environmental conscious detailed deconstruction planning and decision making. In the following, relevant definitions related to deconstruction planning are outlined before the approach is described in detail.

**Definitions Related to Deconstruction Planning**

A deconstruction activity $j$ is a unit of the overall deconstruction process based on a single component of the building shell. The activity duration is composed of three segments. The first segment $d_{j,f,b}$ is the duration to deconstruct the component itself with the deconstruction technique $f$. The time $d_{j,f,sep}$ required to separate and $d_{j,f,cr}$ to crush the material of the deconstruction unit to reach a high material quality for recycling are the second and third segment. $d_{j,f,b}$ depends on the material-related performance value $p_{f,b}$ ($h/m^3$) of a deconstruction technique $f$ deducted from technique-specific and material-related performance values in literature (Weimann et al. 2013, Lippok und Korth 2007, Seemann 2003, Rentz et al. 2002, Willkomm 1990) and the material $b_j$ of the building shell component as well as the material volume $m_{j,b}$ ($m^3$) of this component the activity is related to.

$$d_{j,f,b} = p_{f,b} * m_{j,b}$$

$d_{j,f,b,sep}$ ($d_{j,f,b,cr}$ respectively) depends on of the material-related performance value $p_{sep,b_j}$ ($p_{cr,b_j}$) ($h/m^3$) to separate (crush) the building component material $b_j$ (cf. Lippok und Korth 2007), the component material volume $m_{j,b}$ ($m^3$) and the classification number $g_{f,b_j}$ ($g_{cr,b_j}$), which is based on practical experiences and expert knowledge and expresses the degree of pre-separation (pre-crushing) of a deconstruction technique $f$ applied to material $b_j$.

$$d_{j,f,b,sep} = p_{sep,b_j} * g_{f,b_j} * m_{j} \quad (d_{j,f,b,cr} = p_{cr,b_j} * g_{cr,b_j} * m_{j})$$

Whereas, the material and the volume are fixed characteristics of the existing building, the technique can be chosen from different alternatives due its material-related suitability (DIN-Standard 2000, Lippok and Korth 2007). A technique is a combination of the deconstruction method, such as gripping, and equipment. Table 1 lists an extract of the relevant alternative deconstruction techniques listed in DIN-Standard 2000.
Table 1. Deconstruction techniques

<table>
<thead>
<tr>
<th>Deconstruction technique</th>
<th>Equipment</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Abbreviation</td>
<td>Support frame</td>
</tr>
<tr>
<td>Gripping with</td>
<td>Grip</td>
<td>Hydraulic excavator</td>
</tr>
<tr>
<td>hydraulic excavator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortising with</td>
<td>Mort</td>
<td>Hydraulic excavator</td>
</tr>
<tr>
<td>hydraulic excavator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press-cutting with</td>
<td>Press-Cut</td>
<td>Hydraulic excavator</td>
</tr>
<tr>
<td>hydraulic excavator</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Especially deconstruction of the building shell can generate environmental impacts in the form of noise, dust and vibrations (DIN-Standard 2000). Hence, the shell of the existing building is defined as deconstruction object. The deconstruction object is modelled based on single vertical and horizontal building shell components (table 2). Appropriate deconstruction techniques are identified depending on the material, thickness and the height above ground of these single components. Furthermore, the available space on site influences the suitability of the techniques (DIN-Standard 2000, Lippok and Korth 2007).

Table 2. Selected building shell components constituting the deconstruction object

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Vertical components</th>
<th>Horizontal components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name</td>
<td>Material (b)</td>
</tr>
<tr>
<td>Steel frame construction</td>
<td>Column</td>
<td>Steel</td>
</tr>
<tr>
<td>Masonry construction with reinforced</td>
<td>Wall</td>
<td>Masonry:</td>
</tr>
<tr>
<td>concrete slab</td>
<td></td>
<td>• Brick</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Concrete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Natural stone</td>
</tr>
<tr>
<td>Timber frame construction</td>
<td>Column</td>
<td>Timber</td>
</tr>
</tbody>
</table>

The deconstruction sequence is performed reverse of construction, top-down and building level-wise, according to an actual popular deconstruction approach (Schultmann 1998, Lippok and Korth 2007). Furthermore, it is assumed that only one activity is performed at a given time.

**An Approach for Decision Making in Operational Deconstruction Planning**

With the help of the following in detail described approach of decision making in operational deconstruction planning, it is aimed to select one technically, economically and environmentally appropriate deconstruction technique for each activity of the deconstruction process of the building shell. The approach can be divided into two parts

---

6 Combination of equipment and method.
First, the overall planning and decision making process is modelled, including the single deconstruction activities. Within this context the technically feasible deconstruction alternatives of each activity are determined and their economic and ecologic characteristics are calculated. Secondly, the decision making logic is applied, which is a combination of the multi-criteria decision analysis methods Analytic Hierarchy Process (AHP) and Multi-Attribute Value Theory (MAVT). Here decision is made on the appropriate deconstruction technique of each single activity based on the calculated economic and ecologic characteristics.

**Mapping of the planning and decision process**

1. Specification of the deconstruction object - materials, masses and positions of the building components
2. Generation of the deconstruction process - number and order of the deconstruction process activities based on the building components
3. Identification of technically feasible deconstruction techniques per activity based on:
   - Component type
   - Component material
   - Material thickness
   - Deconstruction height above ground
   - Available space on site
4. Calculation of economic and ecologic characteristics of the technically feasible deconstruction alternatives per activity based on:
   - Material-related performance values of deconstruction techniques
   - Hourly cost rates
   - Emission classification numbers
   - Specific emission level values

**Logic of decision making**

1. Calculation of utility values of deconstruction activity alternatives based on normalised characteristics
2. Calculation of the overall weighted utility value of deconstruction activity alternatives
3. Selection of an appropriate deconstruction technique for each activity

**Figure 1. Process mapping and decision logic**

**Mapping of the planning and decision process**

Step 1: the deconstruction object is specified building level- and component-specific, including the materials $b_i$ and volumes $m_{i,b}$ of single components of the building shell.

Step 2: one activity $j$ of the deconstruction process is assigned to each component and the deconstruction sequence is generated as predefined top-down and level-wise with only one activity at a time.

Step 3: for each activity $j$ the technically feasible deconstruction techniques $f$ are identified, which have to be evaluated by the economic and ecologic criterion $k$ and respective sub-criteria $i$ (economic: costs; ecologic: noise, dust, vibrations) for decision making.

Step 4: the economic and ecologic characteristics of each technically feasible deconstruction alternative per activity are calculated. The economic characteristic $S_{j,f,b,econ}$ of activity $j$ performed with the alternative deconstruction technique $f$ (including related tasks of material separation and crushing) is defined as the sum of variable/duration-dependent costs to hire equipment (hourly rate of equipment costs $c_{f,eq,sep}$, $c_{f,eq,cr}$, $c_{f,eq}$).
BGL 2007)) and costs for workers\(^7\) (hourly rate of labor costs \(c_{\text{labor}}\) and amount \(n_f\) of required workers dependent on the technique (Lippok and Korth 2007)). For material separation and crushing only one worker is required at a time.

\[
s_{j,f,b,\text{econ}} = d_{j,f,b} \cdot (c_{\text{equip}} + c_{\text{labor}} \cdot n_f) + d_{j,f,b,\text{sep}} \cdot (c_{\text{sep,equip}} + c_{\text{labor}}) + d_{j,f,b,\text{cr}} \cdot (c_{\text{cr,equip}} + c_{\text{labor}})
\]

Furthermore three ecologic characteristics are defined with respect to the identified major deconstruction-related impacts on the local environment, namely emissions of noise, dust and vibrations. The characteristic of noise emissions \(s_{j,f,b,\text{noise}}\) of activity \(j\) performed with the alternative deconstruction technique \(f\) is a product of the activity-related durations \(d_{j,f,b}\), \(d_{j,f,b,\text{sep}}\) and \(d_{j,f,b,\text{cr}}\) and the specific, material-related values of noise levels \(l_{f,b,\text{noise}}\) of the applied deconstruction technique \(f\) and \(l_{\text{sep,b,noise}}\) and \(l_{\text{cr,b,noise}}\) of related tasks of separating and crushing material to reach a high material quality for recycling.

\[
s_{j,f,b,\text{noise}} = d_{j,f,b} \cdot l_{f,b,\text{noise}} + d_{j,f,b,\text{sep}} \cdot l_{\text{sep,b,noise}} + d_{j,f,b,\text{cr}} \cdot l_{\text{cr,b,noise}}
\]

The characteristics of dust and vibration emissions \((s_{j,f,b,\text{dust}}\) and \(s_{j,f,b,\text{vib}}\)) are calculated likewise with specific, material-related values of dust levels \(l_{f,b,\text{dust}}\), \(l_{\text{sep,b,dust}}\) and \(l_{\text{cr,b,dust}}\) respective vibration levels \(l_{f,b,\text{vib}}\), \(l_{\text{sep,b,vib}}\) and \(l_{\text{cr,b,vib}}\) of the applied deconstruction technique as well as of related tasks of material separation and crushing. To date neither are specific, material-related values of emission levels existing nor is related required data to generate these values sufficiently available in literature. Hence, the specific, material-related emission levels of noise, dust and vibrations are deducted from semi-quantitative, nine-stage classification numbers according to the human sense and legal critical limits (0: no emissions/not annoying, 1: little emission/little annoying, 2: medium emissions/medium annoying, 3: high emissions/annoying, 4: very high emissions/painful, and respective midpoints: e.g. 1.5) gained from prior experiences, expert knowledge and experimental noise, dust and vibration measurements. Figure 2 shows the classification numbers of noise, dust and vibration emissions of the extracted alternative deconstruction techniques (cf. table 1) exemplary applied to the material brick.

![Classification Numbers](image)

Figure 2. Emission classification numbers of deconstruction techniques applied on the building material brick as an example

According to the human sense and legal critical limits the classification numbers represent intervals of emission levels, which differ in interval size. This has to be considered in determination of the specific values of emission levels. Hence, in this determination of specific emission level values (e.g. \(l_{f,b,\text{noise}}\)) the differences between the

---

\(^7\) Costs for one worker are the calculated average wage of a skilled construction worker and an operator on a German construction site.
mean value of each interval and the emission level assigned to the classification number “0” is calculated. For instance, noise emissions less than 70 dB(A) are classified as “0”. Emissions between 70 and 85 dB(A) are assigned to “1”. This interval has a mean value of 77.5 dB(A) with a difference of 7.5 dB(A) to 70 dB(A) (“0”). A noise level difference ($\Delta L$) of 7.5 dB(A) corresponds to an increase of the experienced noise by humans of 0.7.\(^8\) Hence, $l_{f_b, \text{noise}}$ is set to 0.7.

Logic of decision making

Decision making on the appropriate deconstruction technique of each single activity on the basis of the calculated economic and ecologic characteristics with the help of AHP and MAVT encompasses three steps described in the following.

Step 1: utility values of the deconstruction alternatives per activity are calculated. Therefore, utility values $v_{i,j,f}$ with respect to each economic and ecologic sub-criterion $i$ are calculated for each applied alternative deconstruction technique $f$ (enclosing related tasks of material separation and crushing) of activity $j$. Within this context the economic and ecologic characteristics of each alternative have to be transferred to a common scale by normalization to enable the comparison of alternatives of an activity based on these different-scaled characteristics. Thus, for each characteristic, the maximum ($\max s_{j,f_b,\text{econ/ecol}}$) and minimum ($\min s_{j,f_b,\text{econ/ecol}}$) related to an activity is identified. The maximum characteristic is set equal to 0 and the minimum characteristic equal to 1. The other normalized characteristics of each activity and each attribute are calculated based on a linear scale between the identified maximum and minimum. Following section describes this proceeding using the exemplary application of the deconstruction planning system.

Step 2: the overall weighted values of the technique alternative $f$ of each deconstruction activity $j$ are calculated by the additive aggregation of the utility values ($v_{i,j,f}$) of this alternative with respect to each economic and ecologic sub-criterion $i$ multiplied by the weight of this sub-criterion ($w_{i,k}$).

$$V_{j,f} = \sum w_{i,k} * v_{i,j,f}$$

The weight $w_{i,k}$ represents the importance of the economic and ecologic sub-criteria $i$, which is the preferences of the decision maker depending on the neighborhood characteristics of the individual deconstruction site. For the calculation of weights AHP (Saaty 1980) is applied. A hierarchy of criteria and sub-criteria is built as shown in table 3. One weight $w_{i,k}$ is the product of the weighting factor $w_i$ of one sub-criterion $i$ and the weighting factor $w_k$ of its higher criterion $k$.

$$w_{i,k} = w_i * w_k$$, with $\sum w_{i,k} = 1$, $w_{i,k} >= 0$ for all $i$

The sensitivity of the deconstruction site neighborhood influences the weighting factor height of each criterion and sub-criterion. For instance, table 3 shows a possible weighting vector for a residential neighborhood, which is very sensitive to noise and sensitive to dust and the economic aspects are less important, but should be considered as well.

Step 3: the appropriate deconstruction technique for each activity is selected by selecting the alternative with the highest overall weighted utility value.

\(^8\) Calculation of the increase in in experienced noise: $1 - 2^{\frac{\Delta L}{10}}$ (cf. Sengpielaudio 2014).
Table 3. Assumed exemplary weights for a deconstruction project in a residential neighborhood

<table>
<thead>
<tr>
<th>Criteria (k)</th>
<th>Weighting factors of the criteria (w_k)</th>
<th>Sub-criteria (i)</th>
<th>Weighting factors of the sub-criteria (w_i)</th>
<th>Weight (w_{i,k})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>0.2</td>
<td>Costs</td>
<td>1</td>
<td>0.20</td>
</tr>
<tr>
<td>Ecologic</td>
<td>0.8</td>
<td>Noise emissions</td>
<td>0.7</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dust emissions</td>
<td>0.3</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vibration emissions</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Exemplary application of the deconstruction planning system

The model is applied using the example of the deconstruction of a small one level building, consisting of four brick walls (volume of each wall: 15 m³) and one reinforced concrete slab (10 m³). This building specification is the first step of mapping the planning and decision process. In the second step the deconstructed sequence is defined top-down, starting with the slab followed by the walls. In the example the walls can be deconstructed subsequently, each wall separately or two walls at a time as one activity. Both options are analyzed as alternative deconstruction activities in the following. Alternative deconstruction techniques are those listed in table 1. The technical feasibility of the techniques due to component type and material type and thickness, due to the deconstruction height above ground and available space on site is given. Table 4 shows the result of the third and fourth step, the alternative activities j, including the technically feasible alternative deconstruction techniques applied to the components (reinforced concrete slab, brick walls) as well as respective economic and ecologic characteristics.

After the planning and decision process is mapped the decision making logic is applied. Here in the first step, the utility values v_{i,j,f} with respect to each economic and ecologic sub-criterion i for each alternative deconstruction technique f of activity j are calculated based on the activity-related characteristics in table 4. Therefore the characteristics are normalized. For instance, the utility value of press-cutting of two walls at once due to the sub-criterion noise (v_{noise-emissions,press-cut-2-brick-walls,press-cut}) result in 0.95 ((50.4-36.0)/(50.4-35.2)=0.95).
Table 4. Characteristics of the example alternative deconstruction activities\textsuperscript{9}

<table>
<thead>
<tr>
<th>Alternative activities j</th>
<th>Activity-related characteristics</th>
<th>Economic</th>
<th>Ecologic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Costs (€)</td>
<td>Noise (emissions per activity)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$s_{j,f,bj,econ}$</td>
<td>$s_{j,f,bj,noise}$</td>
</tr>
<tr>
<td>Building component</td>
<td>Mort slab</td>
<td>558.8</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>Press-Cut slab</td>
<td>412.5</td>
<td>17.1</td>
</tr>
<tr>
<td>10 m³ reinforced concrete slab</td>
<td>Each wall separate\textsuperscript{11}</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grip 1 wall</td>
<td>1653.0</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td>Mort 1 wall</td>
<td>1737.0</td>
<td>50.4</td>
</tr>
<tr>
<td></td>
<td>Press-Cut 1 wall</td>
<td>1578.0</td>
<td>35.2</td>
</tr>
<tr>
<td>4x15 m³ brick walls</td>
<td>Two walls at a time\textsuperscript{12}</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grip 2 walls</td>
<td>1653.0</td>
<td>45.8</td>
</tr>
<tr>
<td></td>
<td>Mort 2 walls</td>
<td>1737.0</td>
<td>46.9</td>
</tr>
<tr>
<td></td>
<td>Press-Cut 2 walls</td>
<td>1578.0</td>
<td>36.0</td>
</tr>
</tbody>
</table>

In the second step, the overall weighted utility values of the technique alternative $f$ of each deconstruction activity $j$ are calculated. The importance for decision making of the activity performance related to the economic and ecologic criterion ($w_k$) and respective sub-criteria ($w_i$) is depending on the neighborhood characteristics of the individual deconstruction site. With subject to the neighborhood different deconstruction activity alternatives might be more or less suitable. AHP (Saaty 1980) is applied to display the preferences of the decision maker by weights ($w_{i,k}$). For instance, if the neighborhood around the deconstruction site has buildings or facilities in buildings, which are highly sensitive to vibrations and minimal vibrations is the single criterion, gripping of each single wall successively is the most appropriate technique with an overall utility value of 1 (figure 3). However, if the deconstruction project takes place in a residential neighborhood and the exemplary weights of table 3 represent the decision maker preferences, press-cutting of two walls at once has the highest overall utility value (figure 3). To deconstruct the slab, press-cutting suits better than mortising in both neighborhood scenarios.

\textsuperscript{9} Characteristics are calculated by the system with the above described approach. System variables, such as material-related performance values (e.g. $p_{f,bj}$), duration-dependent costs (e.g. $c_{f,\text{equip}}$) and specific, material-related values of emission levels (e.g. $l_{f,bj,\text{noise}}$) are based on literature data, experimental noise, dust and vibration measurements related to different deconstruction techniques as well as expert knowledge.

\textsuperscript{10} Including related tasks of material separation and crushing to reach a high material quality for recycling.

\textsuperscript{11} 1 machine, 2 workers

\textsuperscript{12} 2 machines, 4 workers
In the third step, the system selects the alternative with the highest overall utility value for each deconstruction activity/the deconstruction of each building component (in the scenario of a residential neighborhood: press-cutting of the reinforced concrete slab and press-cutting of two brick walls at once).

These selected activities can be included into a project schedule. The resulting schedule of the deconstruction project as a Gantt chart and the related distribution of the emission levels over the project time are illustrated in figure 4.

Figure 3. Overall utility values of the example alternative activities, when performed in different neighborhoods

Figure 4. Deconstruction project Gantt chart and distribution of emission levels (scheduled in Microsoft Project)
Conclusions

To mitigate local environmental impacts in terms of noise, dust and vibrations caused by deconstruction projects, which can be harmful for humans, animals and the surrounding built environment, principals and deconstruction managers have to perform environmental conscious detailed deconstruction planning. A multi-criteria decision support system for deconstruction planning is provided, which is based on expert knowledge and data from literature and experimental noise, dust and vibration measurements related to different deconstruction techniques. The system supports decision makers in selecting an appropriate technique while balancing economic and environmental issues based on technical feasibility and by considering the neighborhood of the deconstruction site. The system allows detailed/hourly analysis of alternative deconstruction techniques due to the single, independent and partly nonlinear local emissions noise, dust and vibrations. The system model was exemplarily applied to show the unlike environmental impacts caused by alternative activities of the overall deconstruction process and the importance to consider neighborhood characteristics and their differing sensitivities.

As building deconstruction becomes increasingly necessary and project planners and decision makers have to be aware of related possible impacts on the local environment, the practical implementation of the decision support into deconstruction planning is aimed in future. For this purpose the system has to be connected with current available instruments and software for deconstruction project planning and scheduling.

References


Construction Frameworks in the UK Public Sector: A Procurement Performance Model for Driving Improvement of Project Outcomes

Terence Y M Lam¹ and Keith S Gale²

Abstract

Collaborative construction frameworks have been developed in the UK to create longer term relationships between clients and suppliers in order to improve project outcomes. Research undertaken into highways maintenance set within a major county council has confirmed that such collaborative procurement methods can improve time, cost and quality of construction projects. Building upon this and examining the same single case, this research aims to develop a performance model through identification of performance drivers in the whole project delivery process including pre and post contract phases. A priori performance model based on operational and sociological constructs was proposed and then checked by a pilot study. Factor analysis and central tendency statistics from the questionnaires as well as content analysis from the interview transcripts were conducted. It was confirmed that long term relationships, financial and non-financial incentives and stronger communication are the sociological behaviour factors driving performance. The interviews also established that key performance indicators (KPIs) can be used as an operational measure to improve performance. With the posteriori performance model, client project managers can effectively collaboratively manage contractor performance through procurement measures (use of longer term and KPIs for the contract) so that expected project outcomes can be achieved.

Keywords: Public sector, collaborative frameworks, performance drivers.

Introduction

The construction industry is a significant contributor to the economy of the United Kingdom. In 2010, the Gross Value Added (GVA) of the construction industry was estimated to be £110 billion, representing 6.8% of the total GVA of the UK (ONS, 2010). Of the total estimated value of the industry, £41 billion is financed by the public sector (accounting for 37% of all construction expenditure). The importance of the construction industry and its influence upon the overall economy of the UK is specifically mentioned within the Government Construction Strategy (Cabinet Office, 2011).

The need to improve performance is reinforced by providing a holistic vision of the industry through the Industrial Strategy: government and industry in partnership, Construction 2025 (BIS, 2013) by encouraging development and growth of UK construction within overseas markets whilst providing challenging targets for domestic consumption. Such performance improvement suggested a 33% reduction in the initial cost of construction and the whole life cost of built assets based on 2009/2010 benchmarks, supported by a 50% reduction in overall time, from inception to completion, for new build and refurbishment assets based upon the UK industry performance in 2013. Achievement of such targets requires a significant change from traditional procurement methods and in the way how construction projects are managed. The Industrial Strategy report found ‘clear evidence of the fragmentation of the industry and a real demonstration of the challenge of building integrated supply chains’ (BIS, 2013, p.56). The report asserted ‘plentiful evidence of effective use of frameworks’, although such evidence is not specifically cited. Therein lies a dichotomy of suggested approaches – fragmentation of a supply chain encompassed through a structured engagement framework.

Public sector frameworks were developed under EU Directive 2004/18/EC of the European Parliament for coordination of procedures for the award of public works contracts, public supply contracts and public service contracts. A prime objective of a framework is to provide stronger relationships through longer term arrangements using engagement with fewer suppliers (Construction

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Excellence, 2009), providing alignment with initiatives suggested by Latham (1994) and Egan (1998). A framework agreement provides an overarching ‘umbrella’ contract where projects separated into individual ‘work packages’ procured at a call-off stage throughout the period of agreement, which is currently set to a maximum of 4 years. The framework agreement is written to allow for a wide range of project characteristics and values as detailed specifications of individual projects are often not well defined at the outset date of the agreement. The majority of framework arrangements are between a client (or conjoined clients) and multiple suppliers.

Research into project management of performance outcomes of collaborative and partnering long term contracts is limited in terms of what and how quality, time and cost benefits can be achieved (Meng, 2012). A recent paper established, through a localised regional UK public sector based case study, that significant improvements are possible through the use of framework agreements (Lam and Gale, 2014). These include quality (lower defects upon completion and higher health and safety standards during construction), time (substantial number of projects finished on time) and cost (significant number of interim payments agreed within 5% of value and without excessive claims). Other research also suggests that the influence of chosen procurement and engagement method together with conditions of contract may have impact on project outcomes (Forgues and Koskerla, 2008; Koskinen, 2009).

This research aims to build upon such published studies to develop a performance model specifically related to construction framework agreements through identification of performance drivers in the whole project delivery process including pre and post contract phases. This enables the client project managers to effectively collaboratively manage contractor performance within the upper chain.

Sociological Performance Drivers

The link between organisational culture and productivity/performance is well established, being supported by a substantial number of studies from the field of socio-psychological investigation into teams and groups. Recent research places a progressive stratification of interaction between group culture, group behaviour and group performance. Tellis et al., (2009) concluded that culture drives behaviour for groups at a cognitive level using standard procedures following Zhang and Liu’s (2006) ‘culture – effectiveness’ model where culture provides motivated behaviour in order to increase performance with Chinese contractors. In light of such studies, Walker (2011) warned ‘research on the impact of culture on organisational performance is mixed’ and although cited examples from a range across the cultural spectrum, no definitive conclusions were reached. Nonetheless, a review of the published literature places behaviours as a driver for group performance and in reflection of this organisational behaviour forms the sociological drivers for performance.

A literature review of collaborative centric performance based groups identified characteristics that contributed positive results in outcomes with construction projects (Katzenbach, 2000). Ten significant characteristics identified by Katzenbach were reaffirmed by Akdemir, et al., (2010) who ranked 26 characteristics into the most effective ten behaviours. The ten organisational behaviours are collated in Table 1 and supported by other discrete research references.

Traditional behaviour theory directly linked performance to financial payment (Taylor, 1914) where human production is proportional against pecuniary gain. This simplified view was added by development of behaviour theories following investigations into human relations in the workplace by Henry Dennison and Elton Mayo. Mayo (1949) found that individuals desire to stand well amongst the others in the group. Dennison (1925) proposed that removing the fear of unpredictable employment allowed the utilisation of affirmative forces of pride (satisfaction), team spirit and loyalty (relationships), and emulation (group motivation and incentives) (Dennison, 1925). This was reinforced by further studies (Dennison, 1931) where influence upon output performance required an intrinsic mix of non-financial incentives, satisfaction, motivation and economic incentive. Proviso to Dennison’s conclusions was the essential presence of a long term strong relationship between group members. Within a construction framework group, this refers to the ‘long term working relationships’ between clients and suppliers. Construction Excellence (2009) explains that longer term relationships allow greater understanding between all participants, thus resulting in higher level of commitment to achieve mutual goals and continuous improvement from engagement of best practice. This means that clients can achieve better project outcomes and suppliers can maximise their profits and have a higher level of satisfaction.

Project outcomes from construction frameworks can therefore be positively associated with the ten organisational behaviours, which can be developed stronger if a longer term is set up for the contract at the pre contract phase. These organisational behaviours are displayed as the sociological construct within the performance model.
Table 1. Ten Most Significant Group Behaviours

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Emphasis</th>
<th>Literature Source Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>Improved communication enables groups to raise performance level</td>
<td>Greenberg and Baron (2003)</td>
</tr>
<tr>
<td>Trust and confidence</td>
<td>Distribution of fairness with group participants</td>
<td>Culyer (2001)</td>
</tr>
<tr>
<td>Empowerment</td>
<td>Decision making process delegated to individuals</td>
<td>Green (2002)</td>
</tr>
<tr>
<td>Effective incentive system</td>
<td>Non-financial and financial reward methods</td>
<td>Eriksen (2001)</td>
</tr>
<tr>
<td>Diversity</td>
<td>Mixture of group participants and geographic locations</td>
<td>Milakovich and Gordon (2009)</td>
</tr>
<tr>
<td>Motivation</td>
<td>Practice of providing purpose and direction to behaviour</td>
<td>Greenberg and Baron (2003)</td>
</tr>
<tr>
<td>Knowledge transfer</td>
<td>Tacit knowledge shared between group participants</td>
<td>Keskin (2005)</td>
</tr>
<tr>
<td>Relationships</td>
<td>Breaking down barriers and focussing upon group rather than individual outcomes</td>
<td>McCann (2004)</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Achievement of group goal setting</td>
<td>Fischman, et al. (2004)</td>
</tr>
<tr>
<td>Decision making</td>
<td>Critical thinking and conflict resolution skills required for ethical decision making</td>
<td>Fischman, et al. (2004)</td>
</tr>
</tbody>
</table>

Operational Performance Drivers

Within the construction industry additional monetary payments to encourage increased output set against out-turn productivity targets has historically been a popular method of incentive. Bresnen and Marshall (2000) proposed that financial incentives coupled with advanced contracting methods could improve both commitment and motivation within projects. Within the fields of generalised non-specific project management a wide variety of measures are used to describe outcomes of a project and input characteristics that affect outcomes (Banker et al., 1984). Traditionally research into success with construction projects has focussed upon three outcomes – cost, quality and time (Belassi and Tukel, 1996). As projects have become more complex and clients demands more sophisticated, additional outcomes that add value such as long term sustainable development, environmental impact and reliability with use are placed to the fore (Chan and Chan, 2004).

In reflection of the research into critical success factors a constructive approach is taken from measures undertaken to identify a clients’ perception of success. Kerzner (2001) reconfirmed previous studies of a clients ‘iron triangle’ of cost, quality and time as critical success factors of project success. The case study used for this research used additional critical success factors’ reflecting the connection between a safe work environment and productivity (health, safety and welfare provisions) but essence of the performance model is focussed toward the holistic operation rather than individual factors. To this end the interaction of performance outcomes and reward systems is considered the driver of good performance. This view is supported through studies conducted by Tang et al., (2006) which recognised the correlation between direct collaborative tools and collaborative project success. Such operational models are also identified through cooperative procurement in Sweden (Pesamaa et al., 2009) where performance is rewarded through incentivised mechanisms.

In order to test operational metrics and their effectiveness, five critical success factors were used within the case study context. The framework suppliers (contractors) received marks on quarterly basis according to the criteria and measures identified in Table 2.

The reward system placed within the operational construct of the performance model consisted of a graded composite aggregation from results. For each project included within the case study a Project Success Index was assigned by use of the following formula:

\[
\text{Project success index} = \sum_{i=\text{CSF1}}^{\text{CSF4}} \frac{(AS - MV) \times We}{(SV - MV)}
\]

Where:
Project success index = measure of success of a project = sum of the indices of individual critical factors (CSF1A, CSF1B, CSF2, CSF3 and CSF3)

AS = Actual Score of the critical success factor being measured in accordance with the measurement definitions

MV = Minimum percentage value of the critical success factor

SV = Stretching percentage value of the critical success factor

We = Weighting of the critical success factor

Table 2. Operational Metric Critical Success Factors

<table>
<thead>
<tr>
<th>Critical Success Factor</th>
<th>Element</th>
<th>Measure</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSF1A</td>
<td>Starting on time</td>
<td>Time scale</td>
<td>Proportional - 100 for starting on the contractual date and a sliding scale where started late</td>
</tr>
<tr>
<td>CSF1B</td>
<td>Finishing on time</td>
<td>Time scale</td>
<td>Proportional - 100 for finishing on the contractual date and a sliding scale where finished late</td>
</tr>
<tr>
<td>CSF2</td>
<td>Accuracy of payments</td>
<td>Cost</td>
<td>Proportional - 100 for a payment submitted within 5% of certified value and then on a sliding scale where payment values are different</td>
</tr>
<tr>
<td>CSF3</td>
<td>Right first time</td>
<td>Quality</td>
<td>Projects completed without defects – binary result – yes 100, no 0</td>
</tr>
<tr>
<td>CSF4</td>
<td>Health, safety and welfare inspections</td>
<td>Quality</td>
<td>Proportional – percentage of inspections meeting minimum criteria</td>
</tr>
</tbody>
</table>

Dependant upon aggregated values, suppliers are placed into one of three zones – red, amber or green. The zone positions are used for tender assessment purposes for a succeeding three month period where a green zone supplier will gain a 10% advantage in tender assessment, an amber zone supplier receives neutral tender assessment and a red zone supplier has a 10% disadvantage in tender assessment. These results offer a financial advantage or disadvantage for each supplier according to objective and measured past performance that may be used in the selection of suppliers for future projects.

Operation of such incentive based financial systems used to facilitate project success follow propositions made by Bayliss et al., (2004) and Tang et al., (2006). The metrics are displayed as an operational construct within the performance model. The project success index and the critical success factors should be built into the contract as key performance indicators (KPIs) to improve project outcomes.

Proposed Model and Research Methods

Use of cyclic improvement method developed by Wu and Barnes (2009) but applied to performance measurement and management research provides a dynamic directional property to the performance model. Each component follows discovery of sociological group performance theories and performance management theories applied to the model. The proposed ‘priori performance management model’ is composed of the following.

- A sociological construct developed from group performance theories consisting of ‘ten identified behaviours’ placed in a construction industry context.
- An operational construct developed from performance management theories collated from collaborative working and performance management related toward ‘measurement and operation of key performance outcomes’ for determining chance of further projects.
- The focus of the performance model is an impact of ‘sociological and operational performance drivers’ at pre and post contract phases upon contractors involved within the framework.

The predominant research method used for this research is quantitative, supporting a dominance set within a positivist paradigm used to test the sociological construct of the model. As explained by Dainty (2007), the use of empirical quantitative information assists with compelling evidence in order to objectively discover phenomena. Use of such analytical manipulation of quantitative data provides recognition of variables through a scientific process (Walker, 1997) by giving results subjected to statistical comparison of samples undertaken, measuring these against standardised populations allowing
explanatory statements to be made (Czaja and Blair, 1996). In support of the chosen quantitative methods, qualitative interviews were conducted seek to understand the views of practitioners on what and how sociological behaviours drive project outcomes – an important feature of sociological group based research. The qualitative interviews with experienced practitioners were also used to confirm and explain the relationship between performance measures and project outcomes – the operational construct of the model.

In construction project management discipline case studies can provide data of highest quality and depth (Wineburg, 1997), but when applied with construction project life cycles, such data requires a long period to amass collection of data, determine views and provide conclusions. This research is set within a paradigm of a single case study in order to explore data and information relevant for a major public sector organisation. The organisation is of sufficient economic mass (> £1Bn annual turnover) and also has a continuous requirement for construction industry products in delivery of its statutory duties. The organisation also directly employs more than 100 qualified staff, such as engineers and quantity surveyors, with the management of projects allowing access to views from practitioners allied to the construction professions. Furthermore, it is similar to other local authorities in terms of statutory and financial control on procurement of works, thus forming a representative case.

Within the case study, the following source data is available:

- A pilot study with 20 practitioners to gauge initial results through a priori investigation and ascertain if the sociological construct arrived from examination of published literature provided a basis for further enquiry.
- A quantitative questionnaire survey conducted with 100 practitioners (out of an estimated population of 180, 55.6% sample size) from public sector employees and private sector framework contractors. Table 3 refers.
- In-depth interviews with 10 practitioners (5.6% sample size) experienced in both framework and traditional discrete projects.
- Factor analysis and central tendency statistics from the ‘questionnaires’ and qualitative content analysis using node values from the ‘interview transcripts’ to validate and explain sociological behaviour factors and operational performance measures. Use of quantitative and qualitative approaches in tandem can provide objectivity, generalisation and authenticity to the research (Raftery, et al., 1998).

A simple random probability sampling technique was used whereby all 180 participants were chosen through a general contact email – internally to the client organisation and externally to nine suppliers. All nine suppliers had experience of both framework agreements and discrete procurement methods with the client organisation. Within the client organisation, 60 of the 108 participants had a detailed knowledge of framework agreements generally whilst the remainder admitted a cursory and distant awareness. Of the 180 maximum estimated participants, 109 offered to take part in the questionnaire and 100 returned questionnaires that could be used for data collection. Participants who offered to return questionnaires are 60.6% of the total estimated population and returned usable data is 55.6% of the total estimated population. These are very high results that meet the ‘rule of thumb technique’ suggested by Neuman (1994) of 30% minimum sample size for populations under 1000.

Table 3. Estimated Total Population of the Case Study

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Participant group</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Design group – highways section</td>
<td>30</td>
</tr>
<tr>
<td>Client</td>
<td>Contracts – quantity surveyors</td>
<td>8</td>
</tr>
<tr>
<td>Client</td>
<td>Design group – structures section</td>
<td>30</td>
</tr>
<tr>
<td>Suppliers – (9 number)</td>
<td>Estimating and contracts</td>
<td>27</td>
</tr>
<tr>
<td>Client</td>
<td>Supervision</td>
<td>32</td>
</tr>
<tr>
<td>Suppliers – (9 number)</td>
<td>Contract management</td>
<td>45</td>
</tr>
<tr>
<td>Client</td>
<td>Strategic project management</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
</tr>
</tbody>
</table>
Findings and Discussion

Pilot Study
The operational construct using metrics and performance zone was operated for a 24 month period (8 consecutive 3 month performance periods) to gather project success index results and establish the incentive mechanism. During this period the significant group behaviour factors were subjected to a pilot study involving 20 participants. Confidence with results from the pilot study confirmed recognition of the same ten behaviours identified from research into characteristics of high performance organisations (Akdemir et al., 2010). This allowed construction of a research questionnaire for further refinement and issue to case study participants. Responses were filtered to remove reverse test questions and the remaining ten questions are included in Table 4 for empirical analysis.

Table 4. Identification of Behaviour Factor Questions for Empirical Analysis

<table>
<thead>
<tr>
<th>Question number</th>
<th>Predominant sociological behaviour factor</th>
<th>Literature source reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Communication</td>
<td>Greenberg and Baron (2003)</td>
</tr>
<tr>
<td>24</td>
<td>Knowledge transfer</td>
<td>Keskin (2005)</td>
</tr>
<tr>
<td>25</td>
<td>Incentives</td>
<td>Eriksen (2001)</td>
</tr>
<tr>
<td>29</td>
<td>Trust</td>
<td>Culyer (2001)</td>
</tr>
<tr>
<td>30</td>
<td>Empowerment</td>
<td>Green (2002)</td>
</tr>
<tr>
<td>35</td>
<td>Diversity</td>
<td>Milakovich and Gordon (2009)</td>
</tr>
<tr>
<td>37</td>
<td>Motivation</td>
<td>Greenberg and Baron (2003)</td>
</tr>
</tbody>
</table>

Questionnaire Survey: Central Tendency Statistical Analysis Results
As a conformational check to the factor analysis, the ten behaviour characteristics tested though responses from participants were subjected to a measure of central tendency using a mean score. For this check, responses were assigned a ranking against participant responses for a Likert scale between 1 and 5 to the manipulated values in Table 5.

Table 5. Measure of Central Tendency for the Ten Behaviours

<table>
<thead>
<tr>
<th></th>
<th>Q21 Rel</th>
<th>Q22 Com</th>
<th>Q23 Des</th>
<th>Q24 Kn</th>
<th>Q25 Inc</th>
<th>Q29 Tru</th>
<th>Q30 Emp</th>
<th>Q35 Div</th>
<th>Q36 Sat</th>
<th>Q37 Mot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.92</td>
<td>3.49</td>
<td>3.25</td>
<td>3.25</td>
<td>3.30</td>
<td>3.35</td>
<td>2.31</td>
<td>3.21</td>
<td>3.26</td>
<td>3.30</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>10</td>
<td>9</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

The central tendency results provide an indication of the most significant group behaviour characteristics with which to explore in greater detail. Participants do indicate that longer term working relationships between clients and suppliers is of prime importance with successive ordered ranking on communication, trust, motivation and incentives. Although measures of central tendency (in Table 5) represent an approximate method of analysis, further examination through factor analysis was used to identify the underlying trends.

Questionnaire Survey: Factor Analysis Results
Responses from participants to questions regarding ten behaviours for successful group performance included within the questionnaire were subject to an examination of suitability for factor analysis. Inspection of the correlation matrix revealed a significant number of coefficients above 0.3 (68 out of 100). The KMO value was 0.861 and Bartlett’s test reached statistical significance supporting use of data for factor analysis. Eigenvalues exceeded 1 for two components, explaining 42.7% and 10.5% of the variance respectively. An inspection of the scree plot revealed a break after the second component. To aid with interpretation of the two components, Varimax rotation was performed and showed six strong loadings with three cross loadings. The strongest values loaded substantially on one component in which incentive, decision making, relationships, trust, knowledge transfer and motivation have a factor loading
of greater than 0.6. The two component solution explained a total of 53.2% of the variance, with component 1 contributing 33.9% and component 2 contributing 19.2%.

**Qualitative Interviews: Content Analysis Results**

Qualitative methods selected for analysis of interview transcripts comprised word frequency, node theme classification and meta-synthesis in order to elicit individual participant statements and these are aggregated into group views. Interpolation of the aggregated group views are designed to represent predominant views of the sociological group class provided that saturation has occurred (Guest et al., 2006). Aggregated coding results synthesised into a structured node tree displayed commonality with clusters allowing group views to be summarised. The thematic meta-synthesis analysis was used to uncover an interrelated number of key results (or themes) that can be placed according to frequency into a hierarchal structure. Aggregation of results allows strength of a theme to be measured within the sociological group, where higher values represent stronger affirmation to that theme.

The most significant theme concerned relationships, where successful ones improve performance and is operated through incentives (either financial or psychological). The performance node also includes operation of KPI’s as part of performance measures. A sub-node to relationships is communication – where aggregated responses had values in excess of 50 for operational factors with contracts (measurement process) and frameworks (performance process). Sociological behaviour was recognised as being more effective than financial rewards as suggested by Thibaut and Kelly (1959) in *The Social Psychology of Groups* and expanded through a general independence theory by Rusbult, et al. (1998). The case study interview results align with this published research as participants recognise satisfaction of sociological needs and rewards more readily through framework arrangements when contrasted with discrete methods.

During interviews with selected participants a number of themes emerged and were recognised as interrelated. The following is a summary of practitioners own views, which confirm the significant sociological and operational factors and explain how they drive project outcomes within the framework project organisation.

- **Sociological factors** ...encourage a stronger and a closer relationship because you are participating together and as a result you create more common goals and have a key working approach
- **Sociological factors afford** ...better communication and that’s more likely to happen in a framework because of the strong relationships
- **Operational factors** ...are rewarded with incentives from performance and they are benefiting from that
- **Operational factors** ...enable both sides to look at historical performance data related to the project to identify where the client team and the contractor team members need to improve.

Reflective analysis of the model indicates a strong association of performance with each significant element. The operational construct relied upon use of key performance indicators to measure project outcomes where successful projects could place suppliers for selection of a future project by use of a marginal incentive system related to price and quality assessment. Operation of the construct gave a measurable improvement in project performance outcomes on the projects contained in the case study and this investigation formed a separate research paper (Lam and Gale, 2014). The operational construct of the performance model operates in the manner proposed and in the sequence anticipated. In partial explanation and allied to the Hawthorne studies (Mayo, 1949) the process of measurement and desire to compete appears to provide a strong driver to performance improvement. As participants state:

> ‘...the fact that our performance is being monitored and that monitoring of our performance contributes to our future ability, or not, to secure more work ....raises the priority to make the customer that bit more important.’

> ‘... if you’re going to be measured on something it becomes a greater priority for you’.

> ‘... in the public eye with performance data being published ... they will stick to something ..’.

Within the generalised view, individual components – described by practitioners through their own words in response to interview questions – provided a significant awareness of the drivers of performance. The extent of this is perhaps surprising given the traditional conservative views of the construction industry (Davies, 2008) and realisation that case study participants had less than three years experience of framework agreements at the time of interview. Coupled with a natural resistance to organisational change proposed by Smollen (2011), the strength of results and engagement of participants with drivers of performance is somewhat significant.
Summation of qualitative and quantitative data
Analysis from factor analysis results provided a significant component with high factor loadings for incentives, decision making, relationships, trust and knowledge transfer. The factor, labelled duration, required a continuance of passage of time with which to gain performance outcomes. A measure of central tendency found three behaviours (relationships, trust and incentive) that aligned with strong factor loadings. Nodal aggregated values taken from interviews provide that relationships, communication and incentives are the most repeated themes. The combination of questionnaire and factor analyses (quantitative evaluation) and interview analysis (nodal aggregation) provides a comprehensive and compelling view of group views which confirm that relationships, communications and incentives as key components of sociological group themes. All the results are summarised in Table 6.

Table 6. Summation of Significant Behaviour Results

<table>
<thead>
<tr>
<th>Loaded factors from factor analysis</th>
<th>Rotated component value</th>
<th>Central tendency from questionnaire</th>
<th>Mean value</th>
<th>Significant qualitative nodes from interviews</th>
<th>Node aggregate value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationships</td>
<td>.725</td>
<td>Relationships</td>
<td>3.92</td>
<td>Relationships</td>
<td>174.56</td>
</tr>
<tr>
<td>Incentives</td>
<td>.778</td>
<td>Communication</td>
<td>3.49</td>
<td>Communication</td>
<td>46.99</td>
</tr>
<tr>
<td>Decision making</td>
<td>.772</td>
<td>Trust</td>
<td>3.35</td>
<td>Incentives</td>
<td>58.15</td>
</tr>
<tr>
<td>Trust</td>
<td>.636</td>
<td>Incentives</td>
<td>3.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge transfer</td>
<td>.608</td>
<td>Motivation</td>
<td>3.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Construction of Performance Model
The tripartite data collection – pilot, questionnaire and interview – where results align provides confidence to conclusions made with the performance model, as shown at Figure 1. Completion of the analytical phase of the research allows reevaluation of performance model. Following an initial pilot placement of components, two constructs were prevalent. Construct one consisted of the operation of incentives through collection of project data being compiled into performance zones and forming incentivised drivers to encourage and maintain project performance levels. In the model construct one is labelled the operational construct. The influence of organisational group behaviour upon performance outcomes through integration of views from a class of technical professions is represented through construct two and this is labelled sociological construct.

Data analysis collated for the posteriori model provided confirmation that the original constructs of the priori model remained unchanged. At the centre of both models, performance and the desire to improve also remained constant. Examination of each construct is undertaken to identify changes in the elemental components which appear in the construct. For the sociological construct, the priori model identified incentives, motivation, satisfaction and relationships as prime behavioural components arising from a pilot study. Prime behavioural components for the posteriori model following factor analysis, central tendency and qualitative node aggregation placed relationships, incentives and communication at the fore. The predominant underlying factor for the sociological construct was duration. Obviously longer duration of framework allows stronger relationships and communication to be developed between participants as well as more non-financial and financial incentives to be gained by contractors.

It was clear through examination with published research and the methods used for this study that each construct – operational or sociological – had the capability of independent performance improvement, but operating together produced a vortex effect where one construct had an immeasurable but recognisable (by participants) influence upon the other. Participants mentioned behavioural factors and performance measures as interlinked for performance outcomes. Examples of such holistic approaches displayed by participants rather than viewing individual constructs are:

‘...you've got a system which balances the reward for positive or negative performance on issues other than financial ones and I think that's a balance you've got quite good...

'...in the framework I think the incentives...of good performance benefiting their next submission in terms of appraising, and the competition improves performances...’
Conclusions

Through a literature review and application of research methods, a model is developed for performance improvement through use of collaborative framework methods. Reflection of the performance model confirms that operational methods at the post contract phase drive performance as anticipated and that these are readily accepted by participants. Use of contract KPIs (critical success factors) and performance measurement provides a focus upon performance outcomes provided these engage with operational methods used by construction management (key dates for projects, contractual records and the like). Synthesis of results identifies three significant behaviours for performance improvement - relationships, incentives, communication, set within a factor of duration. The underlying factor of duration infers that longer term should be set at the pre contract phase for construction frameworks to allow development of the three significant behaviours. This means that stronger relationships and communication can be developed between participants and that more incentives can be gained by contractors, and consequently all of these drivers augment performance and project incomes.

Results from the *posteriori* procurement performance model have been incorporated into a second generation collaborative framework set within the South East Region of the UK. An examination of project outcomes indicate that data compiled as of June 2014 displays performance improvement effect comparable to results included in research conducted by Lam and Gale (2014). The deduction, by inference, is that provided elements of the model in this paper are included in collaborative procurement systems, such results can be expected to continue. As the model displays geared influence, critical success factors and project success outcomes are expected to remain at the fore of participant’s objectives, enhanced by the pressure to perform. Practically client project managers can use the performance model developed to effectively manage the upper chain and drive the project outcomes in construction framework contracts through procurement measures (longer contract term and use of KPIs). In relation to the theoretical implication, the research findings make significant contribution to the construction framework procurement by identifying the interrelated sociological and operational performance drivers in the whole project delivery process including pre and post contract phases.

This case study is set predominantly in the field of highways civil engineering. This has allowed detailed comparison of outcomes due to containment within a specific classification, but other types of projects could be explored. It is suggested that building based projects or other projects that share characteristics are grouped together and used for further research of the phenomena discovered. Contextual placement of this research is limited to construction projects set within the public sector and subject to European legislation and UK regulation. The influence of latter legal restrictions may be significant when transferred to other counties. It is also suggested that this study is replicated in other
countries where collaborative framework agreements display similar characteristics in order for comparative analysis to be undertaken.

References


A Comparative Study of Construction Joint Ventures in Australia and Malaysia

Tony Ma¹ and Michelle Voo²

Abstract
A Construction Joint Venture (CJV) refers to the collaboration of at least two construction organisations with a view to accomplishing mutually-agreed-upon objectives, wherein they share project risks, knowledge and resources. The Governments of Australia and Malaysia are encouraging and supporting local contractors to implement CJV approaches based on their expertise and experiences in construction. Although both countries fall into the Asia-Pacific region, but their experiences with CJVs might be different. A comparative study would help to indicate how well both countries have fared using this method. The aims of this research are to identify the reasons, perceived benefits and potential difficulties of implementing the joint venture approach, and to understand how the project performance on joint ventures are being measured.

Four in-depth case studies of CJV projects were carried out by means of interviews with project or contractor representatives to compare their perceived project performance and cost risk allocations. The results suggest that the most common barriers to CJV success in both Australian and Malaysian construction industries include differences in organisational policies, inconsistent management styles, a lack of mutual understanding between joint venture team members and a lack of mutually-agreed-upon conflict resolution mechanisms between joint venture contracting parties.

Keywords: Construction joint ventures, success factors.

Introduction
In construction industry today, the construction joint ventures (CJVs) have become one of the major organizational forms utilized in large-scale projects (Lin and Ho 2012). Due to the growing scale and complexity of construction projects, as well as technological advancements, organizations have begun to set up CJVs to utilize partner resources (Famakin et al. 2012; Zhao et al. 2012). Joint venture (JV) formation between construction companies has become one of the most commonly adopted methods in both developed and developing countries.

It has been argued that CJVs are very sensitive to regional conditions, as well as to the uncertainties of external environments such as political, economic, cultural and legal risks. There is also a wide variety of types of ventures, and the formation and operation of CJVs are different across countries (Park et al. 2011). Australia is a developed country whereas Malaysia is a developing country. However, both of them fall into the Asia-Pacific region; a comparative study would help to indicate how well both countries have fared using this

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joint collaboration method. The various experience of CJV in Australia has captured the authors’ interests to pursue a study of PPP in Malaysia.

The overall aims of this research are to identify the perceived benefits and potential difficulties of implementing the joint venture approach, and to measure the impact of joint ventures on the project performances in Australia and Malaysia. It also attempts to examine the process and implementation of joint ventures in both Australia and Malaysia.

Construction Joint Ventures in Malaysia

Bank Negara’s statistics indicate that Malaysia’s construction sector remained robust in the third quarter of 2012 at 18.1% (BNM 2012). The Malaysian construction industry is expected to play a vital role in nation’s economy, contributing 11.2% to the GDP growth in 2013, driven by the civil engineering sub-sector (CIDB 2013). The Malaysia government implemented the 10th Malaysia Plan (10MP), the Government Transformation Programme (GTP) and the Economic Transformation Programme (ETP), that will set the stage for a major national structural transformation towards that of a High-Income Economy. The plan which covers the period from 2011-2015, will potentially have a high impact on the Malaysian construction sector (RSM RKT Group 2012; PMD 2010).

Since the early 1990s, construction joint ventures in Malaysia evolved rapidly in order for both multinational construction firms and local government to achieve objectives (Mahmud and Yu 2009). There are established joint ventures between local contractors and foreign contractors (Adnan & Morledge 2004; Mahmud and Yu 2009). Malaysia is one of the leading countries in Southeast Asia involved in international joint ventures (Adnan & Morledge 2004; Adnan 2008). Over the years it has managed to attract a great deal of well-known multinational companies from around the world, for projects in both the private and public sectors focusing on infrastructure, civil engineering works, airports and hospitals (Mahmud and Yu 2009). Many large-scale construction projects in Malaysia have intended to be used the joint venture collaboration method for delivery including the Petronas Twin Towers, the Kuala Lumpur International Airport (KLIA), the Likas Specialist Hospital and Klang Velley Mass Rapid Transit (Adnan 2008; Adnan2004).

The Malaysian government is both encouraging and supporting local contractors to participate in regional and global markets based on their expertise and experience of building construction, infrastructure works, civil engineering works, mixed developments and airport works (Mahmud and Yu 2009; Adnan 2008). Malaysian construction sectors participate in a variety of construction projects in India, China, Singapore, Australia, South Africa and the United States (Adnan & Morledge 2004; Adnan 2008).

Construction Joint Ventures in Australia

The construction industry is the fourth largest contributor to Gross Domestic Product (GDP) in the Australian economy and plays a major role in determining economic growth. Prior to the 2008-09 financial year, the construction industry had steadily increased its share in the GDP from 6.2% in 2002-03 to 7.0% in 2007-08 (Australian Bureau of Statistics 2010). The rate of increase of total value of engineering and commercial construction work is expected to settle to 10% in 2012-13, after an increase of 14% in 2011-12, and an expected increase of 8% for the 2013-14 (Australian Industry Group 2012). Public investment in infrastructure projects has increased significantly as well, adding to the growth momentum of the Australian construction industry.
Joint ventures between construction organizations in Australia, both international and local partnerships, have become increasingly popular when delivering large-scale infrastructure construction projects. Example projects include the New Royal Adelaide Hospital (NRAH), the Southern Expressway Duplication, the Gateway Upgrade road and bridge project, and the Orange Hospital NSW (Cheung 2009; SA Health Partnership 2013; Infrastructure 2012). It is no secret that all levels of Australian government are finding it difficult to raise funds for critical and major infrastructure projects. Local governments encourage the private sectors to work together and to enter into joint venture arrangements for better outcomes (Australian Construction Resources 2013). The Australia Japan Business Co-operation Committee has undertaken a programme of activities to encourage the use of joint ventures for works in Australia and Japan (AJBCC 2011).

Four Case Studies by Interviews

The case study methodology has been adopted to identify the effectiveness of the joint venture approach used in Australian and Malaysian construction industries. Four case studies have been selected to explore how the practice in the construction industry compares to information obtained from the literature review, and to examine perceived benefits of joint ventures between parties. In order to obtain a better understanding of and up-to-date information using real-life examples of CJVs in both Malaysia and Australia, a series of interviews were conducted with joint venture contractors of the case study projects to examine current practices. Both quantitative and qualitative approaches were adopted and integrated in the interviews. The following projects have been selected and summarized in Table 1 below:

Table 1. Brief summary of CJV projects in Malaysia and Australia

<table>
<thead>
<tr>
<th>Joint Venture Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MALAYSIA</td>
<td>Sabah Women and Children's Nuclear Medical Centre and Radiotherapy Hospital (Likas Specialist Hospital) is a completed joint venture project that incorporated the design, construction, completion, equipping, commissioning and maintenance of the Nuclear &amp; Radiotherapy Medical Centre at Kota Kinabalu, Sabah, Malaysia. The design and construction of the project was delivered by Health Solutions (Malaysia) Sdn Bhd and Warisan Harta Property Development Sdn Bhd (Yusof 2013).</td>
</tr>
</tbody>
</table>

Client: Sabah Public Works Department  
Commission Date: April 2008  
Actual Completion Date: December 2012  
Contract Sum: MYR223 million (AUD$74.3 million)  
Private Consortium: Builder: Health Solutions (Malaysia) Sdn Bhd
Location: Kota Kinabalu, Sabah, Malaysia.

Type of Contract: Design and build, Selective Tendering

Progress: Completed six months behind schedule due to design changes in façade of hospital

Extension of Time (EOT): Granted according contract requirements. The original practical completion was June 2012. A penalty of MYR40,000 was enforced due to the delay.

Overall Performance: Behind schedule, within budget

**Kuala Lumpur International Airport 2 (KLIA2)**

The KLIA2, with a total area of 242,000 square meters, is built to be Malaysia's next-generation international airport hub, intended to provide seamless connectivity for both local and international low-cost and full-service carriers. It provides business-class services to accommodate AirAsia Airline’s needs. The development of the new KLIA2 and Associated Works is located at KLIA Sepang, Selangor, Malaysia. The new KLIA2 terminal is being delivered by UEMC-Bina Puri Joint Venture, which consists of UEM Construction Sdn Bhd (UEMC) and Bina Puri Holdings Bhd.

Client: Malaysia Airports Holdings Berhad (MAHB)

Commission Date: 2006

Expected Completion Date: April 2014

Contract Sum: MYR4 billion / AUD$1.33 billion

Private Consortium: UEM Construction Sdn Bhd (UEMC) and Bina Puri Holdings Bhd working together as UEM-Bina Puri JV

Location: KLIA Sepang, Selangor, Malaysia

Type of Contract: Design and Construct, Open Tendering

Progress: On-going. Behind schedule, previous practical completion was June 2013. 90% of construction is completed. EOT: Granted until April 2014, due to design changes and ground conditions. No penalty of LAD.

Overall Performance: Time overrun and costs overrun due to upgraded the design to boost the capacity of 45 million passengers per year, up from original plan of 30 million.

**AUSTRALIA**

**New Royal Adelaide Hospital (NRAH)**

The new Royal Adelaide Hospital (new RAH) will be the most advanced hospital in Australia and the single largest infrastructure project in the state’s history. It is located at North Terrace, Adelaide. The new RAH has been designed to be a world-class health facility, and will lead South Australia’s new patient-centred model of care, delivering safe,
The design and construction of the New Royal Adelaide Hospital is being delivered as a public-private partnership (PPP) and is managed by joint-venture partners Hansen Yuncken and Leighton Contractors (SA Health Partnership 2012).

<table>
<thead>
<tr>
<th>Client</th>
<th>SA Health Partnership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commission Date</td>
<td>2011</td>
</tr>
<tr>
<td>Expected Completion Date</td>
<td>2016</td>
</tr>
<tr>
<td>Contract Sum</td>
<td>AUD$1.85 billion</td>
</tr>
<tr>
<td>Private Consortium</td>
<td>Builder: Hansen Yuncken and Leighton Contractors (HYLC Joint Venture)</td>
</tr>
<tr>
<td>Location</td>
<td>North Terrace, Adelaide</td>
</tr>
<tr>
<td>Type of Contract</td>
<td>Design and Construct</td>
</tr>
<tr>
<td>Progress</td>
<td>On-going and on schedule, completion anticipated in 2016</td>
</tr>
<tr>
<td>Any EOT</td>
<td>None EOT as of November 2013</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>On schedule; on budget</td>
</tr>
</tbody>
</table>

The South Road Superway project is the biggest single investment and the most complex road engineering construction project in South Australia. It is undertaken by a joint venture of John Holland and Leed Engineering and Construction. The project involves upgrading the stage two of the north-south transport corridor to deliver a 4.8 km non-stop corridor, including a 2.8 km elevated roadway from the Port River Expressway to Regency Road (Government of South Australia 2013).

<table>
<thead>
<tr>
<th>Client</th>
<th>Department of Planning, Transport and Infrastructure (DPTI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commission Date</td>
<td>April 2011</td>
</tr>
<tr>
<td>Expected Completion Date</td>
<td>December 2013</td>
</tr>
<tr>
<td>Contract Sum</td>
<td>Overall Contract Sum AUD$842 million (including Property Acquisition). Contract sum of project: AUD$650 million</td>
</tr>
<tr>
<td>Private Consortium</td>
<td>John Holland (80%), Leed Civil &amp; Engineering (20%)</td>
</tr>
<tr>
<td>Location</td>
<td>South Road, connecting the Port River Expressway to Regency Road north of Adelaide</td>
</tr>
<tr>
<td>Type of Contract</td>
<td>Design and Build, Open Tendering</td>
</tr>
<tr>
<td>Progress</td>
<td>On schedule, anticipated to completion in December 2013</td>
</tr>
<tr>
<td>EOT</td>
<td>EOT has not been required</td>
</tr>
<tr>
<td>Overall Performance</td>
<td>On schedule; on budget (budget very tight)</td>
</tr>
</tbody>
</table>
In order to understand the reasons of using CJV, the potential barriers and the critical success factors in adopting a CJV approach in construction projects in both Malaysia and Australia, as well as to measure the performance of CJV projects in both countries, the key findings from the four cases are summarised in Table 2 below which provides a brief summary based on the headings of reasons of establishing CJV, efficient risk allocation, project delivery, key performance indicators (KPIs) and critical success factors.

According to the individual ranking by the interviewees, the critical factors that lead to the success of the CJV projects were the Agreement of contract, financial stability, commitment, inter-partner trust, cooperation, communication and partners’ experience. These critical success factor methodologies provide a good basis to identify possible solutions in seeking ways to improve CJV experiences.

**Analysis of Project Outcome in Australia and Malaysia**

The natures of the selected Australian and Malaysian case studies are same. Each case study projects has been or is being delivered by two building contractors. For companies to implement the CJV approach for project delivery, the reasons must be viable and the benefits evident. All case studies have demonstrated clear reasons for establishing CJVs for the projects. Reasons for establishing CJVs were discussed with building contractors’ representatives as a part of the interviews. Their main reasons included the sharing of expertise or of resources, the transferring of technology and knowledge, the sharing of risks, and to strengthen financial capabilities. It is seen that both companies in the partnerships are enthusiastic about co-managing risks and having better corporate oversights, which could be due to the size and characteristics of management in the joint venture organization.

The optimum risk allocations have depended on the types and size of the projects. For Likas Specialist Hospital and South Road Superway, the optimal risks have been appropriately transferred to the party who can best manage it. Meanwhile, the risks in the KLIA2 and new RAH projects have been equally shared between the joint venture contracting parties.

All case studies are valuable in measuring the performance of the CJV projects through the identification of KPIs to indicate the success of the project. The success of a CJV project can be identified through time performance, cost performance, safety performance, and quality and risk management of the projects.

These include the importance of the agreement of contract between the joint venture contracting parties, the financial stability of the organizations, commitment, inter-partner trust, cooperation, communication and partners’ experience.

The four case studies have delivered distinct project outcomes due to the different risk allocations, and the effectiveness of project risk management. It is seen that in both Australian case studies are on schedule and within budget. In comparison, both Malaysian case studies suffered delays in the construction project and overran costs. This is due to different management styles, design changes and an unstable project scope. According to the interviewee of the hospital project in Adelaide, the most important lesson that he has learnt from the joint venture project is the mutual understanding of the new JV organisation, including the organisational cultures of the partners. Whereas in Malaysia, one interviewee indicated that contractors have faced some different opinions in construction methods and communication delays. Table 2 below illustrates more in-depth comparative studies based on four interviews:
Table 2. Comparison of case study project outcomes in Australia and Malaysia

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Malaysia</th>
<th>Australia</th>
<th>South Road Superway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Likas Specialist Hospital</td>
<td>Kuala Lumpur International Airport 2 (KLIA2)</td>
<td>New Royal Adelaide Hospital (new RAH)</td>
</tr>
<tr>
<td>Interviewee</td>
<td>Interviewee A</td>
<td>Interviewee B</td>
<td>Interviewee C</td>
</tr>
<tr>
<td>Tendering Method</td>
<td>Selective</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>Procurement Method</td>
<td>Design and Build</td>
<td>Design and Build</td>
<td>Design and Build</td>
</tr>
<tr>
<td>Reasons for Establishing CJV</td>
<td>• Sharing of expertise</td>
<td>• Sharing of experience</td>
<td>• Sharing of</td>
</tr>
<tr>
<td></td>
<td>• Sharing of resources</td>
<td>• Sharing of resources</td>
<td>experience</td>
</tr>
<tr>
<td></td>
<td>• Transferring of technology</td>
<td>• Strengthen financial capability</td>
<td>• Sharing of risks</td>
</tr>
<tr>
<td></td>
<td>and knowledge</td>
<td>• Sharing of risks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sharing of risks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficient Risk Allocation</td>
<td>The risks have been allocated to</td>
<td>The risks are shared equally</td>
<td>The risks are being</td>
</tr>
<tr>
<td></td>
<td>the party most appropriate to</td>
<td>between joint venture</td>
<td>shared equally</td>
</tr>
<tr>
<td></td>
<td>efficiently manage the risks.</td>
<td>contracting partners.</td>
<td>between joint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>venture partners.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HYLC had prepared</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>a risk profile and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>risk management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>plan in advance for</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the new RAH.</td>
</tr>
<tr>
<td>Project Delivery</td>
<td>The project was not completed</td>
<td>Several components of the</td>
<td>The project is</td>
</tr>
<tr>
<td></td>
<td>on time due to design changes</td>
<td>construction works were not</td>
<td>on schedule; there</td>
</tr>
<tr>
<td></td>
<td>and delayed delivery of treatment</td>
<td>completed on time</td>
<td>have been neither</td>
</tr>
<tr>
<td></td>
<td>equipment. A penalty of</td>
<td>due to unexpected ground conditions</td>
<td>delays nor EOTs to</td>
</tr>
<tr>
<td></td>
<td>MYR40,000 (AUD$13,333) for</td>
<td>and variation works on the</td>
<td>date.</td>
</tr>
<tr>
<td></td>
<td>liquidated damages was</td>
<td>baggage handling system that</td>
<td></td>
</tr>
<tr>
<td></td>
<td>enforced.</td>
<td>necessitated extra time and cost.</td>
<td></td>
</tr>
<tr>
<td>Key Performance Indicators (KPIs)</td>
<td>• Time performance</td>
<td>• Health and safety</td>
<td>• Safety consideration</td>
</tr>
<tr>
<td></td>
<td>• Cost performance</td>
<td>• Risks management</td>
<td>• Risks allocation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Quality control</td>
<td>• Cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Project time-line</td>
<td>• Quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to agreed-upon schedule</td>
<td>• Program</td>
</tr>
</tbody>
</table>
**Conclusion**

The case study of Likas Specialist Hospital demonstrated that although Health Solution Contractors has experience with the construction of health care buildings, they were not familiar with the rules and regulations of the Sabah Government. Thus, they chose to establish a joint venture approach with Warisan Harta to share knowledge. The case study of Kuala Lumpur International Airport 2 illustrated that the major reasons of using the joint venture approach were to share capital and resources. Due to financial limitations, they decided to implement a joint venture approach with Bina Puri Holdings. The case study of the new Royal Adelaide Hospital illustrated that the reasons for implementing a joint venture approach were to share expertise, resources and risks between partners. The case study of the South Road Superway noted that John Holland was not familiar with the South Australian legislation for road projects; therefore, they chose to work with Leed Civil and Engineering in order to share knowledge as well as risks.

An appropriate risk allocation is essential for CJV efficiency, where risks must be well-managed by joint venture contracting parties. This can be done either by transferring the risks to the most appropriate party, or sharing risks equally among the joint venture contracting parties. The case studies of the Kuala Lumpur International Airport 2 (Malaysia) and the new Royal Adelaide Hospital (Australia) prepared risk management plans, and risks were being shared equally between joint venture partners. Meanwhile, risks in the Likas Specialist Hospital (Malaysia) case study and the South Road Superway (Australia) were allocated to the party best-equipped to bear it from commission to completion of the projects.

Data collected via case studies for projects in both Australia and Malaysia show that the major KPI elements used to indicate project performance are safety, cost and time performance, client satisfaction and quality of projects. It is seen in both Australian case studies, which both achieved positive outcomes, which the projects are on schedule and within budget. In comparison, both case studies from Malaysia suffered delays in the construction project and cost overrun.

In conclusion, the findings indicated that both Australian case studies achieved positive outcomes, measured by the fact that the projects are currently on schedule and within budget as of this report's finalization. In comparison, both Malaysian case study projects suffered delays in the construction project delivery and overrun costs. Aside from these
differences, however, it is clear that views from both countries regarding specific attributes of collaboration in joint venture projects do not differ significantly, and the association between responses from the two countries is low.

References


A Study of the Skills of Construction Project Managers in Australia and Their Needs for Training and Certification

Tony Ma¹, Cuong Luong², and Jian Zuo³

Abstract

Project management as a discipline began in the late 1950s, primarily in the engineering and construction industries. Project management processes are being increasingly implemented to improve project success rates. This study investigates the current construction project managers in Australia, in terms of their skills, constraints and their needs for training and certification. This study also looks into the outcomes of construction industry projects in Australia managed by certified professional project managers, and comparing them to project outcomes to non-certified project managers. A questionnaire survey was developed based on findings from carrying out the literature review. Nine project managers at senior levels were also interviewed to refine the initial findings from the survey.

The results showed the ranking of top 5 essential attributes and 5 potential constraints of project managers. There is no major difference in rating the success criteria or project success between certified and non-certified project managers across all projects. Both non-certified and certified project managers deliver their projects to their clients’ expectations. It emerges that there is less demand for a project manager being certified in Australia, which enables them to work as superintendents with their original trained skills. Registered project managers are only needed when or if the client so demands.

Keywords: Project managers, skills, constraints, certification.

Introduction

Project management involves the discipline of planning, organising and managing resources to achieve specific goals. Currently project management has proved its worth beyond the construction, information systems, health and manufacturing sectors (Wirth 1996). White and Fortune (2002) have defined as a domain for both the exercise of professional expertise and academic knowledge. Barber (2003) expressed the view that project management has changed substantially from its traditionally specialist character to now include numerous senior and middle managers. This change has resulted in a huge variety of project managers in both the public and private sectors working for many different types of organisations.

Many studies have demonstrated that most project failures are due to not meeting the designated time and budget goals, or failing to satisfy customer or company expectations (Sauser et al. 2009). Project success means not only just completing on time and within budget goals, but also taking into account future concerns for the business. These authors

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also stated that many researchers have tried for years to find the reasons for project success or failure; the search for critical success factors is one of the most common approaches.

Projects succeed or fail for similar reasons such as, project mission, planning, communication, politics, control, senior or top management support, technical tasks. The researcher’s objective is to identify these reasons. Client satisfaction, perceived quality of output and implementation process factors are the three primary means of determining whether failure did or did not take place. The major contributor is client satisfaction as the causes of failure varied more when client assessment was used to determine failure (Jeffrey et al. 1990). Hence the importance of the project manager came into play.

If a project task is assigned to a project manager who lacks experience or skills, project success will potentially be compromised. These issues could put the project at risk due to the lack of suitably qualified personnel (Barber 2005). Hence the individual project manager should be clear about career expectations and know-how (El-Sabaa 2001). The key factor on the successful project manager career path is having a qualification that is aligned with relevant career path levels and a sense of progressive continuity in the organisation that he or she works for (Holzle 2010).

However, not everyone can become a project manager. Project managers require outstanding behaviours to lead to the best possible outcomes. Fisher (2010) suggested specific behaviours for each skill need to be applied by project managers to make these skills truly effective. Knowing the skills and understanding the problems, project managers also need to develop a good project strategy before the project commences. By implementing of differentiation, operational and quality strategies, project managers may improve project outcomes in terms of schedule, quality, and innovation performance. It is important for the project team to provide customers with high value products so that their relationships with customers are consolidated (Yang, 2012).

This study aims to address the competency of construction project managers in Australia and the objectives are to capture their skills, constraints and the need for training and certification. This will include the most important project management skills that a project manager must possess, and whether any additional skills or issues should be obtained in the rapidly changing economy of the twenty-first century. Every client or developer would like to see project success and therefore choosing an appropriate project manager will interest those who play a role in the selection process.

Project Management Standards

The International Organisation for Standardisation (ISO) defines a standard as a ‘document established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context’ (ISO 1996, p1). According to Ahlemann et al. (2009, pp.293), ‘standards may be regarded as socio-economic constructs reflecting a balance of perspective between stakeholders. They spread by market exclusion or joint modification. For a standard to be really beneficial it is important that the group of stakeholders accepting this standard is as large as possible. This may be explained by the network effect theory, since each additional stakeholder applying a standard makes it more useful for the rest of the community.’

Over the last decade, Project Management Standards (PMS) have increased significantly. Crawford (2007) addressed PMS in three areas, i.e. project, organisation and people:

- **Projects** - knowledge and practices for management of individual projects
- **Organisations** - enterprise project management knowledge and practices
People - development, assessment, and registration/certification of people

Traditionally, many construction project managers begin their careers in a technical field and because of their experience and skills; they would be assigned management roles in their projects. As project management develops and becomes recognised, there are a number of institutions and associations established to promote education, professional accreditation and the compilation of project management body of knowledge as standards. These standards form the basis of training and the certification of project managers. Nowadays, there are many academic programmes available from training providers, vocational colleges and universities. Below is a list of common project management body of knowledge developed by institutions:

- PMBOK Guide - Project Management Institute (PMI)
- APM Bok - Association of Project Management (APM)
- Professional Competency Standards - Australian Institute of Project Management (AIPM)
- IPMA Competence Baseline (ICB) - International Project Management Association (IPMA)
- PRINCE2 - first established in 1989 by Central Computer and Telecommunications Agency (CCTA)

As illustrated by Burke (2010, p50), the PMI’s Project Management Professional (PMP) is a certificate programme, which measures explicit knowledge directly through a multiple choice test, and a tacit knowledge and skills indirectly by assessing the candidates experience. The knowledge based test is based on the PMBOK Guide. However, in Australia, the certificate program is a workplace competence based process which assesses a person’s ability to perform. There are four levels of certification namely certified practising project practitioner, project manager, project director and portfolio executive. The AIPM does not produce its own body of knowledge but instead the competency standards have been based on a number of national and international project management standards such as AIPM standards, APM standards and PMI standards (AIPM website). From the researchers’ point of view, the competency standards endorsed fully the principles of PMBOK Guide. Currently there are over 10,000 members in Australia.

Project Management Institute’s A Guide to the Project Management Body of Knowledge (PMBOK® Guide, PMI), is the most standout distributed of a number of body of knowledge guides to offer a general standard to manage most projects most of the time (Crawford 2007). The Fifth Edition (2013) of PMBOK is the latest document resulting from work overseen by the PMI that provides guidelines for managing individual projects and defines project management-related concepts, and the project management life cycle and processes. This particular edition addresses 47 processes that fall into five basic process groups identified as initiating, planning, executing, monitoring and controlling, and closing. This latest edition explained ten knowledge areas that are typical of almost all projects that contain the essential processes that need to be accomplished and in essence show that a project management program has been effective:

1. Project Integration Management
2. Project Scope Management
3. Project Time Management
4. Project Cost Management
5. Project Quality Management
6. Project Human Resource Management
7. Project Communications Management
8. Project Risk Management
9. Project Procurement Management
10. Project Stakeholder Management

Apart from the major inclusion of a new knowledge area of stakeholder management, there is also a new appendix of interpersonal skills to signify the importance of these skills to project managers.

**Project Manager**

The project manager is the professional who is responsible for completing the project and project management would not exist without the project manager. Blackburn (2002, pp.5) concluded that ‘adding a project manager to a project (not uncommon: organizations do not know how early they should initiate a project, and the project manager is often brought in late) is like introducing a sheep dog to a field full of wandering sheep’. Furthermore the project manager is the communication hub for most reports, requests and complaints. The successful project manager is able to imbue team spirit and confidence that drives the team toward excellence or when the project becomes stressful and frustrating. Nicholas (2012) also stated that the project manager is ultimately accountable whether the project succeeds or fails.

In the delivery of successful projects, certain knowledge, skills and personal attributes are required for a project manager to be effective. This refers to the project manager’s competence. Their competence is clearly a vital factor in the success of projects, yet it remains a quality that is difficult to quantify (Crawford 2000). The authority of the individual project manager depends on the status of the particular project and their reputation and influencing skills.

The role of the project manager is changing from being an administration position into a much more managerial one. Holzle (2010) agreed that capabilities and competencies are required for project manager. As suggested by El-Sabaa (2001), human skill is primarily concerned with working with people. By developing high level human or interpersonal skills, the project manager will be sufficiently sensitive to the needs and motivations of others in his or her project when communicating through behavioural norms what has to be achieved in certain contexts. He found that the human skills of project managers have the greatest influence on project management practices rather than technical skills.

Knowledge, skills and personal attributes of project managers are the factors that contribute to completion of successful projects (Crawford 2000). Competent project managers are those who consistently deliver, on time and within budget, projects that meet or exceed stakeholders' expectations. Understanding of leadership principles and people skills are even more important to good project management. Muller et al. (2009) concluded that developing the project managers’ leadership styles so that these target profiles are achieved will contribute to better project results and the personal success of individuals. Thus leadership competencies should be taken into account when assigning project managers to projects.

Dolfi et al. (2007) agreed that the important contributor to an organization’s ability to achieve its strategic goals is competency of the manager. Dolfi et al. (2007) pointed out that success in project management is dependent on many variables, the most important being leadership and interpersonal skills. Muller et al. (2005) found that competency can be segregated into a number of classifications, such as leadership being a managerial competency imbued with personal characteristics. They concluded that successful project managers must have emotional intelligence such as self-awareness, emotional resilience, motivation, sensitivity, influence, intuitiveness and conscientiousness rather than being a pure tactician. Knowledge of project management tools and techniques are built upon and enhanced by the managerial skills, personal skills and learning skills (Blackburn, 2002).
According to Pant et al. (2008), the focus of most project management training has been on the technical skills (time, cost and quality) deemed essential to achieve project success because technical skills are easier to deal with when compared to the more difficult areas of soft skills. They concluded that project management practices need to emphasize training and relevant education for up and coming professionals. Regarding the career path, the project manager needs to be clear about expectations of competencies and know how to acquire them (El-Sabaa, 2001). The personality of the project manager strongly influences the decision concerning which career path to choose (Tremblay et al. 2002) and how to succeed in a project management work environment.

Holzle (2010) found that the qualification of the project manager has to be aligned according to the chosen career path levels. Project managers who are able to develop the appropriate knowledge and skills described in this thesis would position them for future career success. He suggested the needs of providing the continuity development to project managers by their organizational recognition and the needs of supporting project organization by project managers.

PMP qualification is used here as an example for illustration. PMI established a professional certification exam in 1984 that led to Project Management Professional (PMP) certification. PMI became the first organization in its field to attain International Organization for Standardization (ISO) recognition in 1999.

To be eligible for the Project Management Professional (PMP) credential, professionals must meet specific project management knowledge and work experience requirements. The value of project management certifications is hotly debated in terms of whether: firstly, certifications make better project managers; and secondly, projects staffed by certified project managers are more successful than projects without PMPs. Starkweather and Stevenson (2011) concluded that PMP certification is a necessary, but not sufficient factor affecting project management success. Certification should be viewed as more than a paper chase; a more relevant curriculum and experiential knowledge base must be developed.

Muller and Turner (2007) maintained that project management certification does mean that projects will be executed well. The project manager, who has a track record of good projects plus a certification, strongly indicates a high performing professional. They found there is no difference in rating the success criteria or project success between certified and non-certified project managers across all projects. Many organizations are using PMI as an entrance requirement when hiring project managers.

**Questionnaire Survey**

In order to achieve the aims of this research, an anonymous questionnaire was developed based on the abstracts from various literatures. A total of 36 variables were identified and respondents were requested to rate their relative importance based on a 5-point likert scale:

- 15 attributes regarding the essential skills of project managers.
- 9 constraints the project managers have to overcome.
- 6 success criteria to compare the percentages between certified and non-certified project managers.
- 5 education levels to determine the education level of project managers.
- 1 level regarding the importance of being a certified project manager

The questionnaires were distributed to various construction professionals from the work-related network of the researchers. A total of 77 survey invitations were sent by
electronic means. A total of 57 completed answers were received, making a total response rate of 74% which is considered quite high.

- Of the total sample, 86% participants have over 7 years of working experience in the construction industry while 14% participants have over 3 years of working experience.
- The results indicate that the top 5 skills that project managers should have are: communication skill, decision-making skill, leadership and motivation skill, listening skill and time management skill.
- The top 5 constraints that project managers have to overcome are: poor communication skill, poorly defined goals and objectives, misunderstandings, stakeholders and senior Management in their organizations.
- 52 out of 57 (92%) participants responded to the success criteria rating against the non-certified project managers. Client satisfaction is the top of the list, followed orderly by budget, schedule, quality, client business and lastly the contractor satisfaction.
- 55 out of 57 (96%) participants responded to the success criteria rating against the certified project managers. Client satisfaction is the top of the list, followed by orderly schedule, client business, budget, and quality and contractor satisfaction.
- The importance of education level for a competent project manager is in order of bachelor degree, diploma, high school, master degree and PhD.
- 36.84% believe it is of medium importance for a project manager to have a professional certification, while 29.82% believed it to be of high importance.

**Interviews**

In order to clarify and refine some of the findings from the survey results, 9 structured interviews were conducted. All participants hold senior positions in the construction field and they have at least 20 years of experience in project management. Their profiles and answers were summarized in the Table 1 below:

Regarding the definition of project success based on time, cost and quality, all interviewees answered ‘no’ to this question. They said that it was only the success criteria of the company. Other contributing factors such as people (team work), innovations, safety, and engagement of client for the next project cannot be neglected. When it comes to the project performance, the interviewees commented that there is no major difference between the certified and non-certified project managers because they work and achieve things in similar ways. In their opinions, technical experience and skills from their original background can compensate for this shortfall in paper qualification. According to the findings, it showed that it is not essential to have a professional certification for project managers in Australia. It is beneficial but not essential. Certification is, however, add value to project managers in terms of employment opportunities or where the client so demands for it.

With reference to the future career of the project manager, all interviewees recommended graduates or tradespersons should work their way up from the ground and develop technical expertise with more education and training. Most large organizations offer leadership and training programs. They develop a training framework matrix so that employees can advance in their careers. Small organizations generally do not have the resources to do so. In Australia, most universities offer project management programs at a post-graduate level but they do have undergraduate degree programs in construction and engineering where there are curriculums of construction project management components.
Table 1. Summary of Interviews

<table>
<thead>
<tr>
<th>Participants Education level and (professional qualification)</th>
<th>A project is a success if within time, cost and quality</th>
<th>In terms of project performance, is there any major difference between certified and non-certified project managers?</th>
<th>As project manager, is it essential to hold a professional certification?</th>
<th>However, is project management training necessary?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TAFE (none)</td>
<td>No</td>
<td>No difference</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2 Degree (member)</td>
<td>No</td>
<td>No difference</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3 Degree (member)</td>
<td>No</td>
<td>No difference</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>4 Degree (member)</td>
<td>No</td>
<td>No difference</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5 TAFE (none)</td>
<td>No</td>
<td>No difference</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>6 Degree (fellow)</td>
<td>No</td>
<td>No difference</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>7 Degree (member)</td>
<td>No</td>
<td>No difference</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>8 TAFE (none)</td>
<td>No</td>
<td>No difference</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9 Degree (member)</td>
<td>No</td>
<td>No difference</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Conclusion and Recommendations**

The study looked at the career development path for project managers in Australia by assessing their essential attributes and competencies. It also set out to define project success and having a certified and non-certified project manager made any difference. Project managers must have good communication skills because they are the main communication hub for most construction reports, requests and complaints. They must know how to effectively liaise with internal and external stakeholders. It is evident that technical skills are not so important.

There is no difference in rating the success criteria or project success between certified and non-certified project managers across all projects. Both non-certified and certified project managers deliver their projects to their clients’ expectations, particularly in terms of budget, time, and specifications. When they do this then they are better able to maintain and enhance their relationships with the client should future contracts arise. Having extensive years’ experience indicated a wider exposure of project managers to many different project phases, experiences and the number projects. The major outcome of this study is that although time, cost and quality are common perceived criteria for project success, these are not complete in its entirety. Other contributing factors such as people, relationship with stakeholders and processes should not be underestimated. In terms of career development, project managers should find it beneficial to have a certification that is recognised in Australia. Certification is recognised globally as having achieved specified
educational and professional credentialing standards. Certification adds more value in terms of seeking opportunities of employment in the construction industry.

Experience has shown that the selection of the project manager with necessary skills is an important appointment which can influence the success or failure of a project. It is this person who integrates and co-ordinates all the efforts from the consultants, contractors and stakeholders with the aim to achieve project objectives. The recommendations concerning the career path of project managers are as follows. A university education qualification is essential for Australian applicants who want to work as registered project managers. They should also have as many years working in the field as possible so that they have a wide exposure to all project management phases and the challenges that can arise.

References


Offsite Manufacturing in Developing Countries: Current Situation and Opportunities

Sherif Mostafa¹, Jantanee Dumrak², Nicholas Chileshe³, and Jian Zuo⁴

Abstract
The mainstream of people living in the developing countries hardly affords a quality house. Housing providers are in a continuous challenge to provide affordable and high quality houses. Offsite manufacturing is a modern method of building houses and has not been widely employed by house builders in developing countries. The house components are produced in offsite factories and transported to the construction site to be assembled. This allows building houses at a controlled environment to ensure high quality, less cost and minimal completion time. An attempt to use offsite manufacturing for improving housing supply in developing countries is presented in this study. It targets the policy makers, developers and designers at the housing sectors in those countries. This paper conducted a systematic review of the literature in 24 developing housing context. Moreover, this paper proposes a leagile supply chain to manage the offsite manufacturing. It is designed to include an integration of lean and agile. Last Planner™ System is used for better coordination among stakeholders. This paper suggests two house building strategies for developing countries. It attempts to include a framework for further research to explore the uptake of prefabricated houses in developing countries.

Keywords: Housing in developing countries, Offsite Manufacturing, legile supply chain, Last Planner™ System.

Introduction
The construction sector represents a significant part of the Gross Domestic Product (GDP) and employment in most countries. In many developing countries, the construction industry is one of the second largest economic sectors (Preece et al. 2011). The industry commonly includes three broad activities: residential building, non-residential building and engineering construction. More than 50% of the world’s population lives in developing countries at high population densities and increasing urbanization (Raftery et al. 1998). Moreover, most of those countries do not have sufficient basic infrastructure to permit rapid economic development. As a result, the supply of houses is inadequate (Preece et al. 2011). The economic-related factors such as consumer price index, changes in the interest and inflation rates are the key driving factors to the demand and supply of houses. Developing countries Government policies, the availability of skilled labor and building materials resources play important roles in the residential building sector. To provide affordable houses within these challenges, some initiatives have been introduced. These

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include Mass House Building Projects (MHBPs) and a sustainable building model for developing countries (Ahadzie et al. 2008). Some initiatives urge for studies of the applicability in transferring the building systems from developed countries to the developing countries. Melchert (2007) reviews the applicability of the Dutch model of sustainable house building to developing countries and finds that the construction sector in developing world remains quite reactive and usually adopting crisis-oriented management approaches. The house building industry suffers from many issues. Many issues are related to quality deficiencies and high production costs of housing. Nevertheless, the house building industry still operates traditionally by focusing on the profits, but not on the house end-user value. As a result, the amplified customer expectations and the international competition, the main driving forces behind changes in house building, are neglected. Improving the house building supply chain is a guarantee to survive in this competitive environment. Some house builders make efforts to improve their performance through inspired ideas from the manufacturing industry, particularly from the production systems i.e. mass customization, lean and agile manufacturing and supply chain management. Applying the manufacturing systems into house building supply chain is referred as offsite manufacturing Hosmer et al. (2013). This application is based on reducing the onsite activities to be undertaken offsite. In this case, it is expected that the activities can be achieved more efficiently in a controlled environment.

Urged by house building issues in developing countries, this paper suggests processes for future research to approach these issues and contribute to housing improvement in these countries. The paper proposes an OSM supply chain based on lean and agile principles. Additionally, the Last Planner™ System (LPS) is reviewed for better coordination among supply chain stakeholders. Although the application of leagile in house building is explained in the previous research of Naim et al. (1999), Childerhouse et al. (2000) and Mostafa et al. (2014). However, these research works have been done in developed countries contexts. Minimal research on applying OSM using lean and agile concepts was found in developing countries. This paper bridges the gap and proposes an OSM supply chain for the housing delivery in developing countries.

**Literature Review**

Offsite Manufacturing offers several benefits such as improve the onsite safety by providing cleaner and tidier site environment, enhancing finished house quality under factory production, reduce waste generation, shorten house completion time and fewer house construction costs (Goulding et al. 2014). The house components/modules are produced in offsite factories and transported to the construction site to be assembled. The factory production shows the closest analogy to manufacturing industry. In spite of the benefits of the OSM, the factory physical production has several forms of waste such as waiting time, transportation, inappropriate processing, excessive inventories, defective products and unnecessary motions (Womack and Jones 2011). Moreover, the OSM houses supply chain suffers from several drawbacks such as high initial cost, lack of flexibility in houses design and comprehensive quality control and testing techniques. Furthermore, three major problems appear in using two working locations (onsite and offsite) including broken junction, jumbled jobsite process and vague demands from unclear customers (Chang and Lee 2004). As a result, it leads to slower responsiveness of the house building supply chain.

A supply chain is a network of materials, information, and services processing links with the characteristics of supply, transformation, and demand (Chen et al. 2013). The term supply chain management includes coordination and integration, cooperation among chain members, and the movement of materials to the final customer. In general, OSM supply
chain includes suppliers, manufacturer, transporters, distributors, retailers and customers. The supply chain must be managed to achieve the house end-user. House builders can achieve the house end-user value through maximizing house quality, service level (customer/product support, product service and flexibility to meet customer demands), safety, and sustainability. Whereas, minimizing the house completion time and house construction costs. Lean and agile concepts have the capabilities to adjust the house end-user value through different strategies based on customer demand.

Lean and agile manufacturing concepts are recognized for enhancing the uptake of OSM (Blismas and Wakefield 2009). The key characteristic of lean concept is the waste removal, while agile is the market responsiveness. Lean and agile can be combined within the same supply chain using a decoupling point (Purvis et al. 2014). A combination of the two concepts is called leagile. Previous research confirm that the applying of lean and agile principles facilitate manufacturing through increasing efficiency, improving quality and safety, reducing lead time, reduce human efforts, reduce investment in tools, improving the flexibility and responsiveness (Koskela 1992; Vrijhoef and Koskela 2000). Therefore, lean and agile concepts have potentials for managing the offsite and onsite processes of the house building supply chain.

Research Methodology
To apprehend the housing supply situations in developing countries, the methodology is designed into four phases to systematically collect and analyze the relevant information. A review of background studies and literature was conducted at the first phase of the research. At this stage, opened online databases were explored. Data collection from the databases focused on the current initiatives employed to commonly generate prefabricated house building in developing countries. The range of the search was limited from 1992 onwards to match with the lean concept which has been introduced to the construction sector by Koskela in 1992. The second phase was to explore the application of lean and agile concepts in the prefabricated house building within the data collected from the first phase. This phase included the studies of current application and challenges of lean and agile application in developing countries. The third phase evaluated potentials of applying synergistic supply chain for prefabricated house building. The fourth phase was to construct a proposed model of synergistic supply chain that could contribute to the improvement of housing supply. The model development relied on the data analysis from the previous phases. The methodology framework of this study is demonstrated as in Figure 1.
Research findings and Discussion
The opened online search discovered 80 accessible publications from 1992 to 2014 that reflected OSM or prefabricated house building concepts practiced in developing countries namely Bosnia and Herzegovina, Botswana, Brazil, Central African Republic, Chile, China, Columbia, Costa Rica, Egypt, Ghana, India, Indonesia, Iran, Jamaica, Kenya, Nicaragua, Nigeria, Peru, the Philippines, Saudi Arabia, Tanzania, Turkey, Uganda and Vietnam. Out of 78 publications, only 16 articles contained the lean concept. The evidence of using a combination of lean and agile concepts was unlikely to be found in articles of OSM in the developing countries. The findings discovered housing supply situation and the OSM practice in those countries are discussed as following.

House Building in Developing Countries
The growing concentration of people in the developing countries is obvious. Moreover, the increasing rate of urbanizations has accelerated its shelter needs [19]. Therefore, the issues regarding the quality of living environment, water drinking, electricity, sewage systems and waste disposal have been arising. The housing problem is a key factor impacting the quality of living. In some developing countries such as Colombia, Egypt, Ghana, India, Jamaica, and Nigeria, there are a great number of unaffordable houses (Follain and Jimenez 1985; Hubacek et al. 2007; Kolo et al. 2014; Potter and Lloyd-Evans 1998; Tiwari 2001). The majority of people living in the developing countries cannot afford a quality house. The economic and market conditions force them to live in a poor housing quality environment. Housing providers are in a continuous challenge to provide affordable and high quality houses. Housing agencies have invested billions of dollars in innovative urban development projects which are designed to facilitate the supply of adequate housing [19]. Mass House Building Projects (MHBPs) is one of the most established projects of the construction industry in most the developing countries. MHBPs comprise of the largest contributor, up to 60%, to the construction GDP (Ahadzie et al. 2008).

The MHBPs term has derived from the manufacturing sector and it describes the mass production techniques of housing projects. The term consists of some notable characteristics including a requirement for more standardized designs, building domestic residences, no customized construction, sharing of a project location under the same contract conditions (Ahadzie et al. 2008). This type of construction project may aid unmet demand in housing acquisition. The unmet housing demand is not a new issue. The situation in developing countries can be dated back to the work of Follain and Jimenez (1985). Similar situations of unanswered housing demand are mentioned in Tiwari (2001) representing housing building situations in India. It is claimed that the shortage of affordable housing has arisen from the increase of construction costs. With limited support from the government, less innovative housing production, lack of resources control process and shortage of house-building materials and components, the unaffordable housing situations have become critical, especially when high demand and inadequate housing supply create sky-rocketed house prices. Taking all requirements to deliver a massive house building project and the shortage of housing supply into account, the idea of prefabricated housing systems can be employed to improve the situations. When the system is effectively operated, it enables the increase in housing supply that can fulfil the housing shortage.

OSM Situation in Some Developing Countries

**OSM in China**
The OSM is known in China as Industrialized Building (IB). It is agreed through many research that IB have a key role in the Chinese residential development due to its benefits
in improving quality, productivity, cost-effectiveness, safety and sustainability (Zhang et al. 2014). However, the uptake of prefabricated was found limited due to the lack of understanding the potential benefits of prefabricated houses. The challenges of the prefabrication technology in China were persistently mentioned. The key challenges included lack of manufacturing capability, product quality problems and lack of supply chain (Arif and Egbu 2010). It was to argue that any achievement of these challenges would provide a fundamental development for local construction sectors for future implementation of prefabrication.

OSM in India
In India, a growing demand for housing was reported. The projected demand was nearly 27 million houses required by 2012. It was noted that 99% of these houses were needed by households in the lower income group (RCIS 2011). Therefore, the Indian Government and construction/manufacturing industries embraced a high volume of housing production with high quality. India has established prefabricated and modular technologies in its construction sector. The India Concept House (ICH) represents construction of affordable housing using prefabricated technology. ICH is considered as an innovative prefabricated housing solution that could help to achieve cost savings (range of INR 900-1200 per sq. ft.) and reduce construction time by 90%. The prefabricated building system enables a 23 square meter house to be built in four weeks and 93 square meter house to be built in six weeks. The ICH conceives as both a dwelling for inhabitation and as a process by which houses are produced through a managed supply chain. ICH designed as 23, 46, 70 and 93 square meter increments that facilitating expansion from one room to four rooms. The prefabricated houses are generally considered as cost effective, quick to assemble and sustainable. However, the maturity of prefabricated technology was found to be steadily developing. It was suggested that the improvement to prefabrication maturity should include the whole supply chain of prefabricated house building (RCIS 2011).

OSM in Malaysia
The research found that the prefabricated house building in Malaysia has reached market maturity. The Malaysia Government has adopted the Industrialized Building Systems (IBS) in the housing projects to improve delivery timing, and producing affordable and quality houses (CIDB 2012). Besides adopting IBS, the government has well established IBS legislation and building codes to enhance the uptake of high quality prefabricated houses for the construction sector. Nevertheless, supply chain integration was urged to maintain the competency of future house building supply (Azman et al. 2010).

OSM in Tanzania
Kalokola (2014) mentioned that prefabricated houses are still rarity in East African countries. Mwamila and Karumuna (1999) studied the advantages of applying semi-prefabricated concrete construction techniques in the Tanzanian housing industry. The highlighted benefits included saving of up to 19% of direct total costs and reducing construction time up to 57%. The concept of prefabricated house building started in Dodoma, the capital of Tanzania, in 2013. The Capital development authority was in charge of planning and development. This conceptual idea aimed to deliver many low cost houses within a short period. Future studies on this project may shade new light to Tanzanian housing growth and house quality development.

OSM in Egypt
The Egyptian housing sector has been encountering a shortage of supplying affordable houses for the low-income group of population. The Central Agency for Public Mobilization and Statistics (CAPMAS) reported shortage of around 40,000 dwellings
The factors contributing to the situation can be classified into economic, legislative, social and construction methods. Although there is considerable concern over the housing situation, the combined efforts of both public and private sectors have struggled to meet the growing demand. Addressing the shortage situation by suggesting new construction methods and building materials were found to be minimal. The OSM in the Egyptian context was found under the name of prefab. It was found that the experience of prefab in Egyptian context only limited to caravan offices or precast concrete. The market of prefab is only produce temporary offices and caravans for the major infrastructure projects or precast buildings (Arabian Construction House for Prefab Building 2014).

**OSM in Nigeria**

Kolo et al. (2014) stated that the OSM in Nigeria still gradually emerging based on learning from other developed countries. They highlighted the core OSM uptake barriers in Nigeria including reluctance to innovate, paucity of codes and standards, supply chain integrations, and skill requirements. To address these barriers, governmental support is a pivotal in helping to establish OSM as a viable alternative to traditional approaches. They observed the need to encourage the awareness of OSM should be through better government policies, and through skilled supply chain partners.

**OSM in Saudi Arabia**

The awareness of prefabrication technology was positive in the construction sector in Saudi Arabia. The prefabrication technologies were found limited to concrete components used in building bridges, wall and façade panels for multistory buildings, and temporary structures such as site offices and portable toilets. The concept of prefabrication was not well-accepted as a key part of construction processes. The growth of manufacturing sector and the promotion of construction-related manufacturing were considered as possible ways of increasing the adoption of prefabrications technology in Saudi Arabia (Aburas 2011).

**Lean and Agile Concepts for OSM**

Lean concept origins are traced to Toyota Production System (TPS). Lean concept has significant interest in the construction sector since Koskela (1992) has conceptualized in three corresponding ways namely transformation of materials into building structures, flow of materials and information through various building processes, and value generation and creation for customers through the elimination of value loss. Lean construction can be defined as a model of building production management based on production management theory. It aims to make the value stream as the centre in the delivery process of construction project by using the professional skills and methods to achieve maximisation of the customer value and minimisation of waste (Abdelhamid et al. 2008). Lean construction practices include pull system, visual management, continuous improvement, Last Planner System (LPS), 5S process, reduce batch size, standardise work structuring and error proofing.

The initiative of agile construction was established in direct response to the Latham report (Lee 2003). The report highlighted the UK construction industry requirement to reduce the construction cost by 30% by the year 2000. To achieve this target the whole industry needed to change. Benchmarking was one method to stimulate the required change in the construction practices. Agile construction exemplifies the characteristics of visibility, responsiveness, productivity and profitability. Agile comprises some management tools such as virtual enterprise, concurrent engineering, information
technology (i.e. Computer Aided Design/Computer Aided Manufacturing (CAD)/ (CAM)) (Daneshgari 2010).

Integration of lean and agile is the best solution to answer all the production issues in the world class market competition (Purvis et al. 2014). Combining lean and agile within the whole supply chain can be accomplished by using the decoupling point and known as leagility. In general, the decoupling point separates the supply chain into lean in the upstream and agile in the downstream. Lean concept is the suitable alternative where there are high volume, low variety, and low predictable change environment. Agile concept is the appropriate where there are high variety, low volume, and high predictable change environment.

**OSM House Building for Developing Countries**

The prefabricated house building supply chain can be visualized as shown in figure 2. It comprises the suppliers, offsite factory, contractors/sub-contractors, construction site and customers. The Last Planner™ System (LPS) is used to establish a better coordination among supply chain stakeholders. LPS is used to transfer planning responsibility between construction organization management and the field persons. The system facilitates the workflow so that labor and material resources can be more productive (Forbes and Ahmed 2011). LPS encompassing four levels of planning processes with different consecutive spans: master scheduling, phase scheduling, Look-ahead Planning (LAP), and Weekly Work Planning (WWP).

![Figure 2. OSM house building supply structure.](image)

Master schedule is describing work to be carried out over the entire duration of a project. It identifies major milestone dates and incorporates critical path method logic to determine overall project duration (Hamzeh et al. 2012). Phase scheduling generates a detailed schedule covering each project phase such as foundations, structural frame, and finishing. The phase employs reverse phase scheduling and identifies handoffs between the different specialty organizations to find the best way to meet milestones stated in the master schedule. LAP indicates the first step of production planning with a time frame ranging from two to six weeks. At this phase, activities are broken down into the level of processes, constraints are identified, responsibilities are assigned, and assignments are made ready (Ballard and Howell 2004). WWP represents the most detailed plan in the LPS showing interdependence between the works of various specialist organizations. WWP guides the production process. At the end of each plan period, assignments are reviewed to measure the reliability of planning and the production system. Analyzing reasons for plan failures and acting on these reasons is used as the basis of learning and continuous
improvement. This paper suggests two decoupling point positions to manage the OSM supply chain for achieving the house customer demands in the developing countries. Each position is suitable for a house building strategy.

**Build to Stock Strategy**

The first decoupling point is located after the onsite construction activities and finished house building. The houses are designed and built to meet low income group. In this strategy, the governments of developing countries could ensure its capacity to serving large-size accommodation projects within the contracted timeframe. Therefore, the activities before selling should be lean to fit the costs. Agile is suitable after the decoupling point to diminish the delivery time, meet the customer satisfaction and speed of return on investment.

**Self-Building Strategy**

In the second strategy, the decoupling point is located at house components suppliers. This strategy is suitable for the self-building houses which a homeowner is closely involved in every aspect of the house building. This strategy is developed on a similar concept of the house building and the personal computer assembly. The house customers are at their own responsibilities to hire builders to assist them with some onsite construction activities. The key role of prefabricated house building organization is to supply the house modules and components to the suppliers. House building organizations should aim at making the house designs as simple as possible. The organizations should provide variable designs to meet different types of house needs. Lean is suitable to run the house modules factory, while agile is the best option for quick responses to demands of self-build house suppliers.

**Conclusions**

Offsite manufacturing has been introduced to increase housing affordability in developing countries. The employment of OSM can be recommended to any building organizations that search for more efficient and responsive strategies to meet growing house demands. In house building sector of developing countries, combining lean and agile concepts may require more study to examine their effect on time reduction and cost overrun. The cutting-edge knowledge in manufacturing sector may provide potential improvement of OSM systems needed by the sector. In a broader sense, the system can be seen as an attempt to increase the supply of affordable housing. Two strategies of OSM systems have been proposed as solutions to enhance the delivery of housing in developing countries. These strategies are built to stock and self-building house.

**Limitations and Suggestion for Future Research**

This paper has been constructed using the existing databases related to OSM in the context of developing countries. The proposed OSM supply chain strategies could be formed a framework for further research relating to OSM in developing countries. As such, it may be useful for housing policy makers, construction executives, managers, designers, developers and scholars to rethink about housing issues by conducting future empirical research within and beyond the domain of construction. For comprehensive realization of OSM benefits to developing countries, more research that rooted in understanding the theory of manufacturing and construction is strongly recommended. Moreover, adopting OSM policies requires collaboration with planning and legislation research.

**References**


Adoption of Reverse Logistics in South Australian Construction Projects: Major Drivers

M. Reza Hosseini1, Raufdeen Rameezdeen2, Nicholas Chileshe3, and Steffen Lehmann4

Abstract

This paper aims to investigate and analyse the perceptions of South Australian construction practitioners on drivers associated with adoption of reverse logistics (RL). To this end, semi-structured interviews were conducted with eight practitioners to collect data and the interview transcripts were analysed using the NVivo (version 10) software package. The study takes advantage of integration of qualitative and quantitative analysis of interview transcripts to rank the drivers on the basis of their relative importance. Results suggested that factors associated with regulations and obligations could act as the most important drivers to promote adoption of RL. The drivers associated with financial gains were identified as the second important category of drivers in RL adoption. Furthermore, environmental concerns were regarded as “slightly important” for practitioners in the South Australian construction context. The study concludes with presenting a model mapping the factors affecting the level of influence of drivers in construction projects in South Australia (SA).

Keywords: adoption, construction industry, drivers, reverse logistics, South Australia.

Introduction

The large share of the construction industry in consuming world’s resources and the massive amount of waste dumped into landfills have become serious issues for many countries (Gorgolewski, 2008). Apart from environmental aspects, the construction industry is still deemed inefficient largely because of the deficiencies with its supply chain management (SCM) (Segerstedt & Olofsson, 2010). This is a contemporary issue for the Australian construction industry as according to recent evidence, industry should take advantage of all viable measures for enhancing the efficacy of its SCM (Allen Consulting Group, 2010).

In response to such issues, adopting reverse logistics (RL) would be a remedial solution that could ease up the detrimental environmental effects in tandem with boosting efficiency (Schultmann & Sunke, 2007a; Aidonis et al., 2008; Kibert, 2012). Nevertheless, RL has yet to become commonplace in the construction industry (Kibert, 2012) and even has been described as an ‘unexploited’ area (Nunes et al., 2009).

As any unconventional strategy, promoting the adopting of RL within the construction context might not materialise without factoring in the intentions of stakeholders

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(Akbarnezhad et al., 2014). Yet, RL is still an under-researched area within the construction context (Chini & Bruening, 2003; Hosseini et al., 2013) and the body of knowledge is not able to provide the field with such information. Moreover, a wide range of drivers for adopting RL rest on the local circumstances and the social values prevalent in the community (Schultmann & Sunke, 2007b). Thus, in view of the lack of such studies in SA, investigating the drivers for RL becomes very relevant and the first step towards promoting RL. That is, the findings would facilitate translating cradle-to-cradle principles such as RL for practical implementations within the construction industry as stressed by van Dijk et al. (2014). Besides, this would raise the general awareness of RL major aspects in construction projects as a prerequisite for extensive adoption of RL within the construction context in other countries as recommended by Hosseini et al. (2014a). It is noteworthy of mentioning that conducting the present study in SA would provide a wealth of knowledge for the field due to maturity of SA in dealing with C&D waste and enforcing environmental regulations as a leading state in international levels (UN-HABITAT, 2010).

**Literature Review**

*Definitions*

As defined by Govindan et al. (2012, p.204) “reverse logistics is the process of moving goods from their typical final destination to another point, for the purpose of capturing value otherwise unavailable, or for the proper disposal of the products.”. For the construction industry, Nunes et al. (2009, p.3717) defined RL as “how the area of business logistics plans, operates and controls the flow of logistics information corresponding to the return of post-sale and post-consumption of the goods to the productive cycle through reverse distribution channels, adding value of various types to them: economic, ecological, legal, logistical, corporate image, etc.”.

**Table 1. Major drivers associated with adopting RL**

<table>
<thead>
<tr>
<th>Category</th>
<th>Drivers</th>
<th>Scholarly support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Drivers</td>
<td>Reducing consumption of raw materials and energy</td>
<td>(Schultmann &amp; Sunke, 2007a; Gorgolewski, 2008; Sassi, 2008)</td>
</tr>
<tr>
<td></td>
<td>Reducing waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reducing pollution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Facilitating meeting the requirements of environmental regulations</td>
<td>Davison, 2012)</td>
</tr>
<tr>
<td>Financial Drivers</td>
<td>Reducing costs through use of less raw materials and energy</td>
<td>(Addis, 2006c; Leigh &amp; Patterson, 2006; Hiete et al., 2011)</td>
</tr>
<tr>
<td></td>
<td>Increasing revenue through selling recovered materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reducing the costs of landfilling and disposal</td>
<td></td>
</tr>
</tbody>
</table>
Social Responsibility

Drivers

<table>
<thead>
<tr>
<th>Drivers</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving health in the community (due to reducing pollution)</td>
<td>Addis, 2006c; Leigh &amp; Patterson, 2006; Aidonis et al., 2008; Denhart, 2010</td>
</tr>
<tr>
<td>Creating more number of jobs</td>
<td></td>
</tr>
<tr>
<td>Enhancing the image and reputation of the businesses that adopt RL</td>
<td></td>
</tr>
</tbody>
</table>

Drivers for adoption of RL

The major drivers of RL within the construction context as identified in previous studies are shown in Table 1.

As captured in Table 1, implementing RL makes construction companies capable of reusing materials and products extracted from existing buildings. This diverts huge amounts of used items from landfills, which is imperative to consider sustainability in the construction context. It has been observed that implementing RL in a construction project could use about 85% of the materials extracted from an old building. Accordingly, associated costs of construction projects could be about 30%-50% lower (see Gorgolewski, 2008 for details of calculations). Communities would suffer from less health problems due to exposure to less pollution as a result of adoption of RL. Additionally, businesses that adopt RL will get an image uplift. Apart from findings of previous studies, as implied by Schultmann and Sunke (2007b), a wide range of RL drivers are interrelated with socioeconomic and cultural aspects, which might glaringly differ for construction practitioners in SA. This necessitated investigating such drivers within its natural context in SA as described in following.

Research Methods

Drawing upon a qualitative approach becomes relevant in this study taking into account the exploratory nature of research purposes alongside the novelty of the topic in the built environment field as discussed by du Toit and Mouton (2012). This is further justified considering the objective of this paper to discover the drivers of South Australian practitioners to adopt RL, which entails a rigorous exploration of their real-life needs. As such, one of the most effective methods for assessing needs in its natural context is proven to be conducting interviews as a qualitative approach (du Toit & Mouton, 2012). The study adopted a semi-structured interview approach taking into account the findings of previous studies as the questions and as a priori list of themes for analysing data. Each interview lasted approximately one hour, and all the interviewees were selected based on their willingness to partake in the study. This led to a small sample size of 8 interviewees as captured in Table 2. Despite such a limitation, deploying self-selected cases might yield valuable results due to their motive to express feelings or opinions about the research question as stated by Simms and Rogers (2006). Besides, according to Bazeley (2013), size of the sample in qualitative research becomes irrelevant due to the fact that the value of the study is based on quality of data.

It is widely acknowledged that using computer packages such as NVivo would enhance the rigour of qualitative data analysis procedures (Bazeley, 2013). As such, analyses of data were conducted using Nvivo 10. As stated by Lewins and Silver (2007) Nvivo 10 is one of the main available software packages for analysis of unstructured data. Nvivo 10 falls within the category of packages for analysing qualitative data termed by Bazeley and Jackson (2013) as QDAS (qualitative data analysis software). Nvivo has been developed by QSR International, equipped by a set of tools to assist researchers in analysing
To investigate the level of importance of drivers, the ability of NVivo in terms of converting qualitative data into quantitative coding was deployed according to the procedure recommended by Bazeley (2013). Whenever one part of a transcript was coded as one of the drivers, the same passage was also coded as an importance code. Levels of importance for each driver was categorized into three themes comprising very important, important and slightly important. Afterwards, befitting queries were run to investigate how each driver was considered to be important, and also compare how different respondents had seen the importance of the drivers as explained in below.

### Table 2. Profile of respondents

<table>
<thead>
<tr>
<th>Title</th>
<th>Designation</th>
<th>Type of business</th>
<th>Years of experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CEO and owner</td>
<td>Salvaging and demolition</td>
<td>25</td>
</tr>
<tr>
<td>B</td>
<td>Executive manager</td>
<td>Construction</td>
<td>15</td>
</tr>
<tr>
<td>C</td>
<td>Managing director</td>
<td>Consulting</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>Executive manager</td>
<td>Salvaging, recycling, demolition</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>Marketing manager</td>
<td>Salvaging, recycling</td>
<td>21</td>
</tr>
<tr>
<td>F</td>
<td>Senior environment protection officer</td>
<td>Environmental regulation</td>
<td>N/A</td>
</tr>
<tr>
<td>G</td>
<td>Architect</td>
<td>Designing</td>
<td>6 in SA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Overall 13 years)</td>
</tr>
<tr>
<td>H</td>
<td>Builder</td>
<td>Construction, renovation and refurbishment</td>
<td>15</td>
</tr>
</tbody>
</table>

**Major Drivers**

The patterns emerging from the interview transcripts on major drivers of RL as perceived by respondents are illustrated in Table 3. The findings of the study reaffirmed the nature of the drivers for RL as detected by previous studies. Besides, a couple of new themes emerged through analyses of transcripts as discussed in below.

It could be inferred from Table 3 that drivers which are related with requirements and necessities are ranked as very important by the respondents. That is, meeting the requirements associated with such drivers is obligatory. This refers to contractual requirements and environmental regulations and acknowledges the statements by Gorgolewski (2008) regarding the influential role of such drivers. Other items in ‘very important’ rank refer to cases in which consumers have no choice but to purchase salvaged items in RL process such as when size, type or shape of product becomes unique. Likewise, as stated by interviewee A, customers come for purchasing salvaged items when a building project involves making small alternations to houses. Addis (2006b) refers to this by stating that small-scale builders in need of limited items source their goods from salvage yards. Presumably, in such cases purchasing salvaged items in limited volumes
might be more cost-effective as opposed to buying virgin items that might not be available in small quantities.

This is the case also when people look for high quality products. To underpin this, Interviewee H regarded quality as one of the main driving forces for people purchasing structural salvaged items. Similarly, the growing interest for high quality salvaged items in Canada was mentioned by Earle et al. (2014, p.27) postulating “Interest is growing as the inventories of old grow woods and certain species of wood are becoming increasingly more difficult to acquire. As mentioned about high quality architectural items such as posts, beams, and trusses are popular reuse items.”.

Table 3. Ranking RL drivers based on scaled codes

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Very important</th>
<th>Important</th>
<th>Slightly important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposal savings</td>
<td>8.57%</td>
<td>87.35%</td>
<td>4.08%</td>
</tr>
<tr>
<td>Enhancing long-term performance</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Transportation savings</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Value for money</td>
<td>51.48%</td>
<td>48.52%</td>
<td>0%</td>
</tr>
<tr>
<td>Contractual requirements</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Environmental incentives</td>
<td>9.18%</td>
<td>29.59%</td>
<td>61.22%</td>
</tr>
<tr>
<td>Environmental regulatory requirements</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Enhancing marketing competitiveness</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Green image</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Mentality and culture of contractors</td>
<td>18.52%</td>
<td>81.48%</td>
<td>0%</td>
</tr>
<tr>
<td>Supporting local economy</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Sustainability concerns</td>
<td>0%</td>
<td>89.61%</td>
<td>10.39%</td>
</tr>
<tr>
<td>History and story behind products</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Higher quality of salvaged items</td>
<td>1.96%</td>
<td>98.04%</td>
<td>0%</td>
</tr>
<tr>
<td>Small projects needing small amount of materials</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Technical incentives</td>
<td>0%</td>
<td>74.58%</td>
<td>25.42%</td>
</tr>
<tr>
<td>Uniqueness of products (size, shape, type of material)</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Interviewee A and G stated that some customers opt to purchase salvaged items or using salvaged items in their new buildings considering “the history, story and sentiment” or “good memories” of recovered items.

Attempting to enhance long term performance within the business environment by contractor was also considered a very important item as in Table 3. Such finding reconfirms the premise of Carter and Ellram (1998, p.97) asserting “the primary driver from outside the firm include pressure from the regulatory and output sectors of the firm’s task environment.”.

The drivers associated with profit and savings are perceived as important or very important. This reflects the high priority of such items when it comes to drivers of RL in the South Australian construction industry. According to Hosseini et al. (2014b), drivers of RL associated with money are the most important ones for industry practitioners. Likewise, Interviewee E postulated that “people recycle as long as it is cost effective for them”. Similarly, Interviewee B indicated that their company would consider sustainability providing that some type of financial gain is included. Interviewee G as a designer described the drivers of clients by opining that the first priority for our clients is budget. This acknowledges that apart from obligations for adopting RL, the most important drivers are those which result in financial gains for practitioners in the construction industry. Such insight has been acknowledged in the construction literature as according to Smith et al. (2007, p.12) RL is implemented if you “show them the savings”. Likewise, Kuehlen et al. (2014) called for quantitative studies to show the benefits of RL in Germany.

The third category of drivers in terms of relative importance concerns the drivers associated with non-financial gains, environmental issues, supporting the local economy and enhancing the environmental image in the community. In comparison to the drivers associated with money and profit, this category was of noticeable lower importance as perceived by the respondents as captured in Table 3. Yet, drivers with the lowest importance were those concerning environmental concerns and incentives as evident from Table 3. This reflects the fact that such drivers should not be regarded as highly influential promoters of RL in the construction industry in SA.

Factors Influencing RL Drivers

According to Parrilli and Elola (2012), studies on drivers of novel practices should attempt to open the “black box of drivers”, namely alongside identifying the drivers, the major aspects affecting the driver should be analysed. Interviewees discussed the drivers for them to adopt RL and in most cases went on to describe the major factors which could positively or negatively affect the level of influence of drivers for adopting RL in SA. As such, the main factors emerged within the interview transcripts are illustrated in Figure 1.

Potential for on-site sorting

The salience of on-site sorting as a promoter for deconstruction activities was mentioned in Canada (Earle et al., 2014) and it was regarded as an attractive practice for the US as stated by Guy (2014). Likewise, as illustrated in Figure 1, six out of eight interviewees stressed that possibility of on-site sorting is a major promoter for drivers associated with RL. Interviewee C and Interviewee E opined that on-site sorting will facilitate achieving the benefits of RL by reducing the costs of the process. For this reason, Interviewee C stated that “regulations should encourage for sorting at source”.

Nevertheless, respondents’ views were contradictory on prospect of on-site sorting. Interviewee E and B contended that on-site sorting is possible in SA. Even more, Interviewee F postulated that on-site sorting is allowed according to contemporary regulations. However, Interviewee A mentioned that on-site sorting is not viable anymore
due to safety regulations and environmental codes. Interviewee C went on to imply that on-site sorting in SA might end up in receiving fines because this is regarded as dumping waste according to imposed regulations. It could be proffered that on-site sorting potential can enhance the effects of RL drivers as identified, yet there is a lack of knowledge about the regulations and the possibility of sorting on-site among the construction practitioners in SA.

Figure 1. Major factors affecting the level of influence of RL drivers (Nvivo output model)

Project type

Unlike what one would guess in regards to the support that should be provided by the government and corporations for RL, it became apparent that a major part of RL drivers are achievable only within the private sector and small projects. To emphasise the effects of project type Interviewee A stated that “we rarely come across a commercial building that uses us for salvaging”. Likewise, Interviewee D implied that using salvaged products in projects funded by the government is troublesome as experience shows less trouble in working with the private sector. The same trend was observed in the US by Guy (2014, p.147) stating “the majority of deconstruction project clients are private homeowners”. The same insight was indicated by Interviewee A opining that “the domestic sector is very huge compared to the commercial sector, both as customers and providers of salvages material”.

The reason for this became fathomable when Interviewee A stated that they avoid high profile projects having big players in it, mainly because unions get involved and interfere with their industrial relations issues. As another cause, Interviewee C explained that there is enormous pressure on the builder and the demolisher to remove the old buildings and clean the site to start the project in commercial and governmental project due to contractual obligations. Such tight scheduling negatively affects the drivers for adopting RL in such projects. Therefore, it could be concluded that type of project in terms of the source of funding, its size and the nature of the contract could modify the level of influence of drivers of RL. It was also revealed that small and private projects are more likely to attract RL adopters as opposed to governmental and high profile projects.
**Partnership**

According to Addis (2006a) and Leigh and Patterson (2006), establishing a partnership between all the parties involving RL is necessary to assure its success. It was also asserted by Carter and Ellram (1998) that to overcome uncertainties, players in RL should increase the level of coordination with their main suppliers. This was endorsed by the statements of the interviewees, because they mentioned the great role of establishing partnership to enhance the positive aspects and drivers of RL. **Interviewee A** postulated that they have developed a good partnership for implementation of RL and their sources of information for such opportunities are their partners in the industry by stating “we have very good informal partnerships with contractors, architects, and demolishers. The demolition contractors call us whenever there is a potential for salvaging”. Even more, **Interviewee B** described the whole process of RL as a partnership by opining “it is like a partnership”. This establishes the salience of developing partnership for enhancing the drivers of RL within the construction industry. Additionally, the findings revealed the lack of formal arrangements to support parties involved in exchanging information regarding RL in SA.

**Consumer attributes**

It was revealed by Guy (2014) that consumers in deconstruction field are largely medium/high-income home owners in the US. This was endorsed by the respondents in SA as **Interviewee G** mentioned that rich clients are much more interested in implementing RL activities. Similarly, **Interviewee H** postulated that “most of the clients looking for salvaged items for the sake of vintage style are wealthy”. This reflects the fact the financial strength of consumers is a determinant for drivers of RL. Another factor associated with demographic attributes of the consumers was age. That is, as asserted by **Interviewee C**, “mostly young practitioners in the building industry are against using old products and materials”. In the same vein, **Interviewee A** pointed out that “baby boomers like salvaged products due to some intrinsic value they find in these materials”. As a result, drivers of RL are not the same for all potential consumers in the community and differ in accordance to the age or income level. A corollary for this could be the necessity of considering different incentives and dissimilar policies for promoting RL within different groups of people in the community.

**Conclusions**

It was revealed that drivers should not be regarded as of equal influence for promoting RL adoption within the construction context. It also came to light that drivers stemmed from obligations and requirements have the strongest effect while drivers associated with environmental and social values could not be regarded as highly influential. Even more, it could be concluded that different regulations and government agencies have contradictory effects on RL adoption levels. As such, government regulations (i.e. the most potentially important drivers) would practically obstruct RL in many ways. Another major finding demonstrated the dependency of drivers on a wide range of factors. As such, different conditions, projects and people are influenced by different drivers for implementing RL.

Future studies should be aimed at unearthing the true perceptions and current practices commonplace concerning RL within the building lifecycle in different regions and countries. In addition, studies targeting the regulatory and technical aspects of using recovered and recycled items in new buildings would greatly contribute to the field. Another fertile ground for research would be investigating the measure for promoting inclusion of RL requirements within BIM as a novel area for encouraging sustainable construction.
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The Development of a Lean Culture Diagnostic Tool
Karl van der Merwe

Abstract
Prevailing research suggests that organisational culture plays a significant role in successful lean manufacturing implementation. Given the abstract nature of organisational culture it would be useful to crystallise the concept so that efforts may be made to identify actions that lead to a lean culture. Prior research has led to the development of a lean culture causal framework that outlines the categories of leadership actions shown to contribute towards a lean organisational culture. The purpose of this paper is to further extend the idea of a causal framework and to develop a tool that can be used to diagnose organisational culture in the context of the lean philosophy.

Keywords: Change management, lean manufacturing, performance improvement, production.

Introduction
Due to globalisation, the need to adopt a manufacturing performance improvement philosophy is arguably now more important than at any time before. Lean manufacturing has been the first choice improvement philosophy for many organisations around the globe and a positive link has been established in literature between the adoption of a lean philosophy and performance improvement (Netland and Sanchez, 2012). Not all of the lean conversions, however, have been successful and Bhasin (2013) cites a failure to address the question of organisational culture as the primary reason for this phenomena. Given the widespread support for this notion (Bernstein, 2005; Dahlgaard and Dahlgaard-Park, 2006; Kelser, 2012; Stone, 2012) it is reasonable to conclude that research aimed on the topic of organisational culture and, more specifically, lean culture per se would assist organisations with lean implementation. Predictable questions in this regard would include:

- What is an organisational culture?
- What are the characteristics of a lean organisational culture?
- What is the primary source of lean culture change?
- How could the level of attainment (of the characteristics) be measured?

The following sections seek to provide answers to these questions with the ultimate aim of providing a tool that can measure lean culture and provide an indication of areas to address in the case of weak lean cultures.

Organisational Culture
Organisational culture is by its very nature difficult to define and this has led to a situation where various researchers and authors have developed differing definitions. A central theme, however, common to many of these definitions is that organisational culture is a set of deeply embedded, commonly held values and beliefs that influence the behaviours of the employees of the organisation (Deal and Kennedy, 1982; Schein, 1992; Kotter and Heskett, 1992, van der Post, de Coning and Smit, 1998). A popular analogy used to explain the concept of organisational culture is to compare it to an iceberg (Sackman, 1991)

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where the values and beliefs are shown to form thinking and emotions, ultimately resulting in behaviours and results. It is these behaviours and results that are observable (Figure 1) and ultimately measurable.

Figure 1. Organisational culture iceberg model (adapted from Sackman, 1991)

Given that values and beliefs effect the daily decisions that employees make and that all of the organisational processes will be either positively or negatively impacted upon by these decisions it has been widely accepted that organisational culture has a definite link to organisational performance. Kotter and Heskett (1992) concluded that organisational culture has a significant impact on long term performance despite their acknowledgement that studies involving organisational culture are difficult to conduct scientifically. Various approaches to establishing the association between organisational culture and performance have been researched (Bititci, Mendibil, Nudurupati, Garengo & Turner, 2006). The challenge has been to determine how a fairly abstract concept, such as organisational culture, can be linked to a solid and measurable characteristic. One approach relevant to this research is the consideration of organisational commitment as a possible link. Research on this topic reveals a significant correlation between these factors (Rashid, Sambasivan and Johari, 2003). Findings confirm that the type of corporate culture and organisational commitment has a definite influence on performance. Other studies (Lee & Yu, 2004) could not conclusively prove the link between corporate culture and organisational performance, but strongly suggest that culture impacts on a range of organisational processes and, by association, organisational performance.

McShane and Von Glinow (2005) argue that an appropriate organisational culture enhances performance for three reasons. Firstly, organisational culture influences decisions and behaviours. An inappropriate culture, therefore, would cause decisions and behaviours not congruent with the desired or chosen strategies. Secondly, it is suggested that organisational culture provides a common framework for employees, thereby affording them a sense of belonging. This is particularly important as it is widely accepted that a sense of belonging is fundamental to realising superior levels of motivation. Finally, organisational culture provides a framework for employees to understand organisational direction or focus. Automatic responses result in time and effort efficiencies, especially when individuals have an internal frame of reference when faced with choices or problems. Accepting these organisational culture characteristics strengthens the argument for research aimed at measuring prevailing lean manufacturing cultures. Having reviewed this and other literature relating to organisational culture and performance, it is apparent that a strong and positive culture can be viewed as a competitive advantage. It is, therefore, a prerequisite for a successful lean programme.
Lean Organisational Culture
Many types of organisational cultures are in existence and each will have characteristics that either inhibit or enable a chosen performance improvement strategy. Denison (1990) conducted extensive research into this link and concluded that certain types of cultures could support and sustain performance improvement initiatives. Support for this conclusion has come from many other researchers (Rashid, Sambavisan and Johari, 2003; Suppiah and Sandhu, 2010; Keiser, 2012; Bhasin, 2013).

In order to establish cultural traits that support the adoption of lean it is first necessary to understand what lean manufacturing is. Here again, some confusion exists with regard to an exact definition of lean manufacturing. Stone (2012) undertook a comprehensive survey of lean literature spanning four decades and finally concluded that lean is a philosophy centred on differentiating between waste and value. This concept has its roots in the definition of waste provide by Womack and Jones (1996) who defined waste as “any human activity which absorbs resources but creates no value”. Murman (2002) offers a more comprehensive view of lean, defining the philosophy as “the dynamic, knowledge-driven and customer-focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value”.

Although these definitions of lean are useful very few authors provide address the issue of defining a lean culture. Two notable exceptions to the brief statement-like explanations of lean culture include the works of Drew, McCallum and Roggenhofer (2004) and Liker and Hoseus (2008). Drew et al (2004) assert that certain mindsets and behaviours support lean systems. Their explanation of mindsets and behaviours closely mirrors that of organisational culture. It becomes apparent that mindsets cannot be observed, but behaviours can. The lean mindset includes the following five beliefs that provide a frame of reference for actions and decisions:

- Don’t think big; think small and flexible. Lean systems respond rapidly to customer demands and decisions made are, therefore, counter-intuitive to economies of scale. The lean practitioner should instinctively select the option that leads to small batch sizes and includes flexible equipment when presented with a range of options.

- Value is added at the front line. The processes that add value require the most attention. Team members should instinctively gravitate towards these value-adding operations. This mindset is described as genchi genbutsu (Japanese term meaning go to the place of action) in Toyota literature.

- Everyone in the organisation needs to understand how his/her actions contribute to achieving business goals. Apart from understanding the overall organisational goals (mission and vision), team members need to accept the need for change based on perceived gains outweighing perceived losses. Lean thinking requires that members are motivated to take on more responsibility (for example, problem solving) with the understanding that they are helping themselves and others by contributing to the greater good of the organisation.

- The root causes of problems need to be addressed, not just the symptoms. Unstable conditions result in team members continually redirecting efforts to create the required system stability without eliminating the true causes of the instability. Ironically, individuals who find quick solutions to problems are generally praised, despite the fact that the solutions are often short-lived (Arnheiter & Greenland, 2008). Lean thinking requires that team members continue to investigate a problem
until it is evident that the root causes have been identified and suitable countermeasures installed.

- A problem is an opportunity to improve, not to blame. Lean systems can only exist in an atmosphere that encourages problem identification. Team members should unhesitatingly expose problems. The likelihood of team members repeating this process is limited if the consequences of this type of action are negative. Continuous improvement, therefore, will not occur.

Arguably the most important contributor to lean thinking is the Toyota Production system. Liker and Hoseus (2008) maintain that this system is supported by two values; namely, *respect for people* and *continuous improvement*. Employees would be expected to use these two values to guide their daily behaviour and decisions. The ideal lean system incorporates “a production system that highlights problems and a human system that produces people who are able and willing to identify and solve them” (Liker, 2004).

Respect for people is an expansive obligation that includes respect for employees, customers, suppliers, investors and the community at large. This belief manifests itself in respect for individuals and teamwork. Respect for individuals results in behaviour patterns that can be observed. Employees, at all levels, display a desire to understand each other and accept responsibility. Consistency in such endeavours creates mutual trust.

With the afore-mentioned definitions in mind van der Merwe, Pieterse and Lourens (2014) developed a lean culture causal framework (Figure 2) that identifies the actions believed to facilitate lean culture.

![Figure 2. Lean culture causal framework model (van der Merwe, Pieterse and Lourens, 2014)](image)

The model is an extension of a previously developed generic organisational culture change model by the same authors and includes four characteristics of a lean culture namely, employee engagement, situational awareness, consistent behaviour and accountability. The degree to which each of these characteristics is enacted was shown to be positively linked to the presence or absence of a lean culture while the remaining seven
characteristics listed above these four were originally developed as generic organisational culture change factors.

**Source of culture change**

Understanding the source of organisational transformation is necessary if a tool is to be developed that can measure lean culture. Schein (2004) maintains that the actions and behaviours of the leadership group are the primary driving force behind organisational culture change. This view has received wide support from many researchers and authors (Adebanjo and Kehoe, 1999; Bamford and Forrester, 2003; Henderson and Larco, 2003; Rashid, Sambasivan and Johari, 2003; Mann, 2005; O’Donovan, 2006; Liker and Hoseus, 2008; Keiser, 2012).

Hellriegel, Jackson and Slocum (2007) argue that in most manufacturing operations leadership is referred to as “management” and exists at three distinct levels namely first-line, middle and top. First-line managers are normally shop-floor based and are made up of supervisors and production team leaders. Middle management consists of department heads and functional managers who are largely responsible for converting strategies into tactics while top managers are tasked with setting overall strategies. All of these groups are ultimately responsible for the prevailing organisational culture – although many argue that top and middle management carry the most responsibility.

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![Diagram showing the source of culture change](attachment:source_of_culture_change_diagram.png)

**Figure 3. Middle management as change initiators (Bamford and Forrester, 2003)**

Bamford and Forrester (2003) support the concept of middle management as the initiator of change and top management as the ultimate decision makers with regards to change (Figure 3). Acceptance of the source of culture change leads to the reasonable assumption that a lean culture diagnostic tool should focus on measuring the actions of the leadership group with regards to the four previously identified lean characteristics.
Measuring Lean Culture

The first point to consider in relation to lean culture measurement is whether or not an organisational culture can be measured. Many of the characteristics of an organisation are intangible and therefore very difficult to gauge. Hofstede, Neuijen and Sanders (1990) are credited with the first scientific research project linked to the measurement of organisational culture. Their findings showed that an organisational culture could be measured quantitatively, on the basis of answers completed by organisational members to written questions.

Further support for these findings came from (but is not limited to) McMillan and Schumacher (2001) as well as Tucker, McCoy and Evans (2003). The latter group of researchers maintains that an objective organisational questionnaire is preferable because organisational culture is often studied as an independent variable for its potential relationship to organisational outcomes, such as managing change, product quality and productivity. Identifying the nature of these relationships is a significant part of the empirical grounding process through which the meaning of the construct of organisational culture is refined beyond its ordinary parameters. This observation is of particular relevance to current research as the measurement of lean culture is closely linked to both change management, as well as the quest for sustainable performance improvement.

The Instrument

The process of developing an instrument that could measure those characteristics believed to be crucial for lean culture attainment was centred on the four categories of actions identified in the lean culture causal framework. A total of 33 questions are contained in the survey instrument with nine each covering situational awareness, engagement and consistency. The final section dealing with accountability is covered with six questions due to the straightforward nature of this category.

Section 1 (Table 1) explores the degree to which managers have successfully implemented systems aimed at creating a shop floor environment conducive to situational awareness. Literature suggests that an overall awareness of prevailing conditions (within value streams) is one of the prerequisites for the development of a lean culture.

<table>
<thead>
<tr>
<th>Table 1. Questions related to situational awareness.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. This section relates to the levels of awareness on the shop floor. Please indicate to what extent you agree with each of the statements below by circling the appropriate number.</td>
</tr>
<tr>
<td>1.1 The concept of a value stream is widely understood</td>
</tr>
<tr>
<td>1.2 A visitor would be able to identify each shop floor value stream</td>
</tr>
<tr>
<td>1.3 We know what measures are important to each value stream</td>
</tr>
<tr>
<td>1.4 Visual systems provide information about the status of each value stream</td>
</tr>
<tr>
<td>1.5 We constantly monitor our visual systems</td>
</tr>
<tr>
<td>1.6 Employees know the location and extent of each value stream</td>
</tr>
<tr>
<td>1.7 Key processes have been identified in each value stream</td>
</tr>
<tr>
<td>1.8 Problems affecting output have been identified</td>
</tr>
<tr>
<td>1.9 Problems on the shop floor become obvious as soon as they occur</td>
</tr>
</tbody>
</table>

Three distinct groups of activities were identified, each of which were addressed by three questions:
Questions 1.1, 1.2 and 1.6 explore the extent to which managers have pursued actions that create awareness of the concept, extent and boundaries of each value stream.

Questions 1.3, 1.7 and 1.8 gauge the efficacy of actions aimed at identifying factors critical to the success of each value stream, as well as the extent to which employees are aware of these factors.

Questions 1.4, 1.5 and 1.9 assess the degree to which visual systems have been implemented.

Positive responses to the above-mentioned questions would indicate that leaders within the organisation have actively made decisions resulting in an operational environment where team members are constantly aware of the conditions prevailing throughout the length of their value stream.

Section 2 (Table 2) was designed to determine the extent to which management have actively engaged and challenged the employees within the organisation.

Table 2. Questions related to employee engagement.

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<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Leaders participate in shop floor improvement efforts</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.2</td>
<td>Team member’s feedback is valued by supervisors and managers</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.3</td>
<td>Team members are challenged to provide the best solutions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.4</td>
<td>A formal procedure exists for obtaining suggestions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.5</td>
<td>Feedback is provided on all suggestions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.6</td>
<td>Leaders discuss work problems and often offer guidance</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.7</td>
<td>Team members are encouraged to discover improvement opportunities</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.8</td>
<td>Experience and guidance has led to improved problem-solving</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.9</td>
<td>Good suggestions are implemented</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Literature supporting the inclusion of Engagement as a lean culture causal factor (van der Merwe et al, 2014) suggests that meaningful interaction between management and operational team members was a key priority in organisations that have successfully developed a lean culture. The inclusion of the word “meaningful” is significant as it describes the nature of the interaction that is so supportive of a lean culture. Normal communication and the acceptance of mediocrity are transcended by intense engagement and the continual pursuit of original solutions to root-cause problems. Implicit in this process is the understanding both that managers have a deep-rooted conviction that team members are capable of providing such solutions, as well as that team members can rely on managers to coach them in the initial stages. Three distinct groups of activities were identified, each of which were addressed by three questions:

- Questions 2.1, 2.2 and 2.6 determine the extent to which managers actively engage team members and value the input of team members.
- Questions 2.3, 2.7 and 2.8 obtain information about the perceived level of meaningful engagement implicit in the process. This establishes the degree to which participants believe they are either challenging (managers), or being challenged (team members), to provide innovative solutions to problems.
- Questions 2.4, 2.5 and 2.9 explore the extent to which formal systems have been implemented for harvesting suggestions, as well as the perceived efficacy of these systems.
It is proposed that a lean culture will develop relatively quickly in an organisation where managers foster a process of meaningful engagement through altered behaviour and the implementation of effective structures.

Section 3 (Table 3) contains questions related to the consistency of managerial actions. These actions are guided by the vision and mission and are supported by a layered organisation-wide interaction plan. This construct is three-dimensional. It includes *adherence* to the vision/mission that is demonstrated by means of *consistent* decisions taken at *standardised* meetings by the leadership group.

**Table 3. Questions related to managerial consistency.**

<p>| | | | | |</p>
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<tbody>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>A regular schedule of lean feedback meetings exists for all leaders</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.2</td>
<td>Regular lean feedback meetings ensure sustained focus</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.3</td>
<td>All levels of leadership are included in the plan</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.4</td>
<td>Leaders make decisions that support the vision and mission objectives</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.5</td>
<td>Daily decisions support our vision and mission statements</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.6</td>
<td>Managers meet with supervisors regularly throughout a shift</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.7</td>
<td>The feedback meeting schedule is written into organisational procedures</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.8</td>
<td>Managers are often too busy to attend scheduled value stream meetings</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3.9</td>
<td>Managers have a common approach to problem solving</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The three dimensions of Consistency (in the context of lean culture) were addressed by the following questions:

- Questions 3.1, 3.2 and 3.6 – explore the extent to which successful layered and standardised leadership plans have been developed.
- Questions 3.3, 3.7 and 3.8 determine the extent of the standardised leadership plan, as well as the degree to which it has been institutionalised and accepted as standard practice (or “the way we do things around here”). Question 3.8 was phrased in the negative to more rigorously test management commitment to the standardised leadership plan. The pilot study confirmed that respondents were aware of the question style. Respondents answered in a manner consistent with their general pattern of responses.
- Questions 3.4, 3.5 and 3.9 examine the aspect of making decisions aligned with the stated lean objectives and the consistency thereof within the management group.

Adherence, consistency and standardisation (of leadership actions), therefore, are the major themes of the above-mentioned questions. It is hypothesised that these factors have a positive correlation to the lean culture development process.

Section 4 (Table 4) examines only two constructs as factors in the development of lean culture; namely, the assignment of corrective actions, and the associated follow-up process. These are grouped under the general heading of Accountability. Literature (van der Merwe et al, 2014) suggests that the acceptance of Accountability is a key factor in the lean culture development process.
Table 4. Questions related to accountability.

<p>| | | | | |</p>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>This section aims to explore the prevailing levels of accountability and associated systems. Please indicate to what extent you agree with each of the statements below by circling the appropriate number.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Corrective actions are assigned to individuals</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4.2</td>
<td>Team members know what is expected of their team</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4.3</td>
<td>Due dates are assigned to corrective actions at all levels</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4.4</td>
<td>Procedures exist for assigning corrective actions to individuals within teams</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4.5</td>
<td>Managers and supervisors follow up on corrective actions</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4.6</td>
<td>Action is taken when deadlines are missed</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The two components of Accountability are each examined by three questions, as follows:

- Questions 4.1, 4.2 and 4.4 explore the extent to which corrective actions are assigned to team members and the likelihood of these actions being sustainable. Sustainability is considered achievable if team members understand what is expected of them. Furthermore, the procedures for creating accountability must be written into standard operating procedures.

- Questions 4.3, 4.5 and 4.6 examine the issue of due date assignment and the consequences of missed deadlines.

Accountability is the overarching theme of the above-mentioned questions. It is hypothesised that this characteristic has a positive correlation to the lean culture development process.

**Conclusion**

It is envisaged that the survey instrument described in the preceding sections will be utilised to gauge the progress towards a lean culture. Results can be compared over time and leaders would be able identify areas where further actions are required to ensure the growth of a lean culture. Successful pilot tests have been conducted and it is expected that full scale testing and validation will be completed by the end of 2014. An automated format is envisaged that will be able to produce instant radar-charts from the aggregate results obtained in an organisation that has been surveyed.

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Development of a Framework for a Lean Based Water and Energy Efficiency Tool

Edward Davies\(^1\) and Karl van der Merwe\(^2\)

Abstract
The manufacturing industry of South Africa is the sector consuming the largest portion of the total energy consumption and second largest portion of total water consumption per annum nationally. With a significant increase in electrical energy cost in recent years, together with the reserve energy margin dropping below the minimum level required for sustainable operation of energy utilities, energy efficiency improvement is becoming imperative for organisational success as well as national economical sustainability. This paper explores selected Lean manufacturing principles and its positive effect on energy and water efficiency. Although the implementation of Lean manufacturing techniques naturally leads to the improvement of energy and water intensity, the author believes that there is even greater potential in the development of a Lean based tool which will specifically focus on the improvement of energy and water efficiency. For this purpose the value stream mapping tool was chosen as the foundation. This paper continues to explain the process undergone to develop standardised energy and water specific waste categories to be used in conjunction with the traditional Lean wastes. The study concludes by detailing the development of the tool, together with its framework for implementation.

Keywords: Energy efficiency, lean manufacturing, value stream mapping, waste, water efficiency.

Introduction
The South African manufacturing industry is facing an increasingly challenging task to remain profitable, as a consequence of the increase in energy and water prices in recent years. The cost of energy has increased by 467\% between 2000 and 2012 (Eskom, 2012). Figure 1 shows the electricity tariff increase of each year, from 2000 to 2014, in comparison to the year before (Eskom, 2014).

![Average annual electricity tariff increase (2000 - 2014)](image)

Figure 1. Eskom’s (South Africa’s main energy utility) average annual electricity tariff increases from 2000 to 2014 plotted in percentage (Eskom, 2014)

An increase of the average electricity tariff of 139\%, between from 2008 to 2012, in comparison to 19\%, of the 5 years prior to 2008, has given birth to a renewed urgency for

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South African companies to become more energy efficient, especially since tariff increases have been higher than annual national inflation levels since 2003 (Ramokgopa & Pietersen, 2007). In order for South African manufacturers to remain competitive in the world market, they have to reduce their operating costs which substantially increased after 2008 (as a result of significant price increases from 2008 to 2012 as illustrated in Figure 1). This has forced manufacturers to reduce their energy consumption and increase their process energy efficiency.

Figures 2a and 2b shows that South African industry is the largest consumer of energy (36.2% of total consumption in 2004) (DOME, 2009) and the second largest consumer of water (27% of total consumption in 2004) (DWAF, 2004) of all sectors in the country.

A minimum electricity reserve margin of 15% is required to allow for regular maintenance of power plants and to ensure that power plants are not overloaded (Wilson and Adams, 2006). The electricity reserve margin has dropped from 25% in 2002 to below the minimum 15% level in 2011 (Ndlovu, 2012). To restore the reserve margin, the electricity generation capacity from the supply side needs to be increased or the electricity demand from the demand side needs to be decreased.

Demand side management initiatives in South Africa currently include load shifting, load scheduling, energy efficiency and strategic growth in order to yield a positive reduction in energy demand (Grobler, den Heijer & Steyn, 2008). This paper focuses on the development of a tool to improve the water and energy efficiency on the demand side. Traditional energy efficiency interventions have been conducted on an ad-hoc basis to achieve large energy savings in the short term, however, the author believes that a continuous improvement approach to water and energy efficiency interventions will yield larger improvements in the long term.

The following section provides a concise literature review of the history and the key principles of Lean manufacturing.

**Lean Manufacturing**
Lean production is a term that was coined by Womack, Jones and Roos (1990) in their book *The Machine that Changed the World*, which was a study conducted for Massachusetts Institute of Technology (MIT) on the Toyota Production System (TPS). Nicholas (2011) defines Lean production as “management that focuses the organization on continuously identifying and removing sources of waste so that processes are continuously improved”.

Taiichi Ohno (1912 - 1990) identified seven wastes which exist in any manufacturing environment (Stevenson, 2009), namely excess inventory, overproduction, waiting time, unnecessary transport, processing waste, inefficient work methods and product defects. These wastes are all aspects of production which are non-value adding and that the end customer is not willing to pay for.

Lean tools and techniques were developed over the years to eliminate or reduce waste in manufacturing processes. These techniques and tools are characterized under five Lean principles, as illustrated in Figure 3.

Figure 3. Illustration of the five Lean principles with its respective tools and techniques listed underneath each pillar [Constructed from Womack and Jones (2003:15-26) and Bicheno & Holweg (2009:17)]

The five lean principles listed in a logical order of implementation are; specifying the value, identifying the value stream, establishing flow, letting the customer pull production and striving for perfection (Womack and Jones, 2003).

One of the most prominent philosophies in Lean is *kaizen*, a Japanese term for continuous improvement. *Kaizen* focuses on sustainable small incremental improvements in a process, which eventually adds up to larger improvements. The author believes that a similar approach can be followed to reduce energy and water waste in manufacturing processes. It has been observed that the implementation of Lean manufacturing techniques naturally leads to energy efficiency improvements (Seryak, Epstein and D’Antonio, 2006). The energy benefits are summarised in Table 1.
Table 1. Energy efficiency opportunities arising from implementation of Lean manufacturing techniques

<table>
<thead>
<tr>
<th>Lean Manufacturing Technique</th>
<th>Energy Efficiency Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory reduction</td>
<td>Reduced space required, resulting in less energy required for lighting, space heating / cooling and ventilation.</td>
</tr>
<tr>
<td>Changeover time reduction</td>
<td>Production equipment idling during changeovers, therefore less idle time with changeover time reduction.</td>
</tr>
<tr>
<td>Downtime reduction</td>
<td>Decreased idle time for production depended equipment.</td>
</tr>
<tr>
<td>Setup time reduction</td>
<td>Quicker setup times result in increased production time, therefore energy usage per unit decreases.</td>
</tr>
<tr>
<td>Cycle time reduction</td>
<td>Energy use of operating hour depended equipment remains the same for increased output, decreased idle time for production depended equipment and decreasing cycle times may increase equipment operating efficiency.</td>
</tr>
<tr>
<td>Increased throughput</td>
<td>Production equipment depended on operating hours. Decreased energy intensity.</td>
</tr>
<tr>
<td>Rework / Scrap Reduction</td>
<td>Energy usage of rework a waste. Energy use per quality product will decrease with reduction in scrap and reworks.</td>
</tr>
<tr>
<td>Part travel reduction</td>
<td>Decrease in WIP, thus shorter travel times resulting in decreases usage of energized equipment (conveyor belts, monorails, and vacuum tubes).</td>
</tr>
<tr>
<td>Space reduction</td>
<td>Decreased use of lighting and ventilation due to reduced open floor space.</td>
</tr>
</tbody>
</table>

From research results shown in Table 1 it would be reasonable to assume that greater savings could be realized if a Lean technique is utilized which specifically focusses on energy and water waste in a process.

In order for a Lean tool to be specifically used for energy and water efficiency improvement, specific energy and water waste categories need to be established to supplement the seven basic Lean wastes. The next section focusses on the determination of these additional energy and water wastes. It also provides an overview of the methodology which was formed to establish these waste categories.

**Energy**

Energy used in the various sectors is generated by the conversion of primary energy sources (coal, crude oil, nuclear, hydro, gas, renewable) into secondary energy sources (electricity, biomass, petroleum, liquefied petroleum gas). Secondary energy sources are referred to as energy carriers.

The decision making process followed to create the standardised energy and water waste categories is shown in Figure 4. Only causes of energy waste were considered for the purposes of this exercise, with the assumption that the root causes of water waste will be similar to that of energy wastes.
Sources included for the selection process were obtained from Journal publications, conference proceedings and books. In stage 1 of the decision making model described in Figure 4, the several source findings with regards to energy wastes were reviewed and recorded in a database. After reviewing all the sources, logical generic waste categories were formed. Only the categories which consisted of at least two waste types were considered. Stage 2 functions as a verification platform. Additional sources had to be collected to support the filtered waste categories. Before the final waste categories were established, each waste category were considered once more and had to represent at least 3 of the energy categories in order for it to be considered adequately representative. The result of this process is shown in Table 2.

Figure 4. Flowchart of the decision making process constructed to establish the novel Lean water and energy waste categories
Table 2. Grouping of energy wastes per category as a result of research

<table>
<thead>
<tr>
<th>Energy Waste Category</th>
<th>Energy Waste</th>
<th>Energy Carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaks</td>
<td>• Steam leaks</td>
<td>Oil products, Electricity, LPG, Biomass, Coal, Water</td>
</tr>
<tr>
<td></td>
<td>• Air leaks</td>
<td>Electricity, Coal</td>
</tr>
<tr>
<td></td>
<td>• LPG leaks</td>
<td>LPG</td>
</tr>
<tr>
<td>Equipment sizing</td>
<td>• Oversized motors</td>
<td>Electricity</td>
</tr>
<tr>
<td></td>
<td>• Oversized HVAC systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improper air compressor size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Over sizing of steam traps</td>
<td>Oil products, LPG, Biomass, Coal, Water</td>
</tr>
<tr>
<td>Idle time</td>
<td>• HVAC running during non-operation</td>
<td>Electricity</td>
</tr>
<tr>
<td></td>
<td>• Lights on during non-operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Water circulation pumps running during non-production</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Engine systems running during non-production</td>
<td>Oil products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering management</td>
<td>• Low power factor</td>
<td>Electricity</td>
</tr>
<tr>
<td></td>
<td>• Lack of variable speed drives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lack of occupancy sensors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Inefficient motors</td>
<td></td>
</tr>
<tr>
<td>Heat loss</td>
<td>• Improper furnace or boiler insulation</td>
<td>Oil products, Biomass, Coal, Water</td>
</tr>
<tr>
<td></td>
<td>• No heat recovery from coolant waters, ovens</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Un-insulated ovens, kilns, heater bands on extrusion</td>
<td></td>
</tr>
</tbody>
</table>

The five new Lean energy and water waste categories which were established are leaks, equipment sizing, idle time, engineering management and heat loss. These newly established waste categories will be used with the Lean based water and energy efficiency tool as discussed in the next section.

**Lean based water and energy efficiency tool**

The main objective of this study is to provide the manufacturing industry with a framework which can be utilised by its Lean and water and/or energy efficiency practitioners. It is expected that it should be able to be used both as a stand-alone tool as well as in conjunction with other existing Lean or water and energy efficiency programs within an organization.

The Lean tool which utilises and combines most of the other Lean tools and techniques is Value Stream Mapping (VSM). For this reason the VSM tool was chosen as the foundation for the proposed Lean based water and energy efficiency tool. VSM is a graphical tool which visualises information about the manufacturing process in a logical manner. The value stream of the current situation is usually observed in person and thereafter drawn by the Lean practitioner in order to create a map of the current situation, referred to as the current state map. The information required for the map is gathered by following a basic methodology as described by Rother and Shook (2003) in their book *Learning to See*. The current state map is then analysed and the proposed (improved) process flow with planned improvements is drawn on the future state map, which becomes a blueprint of the improved process.
The research process followed to develop the framework for the proposed Water and Energy Stream Mapping (WESM) tool is discussed in detail below.

**Stage 1**
Rother and Shook’s (2003) VSM framework was used as the basis for the WESM framework. This provided the WESM framework with a systematic flow required to create a visual map. It was also decided that the framework will be specifically designed with the intention of being used as a continuous improvement tool, therefore following the Plan Do Check Act (PDCA) flow with a feedback loop.

**Stage 2**
Subsequent to creating the outline for the framework, it was decided to further analyse two internationally proven water and/or energy efficiency related frameworks. The frameworks chosen were the Measurement and Verification Methodology (USDoE, 2002) and Energy Audit framework (EMSD, 2007). After analysing these frameworks the elements appropriate to the delineation of study were highlighted and considered for inclusion in the framework.

**Stage 3**
In the final stage all the filtered elements were scrutinised by means of a logic check. The logical questions posed are listed below:
- Does the element fall within the delineation of study?
- Can the element be executed by either a Lean practitioner or water and energy efficiency practitioner within an organisation without outsourcing?
- Is the element executable in any manufacturing sector?

The elements which passed the logic test were included into the WESM framework. Figure 5 shows the flowchart of the novel EWSM framework that was developed.
Figure 5. A flowchart illustrating the developed EWSM framework
WESM Framework

The three main phases of the WESM framework are the *analysis* phase, the *design* phase and the *implementation* phase.

In the *analysis* phase the scope of the study should be the point of departure. The next step will be to start with the creation of the current state map. This will allow the practitioners to physically identify and trace the water and energy use streams in their defined area of study. Any available water and energy consumption data should be collected at this point of the framework and if no such data exists (or additional data is required), this data should be physically recorded for a defined period of time. When the data is available and is being analysed, a comparative analysis to other similar areas should be conducted to ascertain if there are any opportunities to standardise a process over multiple areas or adopt a best practise from another area. The energy usage baseline graphs of the current state of the workshop should then be established. All water and energy usage per process should be catalogued at this point, where after the current state map could be completed. Throughout the analysis phase water and energy management opportunities (WEMOs) should be identified.

In the *design* phase the previously identified WEMOs are compiled in order to be considered for the future state map. The water and energy wastes (as established in this study) are considered at this point for the purpose of the completing the future state map. After the completion of the future state map an action plan should be created with the improvement measures, priority levels and timing. It is also important to note any area where reciprocal effects may be possible to maximise impact of the workshop, as well as to standardise across the organisation.

The final phase of the framework is the *implementation* phase. At this stage the WESM process is complete; however it is critical that the improvements are successfully implemented. Therefore any engineering or technical support which is required should be involved in the implementation phase. Any WEMO identified in the analysis phase where repairs or further technical investigation were required, should be performed before implementation of the complete future state map. In order to complete the PDCA phase for continuous improvement, the implemented future state map becomes the current state map for the next workshop in the studied area. It is important to continue to collect and record water and energy use data for the purpose of quantifying the water and energy efficiency improvement after the WESM intervention.

Conclusions

This paper discussed the challenges the South African manufacturing industry faces with regards to water and energy consumption.

The author believes that a *kaizen* approach to water and energy efficiency by utilising Lean techniques and tools will yield greater savings in the long term, than ad-hoc efficiency improvements. The literature review has revealed that a by-product of the implementation of Lean manufacturing techniques in the manufacturing industry has been the natural improvement of energy efficiency.

Subsequently the author embarked on the development of a framework for a Lean water and energy efficiency tool. The unique contributions made to the field of Operations Management resulting from this study are listed below:

- The formation of five additional standardised Lean waste categories specifically associated to water and energy wastes, namely *leaks, equipment sizing, idle time, engineering management* and *heat loss.*
A systematic framework for the application of the WESM tool to be used in the manufacturing industry by Lean and/or energy efficiency practitioners. Currently the newly established Lean wastes and the framework can be readily utilised in conjunction with the VSM tool. The next phase of this study will focus on adapting the VSM tool to maximise the water and energy savings potential, therefore creating a “sister” tool to VSM, hence named WESM. Future work will consider the plausibility of developing a mathematical model to estimate the conservative water and energy savings possible when using the WESM framework.

References


Designing Postgraduate Project Management Programs for Success

Bassam Baroudi

Abstract
Postgraduate project management program offerings have significantly increased in recent years. Higher education institutions are presenting what they feel is the best education to equip graduates for project management roles within industry. However, project management education programs need to be continually updated to ensure that they are relevant and suit the modern business environment.

The background for this paper is based within the Australian education sector and it essentially sets out to review the redevelopment of the generic Master of Project Management program offered by the University of South Australia. Relevant literature is examined to garner current thinking in respect to project management ideology and higher education. This is followed by a commentary styled review that examines the Master of Project Management program and its redevelopment objectives and expected deliverables. It covers the areas of program content, teaching approach, program transitions and general considerations.

This study provides an insight into how postgraduate project management programs can possibly be improved. The review also outlines how program improvements can be structured. Furthermore, it puts forth a project management education that houses theoretical foundations, advanced concepts and a project lifecycle teaching approach which could be of benefit to students, academics, employers and industry. It is hoped that this study will assist others in the design of their education programs.

Keywords: Project management, university education.

Introduction
The number of project management education programs has significantly grown in recent years with many universities and other education providers delivering programs to satisfy market demand. The author has a great interest in the development and delivery of project management education based on recognised best practices. This extends to providing well educated project managers to the project management profession and industry in general. The stimulus for this paper comes from a desire to reflect on a period of consultation and development in respect to the existing Master of Project Management program at the University of South Australia. This post graduate program is generic in nature and thus applicable to virtually all business, industry and community activities. Whilst the study is based on the experience of redeveloping the project management program at the University of South Australia, the content of the paper is thought to provide significant insight into this particular area of education. It will commence with a literature review on the topic followed by a commentary of the author’s experiences and reflections as the primary program leader at the time.

Project Management Ideology
In the last few decades project management thinking and knowledge has greatly progressed. Managing projects is no longer about just understanding the technical aspects of any
particular project. Parker and Craig (2008) put forth that project managers need to initiate ideas and develop solutions. They further contend that project managers need to be able to plan, organise and work through their team issues all whilst providing leadership and maintaining communication channels with all stakeholders as well as adequate control measures. Hence, it could be said that modern day project management has moved from a focus on the technical knowhow more so to a broader management knowhow. Project management has seen its generic body of knowledge applied to many fields. These include defence, construction, information technology, community events and many more. Publications such as the Guide to the Project Management Body of Knowledge (PMBOK®Guide, PMI, 2013) provide a good foundation in project management ideology and principles to guide practitioners and educators within this area.

Kerzner (2011) contends that project management has gone past the days of just being a quantitative tool for the use of employees. This would be in reference to project management having originally developed its processes on many of the harder concepts such as project scheduling and cost control. He goes on to say that project management is now viewed as an approach that has beneficial effects on the whole organisation. Hence, project management has grown to embody a whole new way of thinking in respect to how businesses manage their organisations. In fact, Foti (2001) predicts that the “managing-by-projects” methodology will ultimately progress and influence the corporate culture of many organisations. Anecdotally his prediction would appear to be quite correct and gaining increasing momentum as time goes on. It is evident by the interest in project management approaches that industry is catching on and organisational change is occurring. As such, project management education providers need to keep abreast of changing professional and business environments.

Central to project management thinking is the delivery of desired outcomes and hence the notion of project success. Nixon et al. (2012) contend that the reasons behind project success or failure have been a much debated topic for some time. Essentially project success is based on the idea of what actions are necessary for projects to meet the planned objectives. Sutterfield et al. (2006) suggest that projects often fail to meet objectives in large part due to the ineffective management of project stakeholders. Stakeholders include anyone that is influenced by a project with these people able to make or break a project. Rolstadas et al. (2014) weigh in with the notion that successful projects are driven by the adopted project management approach as aligned to the challenges involved within any particular project. The viewpoints on the topic can vary but the underlying concepts are based around how can successful projects be created and how can failure be avoided.

Within project management circles there has been a growing awareness amongst practitioners and scholars that project management thinking needs to broaden its base. For example, concepts such as project governance are increasingly seen as critical to project management. Biesenthal and Wilden (2014) contend that governance within project environments is important for success. In general terms an organisation’s strategy and project objectives need to be brought together and this can be supported by good project governance. Further to this the debates on leadership and soft skills are still topical in project management. It could be suggested that there is much more to project management than casual observations may first identify. Hence, it is important that deeper understandings are provided for those working within the field and those planning to study within project management disciplines.

Project Management Education Programs
The growing adoption of project management ideology and practices within business, industry and the community has seen the need for related education programs. Generic
project management programs are now offered by many institutions and providers. These range from short certificate courses to rigorous research doctorates. McCune and Entwistle (2011) contend that university education needs to adopt a 21st century perspective encouraging a ‘will to learn’ in students. Furthermore, they see teaching/learning arrangements as being able to provide students with environments to gain deeper understandings and in the process further develop this potential for understanding. Mtnez-Almela and De Los Rios (2011) put forth that having an appreciation of the student experience can allow universities to focus in on the pedagogic and education factors when teaching project management. These aspects are seen as carrying significant importance to the development of effective teaching programs.

Danielson (2007) contends that all professions establish a “language of practice” which allows professionals to discuss their field in terms of important concepts and understandings. This is very true within project management and the introduction to terminologies quite often commences in the classroom. The aforementioned PMBOK® Guide is a good example of a publication which introduces these terminologies to students and learners of project management. Such terms as project management processes, tools and techniques, knowledge areas, scoping, work breakdown structures and deliverables (PMI, 2013) become known to newcomers at quite an early stage. Furthermore, Burke (2007) suggests that as project management takes hold within industry its participants will need to have the knowledge to utilise a wide-ranging set of planning and control methods for practice. In contrast people such as Young and Young (2012) suggest that due to constant failure within projects we might have reached the limit of our current project management approaches and may need to investigate new ways forward. Whilst this would be a highly unlikely proposition it does highlight the need for a more enlightened view on project management paradigms, practice and education.

The project managers of today have a greater variety of complex issues to contend with than possibly at any time in the past. Moreover, in recent years project management practice has tended to move away from focusing on a rigid technical perspective to one which is more encompassing and broader in its outlook. Hence, project management education should follow suit. Whilst publications such as the PMBOK® Guide are valuable in teaching project management fundamentals they do have an emphasis on process based information rather than broader based concepts. In fact, this publication has been long seen as focusing on “hard” skills at the expense of the “soft” types (Gale & Brown 2003, Bourne & Walker, 2004; Zwikael & Bar-Yoseph, 2004, Pant and Baroudi, 2008). Hence, project management education providers need to be cognisant of this and reflect the broader situation within industry. It needs to prepare students for project management situations in all their dimensions.

According to Mtnez-Almela and De Los Rios (2011) when designing educational programs professional competencies such as that in project management are very important. Hence, this leads one to consider what will be taught and how will it be taught. It would seem that programs need a project management foundation to base teaching and learning on but also a significant broadening of concepts to more closely align with current project management practice. Experiential learning is a good way to impart project management competencies knowledge as it involves teaching in respect to real world experiences and examples. Moon (2004) suggests that experiential learning can also make use of assessment work that is quite reflective in nature which can be quite useful. Moreover, varying assessments of appropriate
styles and rigour need to be in place to test fundamental and advanced knowledge as related to project management professional competencies.

With advancing technologies educators are discovering that in this digital age learning does not only occur in the classroom. Within higher education a concept which is currently quite topical is that of “blended learning” within programs. Beetham and Sharpe (2013) contend that blended learning provides a more student centered learning approach via the use of various modes of teaching – both in the classroom and online. In essence, a mix of teaching styles from the traditional and the new. Hence, in this new modern world all education programs, including those in project management, need to adapt to a changed and ever changing education environment.

**Commentary: Postgraduate Project Management Programs**

The focus of this paper is in respect to generic project management programs at the higher education level. It is most relevant to postgraduate studies such as Masters degrees in project management. Generically based project management programs such as this have been sprouting up at many educational institutions. It is quite common for these postgraduate project management programs to allow those from different fields to add management qualifications to their undergraduate qualifications. This is akin to what many have done with Master of Business Administration qualifications but in that case more so for business rather than projects. This study is based on the on-campus Master of Project Management program as offered by the School of Natural and Built Environments at the University of South Australia. Hence, it is essentially a case study. The program operates within the Construction and Project Management discipline as this is where it originally evolved. Note that this Masters program also has a Graduate Diploma in Project Management and a Graduate Certificate in Project Management nested within it. The nested programs attract a cohort of approximately 50 students a year on-campus and many more online via Open Universities Australia (OUA). These students come from varied backgrounds such as information technology, construction, business, engineering, etc. The Masters program, of one and a half years duration, was initially designed to mainly teach project management fundamentals. This included knowledge and processes strongly underpinned by the Project Management Institute’s *Guide to Project Management Body of Knowledge* (PMI, 2013).

The following looks at the redirecting of the university’s project management program in respect to redevelopment objectives and expected deliverables. This process took place over several years culminating in first delivery of the new program in 2012. The following sections provide an insight into the redesigning of program content and teaching approach followed by a look at program transitional arrangements and some general considerations. It will also incorporate some further program changes which will be introduced in 2015.

**Program Content**

The program’s previous educational content was strongly influenced by the more technical concepts involved within project management. However, it was acknowledged that industry requires broader concepts to suit the modern project management environment. Hence, the programs were designed to contain content and topics that reflected the needs of industry. As such, the program leaders set out to align the content with current project management thinking and practice. Broad ranging sources for information and ideas assisted the formation of a plan for revised content. The sources included industry consultations, academic staff consultations, input from the university’s project management advisory committee, knowledge on current industry practices and academic thinking on project management,
researching other project management providers, university run student surveys and general student feedback. The student surveys and feedback were particularly important to also understand the current student experience.

The plan was for the project management educational material or content to closely align with the program expectations and deliverables. In this respect the emphasis was on providing appropriate direction so that current innovative project management concepts were included into the program. After much research and thinking over a sustained period of time it was generally agreed that the areas of soft skills, strategy and sustainability (3S) were poorly represented within the university’s project management programs. This was thought to be also true for other project management educational providers who at the time seemed to focus on traditional harder concepts. This wasn’t to suggest that the ideas held within traditional based project management education should be ignored. Rather that these older more fundamental concepts be built upon. As such, the 3S concepts seemed a good place to start so that students are offered a greater understanding of the project manager’s role and challenges in this modern and increasingly complex world.

In light of the above it was decided that project management publication, the PMBOK® Guide, should still provide some foundation to the coursework. It was strongly held that fundamental project management technical knowledge and processes still needed to be taught even at the postgraduate level. However, accompanying these areas will be a greater emphasis on the highlighted 3S concepts: soft skills, strategy and sustainability. The intention was that the knowledge within these three areas needed a greater individual focus in addition to being interwoven into general course content. Table 1. provides a guide to some proposed expanded/enhanced teachings within the project management discipline.

<table>
<thead>
<tr>
<th>Soft Skills</th>
<th>Leadership, team building, interpersonal skills, team motivation, personality traits, networking, negotiation techniques, conflict resolution, personal communications and other human behaviours.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy</td>
<td>Business strategies, project strategies, corporate objectives vs. project objectives, maturity models, stakeholder management, systems thinking methodologies and globalisation issues.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Environmental, social and economic aspects, business practices, project practices, global awareness, government initiatives and community welfare.</td>
</tr>
</tbody>
</table>

The areas listed in the above table give an insight into possible new opportunities for content directions. In addition, further consultation found that industry needed graduates to understand areas such as ethical behaviour and governance within business and project management environments. These could be easily associated and built into the 3S thinking platform.

An outline of the Master of Project Management program (as recently revised for 2015) is shown in Table 2 below. It briefly summarises the courses/subjects, teaching and assessment regime and the intended graduate knowledge and attributes. Year 1 provides for some
fundamental courses/subjects alongside other more broadening courses/subjects. In Year 2 the course/subject emphases are on higher level advanced concepts followed by the capstone research project.

Table 2. Project management program: teaching, assessment, and graduate knowledge and attributes (on-campus Masters)

<table>
<thead>
<tr>
<th>Courses/Subjects</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principles of Project Management</td>
<td>Lectures, tutorials, case studies, group discussions</td>
<td>Portfolio &amp; Program Management</td>
</tr>
<tr>
<td></td>
<td>Individual essay Group report Examination</td>
<td>Individual essay Group report</td>
</tr>
<tr>
<td></td>
<td>Theoretical and technical knowledge in a range of principles, skills and techniques</td>
<td>Theoretical and technical knowledge in a range of principles, skills and techniques</td>
</tr>
<tr>
<td>Project Risk Management</td>
<td>Lectures, tutorials, group work, case studies, videos</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual essay Group report Examination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Theoretical and practical knowledge of risk management processes and methodologies</td>
<td></td>
</tr>
<tr>
<td>Procurement &amp; Contract Management</td>
<td>Lectures, tutorials, legal case readings and discussion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual essay Group report and presentation Examination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategic procurement knowledge and contract practices and law as applied to projects</td>
<td></td>
</tr>
<tr>
<td>Project Governance &amp; Ethics</td>
<td>Lectures, tutorials, class discussions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Individual essays Group report</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Understandings of governance issues and ethical perspectives</td>
<td></td>
</tr>
<tr>
<td>Project Control Methods</td>
<td>Lectures, tutorials, computer practicals, team problem solving</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual essay Group report Examination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In-depth knowledge in respect to practices associated with the controlling of project activities</td>
<td></td>
</tr>
<tr>
<td>Project Leadership &amp; Teams</td>
<td>Lectures, tutorials, problem based learning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Individual essays Group presentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Practical knowledge on managing teams with critical links between people, ideas, information</td>
<td></td>
</tr>
<tr>
<td>Economic, Social &amp; Environmental Analysis</td>
<td>Lectures, tutorials, group work, develop business cases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual essay Group report Class test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Awareness in respect to sustainability factors that influence and constrain projects</td>
<td></td>
</tr>
<tr>
<td>Research Theory &amp; Practice Methods</td>
<td>Lectures, tutorials, workshops</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individual essay Workshop exercises Research proposal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge and skills to propose and develop a research agenda</td>
<td></td>
</tr>
<tr>
<td><strong>Year 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio &amp; Program Management</td>
<td>Lectures, tutorials, class discussion</td>
<td></td>
</tr>
</tbody>
</table>
|                                          | Individual essay Group report                                         | Advanced and integrated knowledge of portfolio/}
<table>
<thead>
<tr>
<th>Program</th>
<th>Teaching methods</th>
<th>Assessment</th>
<th>Knowledge and Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Analysis in Research</td>
<td>Lectures, tutorials</td>
<td>Tutorial questions, Major assignment, Oral presentation</td>
<td>Understand the theory of statistics and data analysis within research problems</td>
</tr>
<tr>
<td>Strategy in Project Organisation</td>
<td>Lectures, tutorials, industry presentations</td>
<td>Individual essay, Group report and presentation, Reflective report</td>
<td>Advanced theory and a practical understanding in respect to project and organisational strategy</td>
</tr>
<tr>
<td>International Project Practices</td>
<td>Lectures, tutorials, international case studies</td>
<td>Individual essay, Group report and presentation, Reflective report</td>
<td>Comprehensive knowledge on the complexities of managing projects on a global scale</td>
</tr>
<tr>
<td>Project Management Minor Thesis 1</td>
<td>Directed study under supervision</td>
<td>Multi-part formative assignment</td>
<td>Ability to apply expert, specialised cognitive and technical skills in a substantial research project</td>
</tr>
<tr>
<td>Project Management Minor Thesis 2</td>
<td>Directed study under supervision</td>
<td>Minor thesis submission</td>
<td>Ability to apply expert, specialised cognitive and technical skills in a substantial research project</td>
</tr>
</tbody>
</table>

The new program represents a rich breadth of project management educational content based on a series of topical areas. It is taught via a variety of teaching and assessment techniques as listed in Table 2. Furthermore, note that the teaching generally uses a project lifecycle approach which is discussed in the next section. Table 2 also shows how graduate knowledge and attributes are developed in project management via overarching concepts within basic principles, risk management, control methods, leadership, economic, social & environmental issues, procurement, contract management, organisational strategy, and ethics and project governance. The focus on project governance is possibly the newest of topics within project management education. It is thought to be of particular importance as highlighted by Biesenthal and Wilden (2014). Also note that many of the first year fundamental courses draw elements from the PMBOK®Guide, hence, graduate knowledge and attributes have significant alignment with this publication. The Masters program is rounded off with a minor research thesis on a project management topic of student choice (note that Project Management Minor Thesis 1 and 2 are one project). Furthermore, additional courses/subjects are to be included in 2015. These include advanced concepts in the areas of international project management, portfolio and program management alongside dedicated research methods and data analysis studies to assist with the research thesis. This has evolved in large part due to the Australian Qualifications Framework and the need to increase volume and quality of learning. Hence, as of 2015 the Masters program will be of two years duration with advanced course material as shown in Table 2 reflecting increased student knowledge and attributes.

**Teaching Approach**
When designing the revised program it was acknowledged that the educational content needed to take a big leap forward to ensure deeper project management understandings were achieved.
conveyed to students. However, it was also deemed necessary to assess the way in which the educational content was being delivered. Many of the current programs teach project management knowledge areas based on course/subjects topics alone. It was thought that the revised program should not convey project management knowledge purely via “information silos”. It was proposed that a new teaching approach should encourage the topics to be based around typical project lifecycles where possible. As such, it can still teach the project management knowledge areas but highlight the various components in the context of project timelines. The benefit is that students can then gain a better understanding of project management knowledge from a project lifecycle perspective. As such, students gain a fuller appreciation in respect to where various project management inputs and outputs are occurring throughout a typical project schedule. This is a critical aspect for aspiring project managers and very much needed by industry.

In essence, the teaching of the program was to convey fundamental project management knowledge in tandem with broader and more advanced concepts via a project lifecycle teaching approach. The intention was that the teaching was to continue to utilise traditional lectures and tutorial exercises as this is quite entrenched within most university systems. However, the program does encourage the use of other activities such as industry presentations, problem solving exercises, case studies, research undertakings and innovative methods as selected by the lecturers. In more recent times the concept of blended learning is becoming quite popular to assist in teaching. That is a combination of lecture and online teaching materials/activities as described above by Beetham and Sharpe (2013). The program does have support facilities in the form of corresponding interactive webpages for each course/subject. These allow students access to project management educational materials, assessments, recordings and communications outside of the lecture theatre or classroom.

An important part of any teaching is to ensure appropriate design of student assessments. These would comprise of a variety of assessable items of work per student per semester. Examples of mandated student assessments can be seen in Table 2. These include student essays, reports, presentations, examinations as well as reflective journals. Formal examinations are conducted in many of the fundamental courses/subjects in the program. It is thought that this is an essential part of student assessment to ensure project management knowledge, skills and competence have been developed within each individual student. Another aspect considered important was that all courses/subjects, except the research thesis, should have at least one assessment which allows for group work. This is seen as essential to develop important project management interpersonal skills by working in teams and it also encourages student leadership. Furthermore, presentations should feature wherever possible to develop student confidence and improve communication skills. The research component is also important as constructing a minor thesis challenges students to independently investigate and document significant project management issues.

It would seem that there are many project management guides, standards and systems assisting the profession at this time. It is thought that the program’s teaching approach should not attempt to adhere to all of these but rather have an overall aim to make the project management education current and relevant to industry. However, as previously said the PMBOK®Guide is used as a foundation for the program to build upon. It is arguably the most recognised project management publication globally. This does not mean that the teaching within the program follows this publication dutifully. More so it makes use of its fundamental project management concepts bringing these to the fore. A further benefit of making use of this particular publication is that it is widely seen as underpinning the
requirements by professional bodies such as the Australian Institute of Project Management and the Project Management Institute. These organisations are very important in representing the project management profession.

**Program Transitions and Considerations**

This final commentary section highlights some of the more administrative types of issues when introducing a new or revised university program, in this case the redeveloped Master of Project Management. The program had to be approved by the university’s academic administration prior to first delivery. This was achieved and then the program development team needed to investigate transitional arrangements to ensure the changeover ran smoothly. This is also important for future academic standing and credit arrangements. Also of note is that the on-campus program is supplemented by an equivalent fully online project management program via Open Universities Australia (OUA). This program needed to be kept quite consistent with the on-campus program so it also reflected the program changes.

With the above mentioned transitional arrangements there was a need to provide current students with a pathway from existing courses/subjects to the new courses/subjects. The preference was to finalise all existing courses/subjects at one time and then direct students to enrol into the new designated courses/subjects to complete their programs. As such the revised programs needed arrangements that could adapt to this requirement. This entailed each new course/subject being linked back to a past course/subject. It is thought that the transitions period will still exist for two or three years. This period provides for the management from existing to new. Furthermore, the revised program needed to consider graduate status for past project management studies. Past graduates wishing to continue on with further study are provided with clear program transitions information that assists with their study plans. Ultimately, it is important to maintain fairness and consistency in the system.

The aspect of transitioning academic staff was also an important issue. The first priority of the intended revisions was to bring the project management programs in line with current industry practice and thinking. As such, the assigning of duties to develop and teach the new courses/subjects was carefully assessed. However, consideration also needed to be given to long standing lecturers that wished to continue teaching as best as practicably possible. The program has a history of industry lecturers alongside experienced academics. Many of the lecturers were keen to be involved and assisted in the development of the program content. They then introduced and modified new content into the designated courses/subjects and many were able to be maintained in their positions albeit with some modifications.

There were many other aspects that needed some consideration in the redevelopment of the project management programs. These included possibly accommodating larger student numbers particularly in the fundamentals courses/subjects, international student arrangements, making the best use of university facilities, library training arrangements for new students and funding, policy and time constraints.

**Conclusion**

This paper provides some insight into the redevelopment of the postgraduate project management program at the University of South Australia. It reflects on the experience of the primary program leader during a period of program thinking and improvement. Whilst the paper is based on this one large case study or experience it is believed that it is applicable and
valuable for others in similar situations. It shows how project management programs can significantly broaden their content as well as improve their teaching approach. Moreover, it provides project management academics, practitioners and students with a way forward within the education context. The program adopted ideas from many contributors in its formation. These ideas, helped to significantly lift the quality of the current project management program.

The most important outcome of the program redevelopment process is that it now provides for a more up to date and relevant project management education. It is believed that the redesign of educational content and teaching approach essentially revitalised the project management program at the University of South Australia. The thinking within this paper is thought to be of universal value to all project management education providers. It is thought that education providers of project management can be informed from the author’s experiences as documented in this paper. The hope is for all education providers to deliver well informed high quality project management graduates to industry, business and the community. The provision of effective project management education programs that provide successful outcomes is important for the profession as a whole.

References


Developing a Pollution Measuring System to Manage Demolition Projects Complying with Legal Regulations

Markus Reinhardt¹, Anna Kühlen², and Shervin Haghsheno³

Abstract
Demolition and construction processes usually generate pollutions, namely dust, noise and vibration. These pollutions can have a negative impact on human health or the environment. Hence, pollutions are often a strong argument against necessary demolition and building projects. There are legal regulations of pollution control to minimize these impacts. However, usually no measurements and least of all permanent monitoring are performed on site, as pollution measuring is very costly. Often pollutions are only controlled by goodwill of the contractor, who acts upon his experiences and knowledge. To initiate pollution-reducing actions on site, an inexpensive measuring system is developed, which measures and calculates pollutions in real-time. In this paper, the system is described. First the basic system requirements are introduced. Then the systems components and the system buildup are explained in some detail. The system consists of measurement nodes (usually 6-10), which monitor dust, noise and vibrations. These nodes are supposed to be placed around the construction/deconstruction object. An analyzing unit calculates the estimated level of pollution in every important position. The calculated data is sent directly to the operator, since the excavator usually causes major emissions and resulting pollutions can be reduced by adjusting the working process, such as choosing a proper demolition technique or applying pollution protection measures. The aim of this research is to help the contractor and principal to perform construction and demolition work complying with legal regulations by warning them, when limits are exceeded.

Keywords: Demolition projects, dust, noise, pollution control, vibration.

Introduction
Reports (WHO 2011, WHO 2013) of negative influences on human health caused by pollutions, such as dust and noise, are continuously raising public awareness. Especially, when these pollutions are caused by construction or demolition works in the neighborhood, citizens often try to force authorities to control these actions and to assure compliance with pollution limits (TALuft, TALärm, DIN 4150-2, DIN 4150-3). Related constraints can sometimes even hinder construction or demolition works. A system, which allows continual measurement and control of pollutions, might help to guarantee that limits are met and works can be performed without obstructions. Such a system is not primarily meant to increase labor protection (Lunts 2013), but to reduce impacts on the local environment.

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To allow contractors and principals to perform construction and demolition works within these pollution limits, the Karlsruhe Institute of Technology (KIT) developed an Immission Measurement System (IMS) that continuously monitors the important local pollutions, dust, noise and vibration (Kühlen et al. 2014). This system measures all these important pollutions nearly in real-time. It informs stakeholders about the actual pollution situation on/around site and alerts them, when set limitations are exceeded. Hence, the contractor can take action, such as using counter measures, to comply with regulations. The main purpose of this system is to meet the demands of all major stakeholders in construction and demolition works:

- Residents: No dangerous pollution levels (WHO 2011, WHO 2013) are released during the execution of construction/demolition works.
- Authorities: The regulations (TALuft, TALärm, DIN 4150-2, DIN 4150-3) are met during the execution of construction/demolition works.
- Principal: The construction/demolition work is affordable.
- Contractor: The construction/demolition work can be realized.

The system, including its single components and its implementation in practice, is described in this paper. First, approaches related to the topic in recent research are reviewed. Then the basic pollutions are described and requirements for the system are defined. The chosen sensors for this system and the tests to prove their performance are stated. The buildup of the system and the benefit for any stakeholder are described. Finally the paper is concluded by outlining required future research in this topic.

State-of-the-Art of Science and Technology

In demolition and building projects, there is usually no measurement of any pollution on the construction site. Only occasionally, at important or very exposed construction sites, measurements are done. But the measurement results are regularly not used to improve the situation instantly. Furthermore, usually the validity of the results is limited, as for instance, according to a guidance to control dust emissions from construction and demolition in London (GLA 2006), even in high risk environments just two automatic particulate monitors are demanded on site.

The systems generally applied in these cases are very expensive devices. Therefore, they are used rarely and deliver only punctual measurement results (DIN 4150-2, TALuft, TALärm), which cannot be taken to estimate the complete pollution distribution in the area. Often the proposed systems cannot be used to get information in real time, like sampling cassettes for dust (Kühlen et al. 2014). The focus of these rarely applied measurement systems is the support of authorities in identifying hazards or problems for any stakeholders involved in construction/deconstruction projects. Within this content authorities mainly take the gathered data to identify violations of limits ex post. Hence, it is not possible to influence construction work in real time in order to meet the regulations.

To date the best method to reduce and control pollutions caused by construction/demolition works is the prediction and pre-evaluation of possible pollutions by computer-based models before the actual work on site. Examples of such computer-based models used in Germany are SoundPLAN\(^4\) to calculate the distribution of noise (SoundPlan Acoustics) and dust (SoundPlan Air Pollution) or Austal2000\(^5\) to estimated dust propagation. And there are prototype algorithms to predict vibration propagation like BP-ANN (Armaghani, 2013). But without pollution control by a system allowing extensive

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\(^4\) http://www.soundplan.eu/english
measurements on the real site, the model results cannot be validated and controlled.

The review shows that up to now there is a lack of measurement systems and respective research for their implementation in construction and deconstruction works for sufficient pollution control on site. There is no system known to the authors, which allows the integral monitoring of noise, dust and vibration on construction and demolition sites in real time and which supports the contractor in the adjustment of working processes and the application of counter measures to work in accordance with the regulations.

The IMS system introduced in this paper and described in detail in the following should help to improve the knowledge of pollution control on construction/deconstruction sites. At the moment the IMS is developed and tested applied to deconstruction works. In combination with a support system (cf. Kühlen et al. 2014) here the IMS is supposed to provide solutions for choosing the best practices for demolition to efficiently demolish any building while meeting the limits set by regulation. The focal application of the IMS is the monitoring of the three most common pollutions on construction/demolition sites, namely noise, dust and vibration, in real time to support the contractor to do his work within the regulatory limits. The IMS is planned as a low cost system, which uses many measurement nodes to estimate the complete distribution of noise, vibration and dust in the affected area in nearly real time as good as possible.

Characterization of Relevant Pollutions in This Research

In the following, noise, dust and vibration pollutions and their characteristics within this research are described.

Dust
Dust basically consists of small, solid particles with a higher density than air, but which float in the air. Dust always existed in the air, for instance in the form of sand, volcanic ashes and pollen. But especially in rural areas, there is a great amount of dust, caused by different anthropogenic sources, including dust from organic materials, soot and brake dust. In this research mineral dust resulting from construction/deconstruction works is relevant. There are more criteria to define dust besides the type of material. Due to the effect of dust to human health the particle size is very important. Particles larger than 10 µm are supposed to be of no harm to humans organisms, because they are too large for inhaling. Usually dust of this size is heavy and tends to deposit soon. Furthermore, particles smaller than 0.1 µm are not considered as critical to human health, as the body can exhale them (WHO 2011).

Noise
Noise is basically a vibration that compresses air. The larger the amplitude, the difference between compressed and uncompressed air, the higher is the sound level. Beside the sound level, the frequency influences the felt loudness by humans (Maue et al. 2003). The human ear is more sensitive to frequencies around 1.000 Hz to 10.000 Hz. To consider this influence of frequency, weightings like the A-, B-, C.- or D-weighing are introduced to define the level of noise. Nowadays most commonly used is the A-weighting, especially for any measurement of industrial or environmental noise.

Vibration
Like noise, vibration is defined by frequency and amplitude. But vibration uses the ground and other solid material as basic transmitting medium (not air as noise does). Vibrations with frequencies usually between 0,1 Hz and 50 Hz can be dangerous to human health and
can cause damages to buildings (DIN 4150-2, DIN 4150-3). Main sources of vibration monitored by the IMS are falling objects or large machinery, like trucks or excavators.

**Basic System Requirements**

There are some basic requirements for the use of the IMS on site. **First**, the system has to be cheap to allow its operation on any construction/demolition site. At the moment costs for single measurements are usually very high, as the costs of the equipment and for the required efforts to use these devices are high. Therefore, it is not affordable for regular construction works. **Secondly**, pollution levels should be measured at diverse locations at the same time to map the pollution situation appropriately. For instance, to estimate the pollution situation of a small construction site adequately, the pollutions at least at six locations should be measured. Current measurements are often performed only at one location (TALuft, TALärm, DIN 4150-2, DIN 4150-3) on/close to the site. Furthermore, to gain a complete picture of the pollution situation over time, **thirdly**, the system should allow permanent monitoring of the relevant pollutions. **Finally**, the system must be intuitive in use and able to measure in every condition. It has to be easily maintained and set up in any situation, so it can be done by the regular personal on site. In the following the single components of the IMS and the concept of the system to measure pollutions are described.

**System Components and Pollution Measuring Concept**

The IMS consists of several nodes (MK for German MessKnoten in Figure 1), whereas one node represents one measuring location. In each node sensors for the different pollutions, dust, noise and vibration, are combined. The electro-technic aspects of the nodes and of the receiver are not in the focus of this paper. They are described in detail in Gaedeke et al. (2014).

![Figure 1. Complete IMS on a construction site](image_url)
The wireless connection is built on a self organizing network on ZigBee basis. This leads to a stable system with far reach. Furthermore batteries and a GPS sensor are integrated.

**Overall System**
The IMS system has to encompass at least six measurement nodes to be able to map the pollutions of a complete area. A Server with a receiver for the ZigBee network is used to gather, analyze and save all data (Figure 1). Besides managing data, the server generates alerts when impact levels are exceeded. The server itself is part of a Wireless LAN or even GPRS, to submit the data to any interested and authorized stakeholder. A portable device should be integrated into any equipment, e.g. excavators, where usually the major polluting actions of the construction/deconstruction site are controlled.

![Figure 2: Elements of a single sensor node (Gaedeke et al. 2014)](image)

**Dust Measuring**
The IMS uses a cheap Compact Optical Dust Sensor GP2Y1010AU (2005) from Sharp to measure dust (Figure 2). The sensor uses an infrared diode to transmit light for the detection of dust particles in the air. The dust particles reflect light, which is transformed by a phototransistor into an electric current. This current is converted into the amount of dust in the air [mg/m³]. To achieve a continuously air flow through the sensor, it is installed in a vent pipe together with a small fan. As shown in Figure 3, the system parameters are tested versus other commercial dust measurement systems (e.g. Casella CEL-712 Microdust Pro (CEL-712)).

![Figure 2. Test of the GP2Y1010AU versus the](image)
Dust is the most unstable measurement, as it is highly influenced by weather and other factors of the local surrounding. To measure dust as good as possible, the system uses multiple measurement points and includes weather data, especially wind. The position of the measurement points is automatically determined by GPS. The overall dust distribution on/around the site is calculated based on the data of position and wind and the different measurement results. It is targeted to estimate the highest anticipated value to check it versus regulation.

**Noise measuring**

As noise is distributed through the air, which is a nearly homogenous medium, noise is easier to determine than the other two pollutions measured by the system, dust and vibration. For the determination of noise the commonly A-weighting is used in the IMS. Affecting obstacles can be easily estimated. Therefore, standard class 2 sound level meters PCE-322A (2014) have been integrated in the system that are just connected by an Analog Digital Changer ADC (Figure 2) to every node. The calibration is directly done over the central server by a calibration tool.

Since noise is the best predictable parameter measured by the IMS, the evaluation with the help of the system is very good. A resulting point noise source of the theoretical sound level is calculated (Figure 4) based on the measured noise levels at each location and their position (GPS). From the resulting point source a mapping of the complete sound levels of the whole area is possible. An accuracy of the source point of about 5m in any direction and of the sound level of 6 dB is proven in tests (Figure 5). This is acceptable for a first estimation. Further evaluation of the system is needed to reduce errors and improve results.

**Vibration Measuring**

The IMS uses Micro Electrical-Mechanical Sensors (MEMS sensors) from Murata (SCA3100-D04), which determine vibration by acceleration. At each node the sensor is mounted in an earth screw (Figure 2). The screw should be brought into a depth, where the amount of vibration matters, e.g. the depth of the near foundation. The vibrations created by this sensor are quite high, but tests versus the professional system ZEB/SM-3C (2012) suggest that the critical levels can be clearly determined (Figures 6 and 7).
The transmission of vibration is done through the ground. In homogenous ground conditions, which are seldom in rural areas, the measurement results are very accurate, according to tests with the IMS and the ZEB. These tests showed as well that the MEMS sensors detect exceed of limitations according to DIN 4150-2 and DIN 4150-3. As for noise, the target of these vibration measurements is the identification of the location, where all energy is emitted. From this location the overall pollution on/around site can be calculated. There are already mathematical models to estimate vibration propagation as described in Armaghani (2013). Since different, usually unknown soil layers respond differently related to vibrations and the vibration might be transmitted in a depth that is not monitored, tests prove that it is very hard to calculate the accurate position of the source. Therefore, at the moment vibrations are monitored by identifying the points of interest including their depth. And the discrete vibration values are measured in these points. Hence, the system is applied to measure near to and at the foundation level of buildings, which may be affected by vibration.

Build up of the system

Definition of the points of interest
There are different considerations by choosing the points of interest for the installation of the measurement nodes. Most obviously it is important to find places/positions for the IMS nodes, where best possible measurement results can be achieved. For dust and noise this is usually done, when there is a clear line of sight. But also adjacent buildings may influence the results. Hence, they have to be considered and adjusted as noise may be reflected by buildings or the wind may be canalized which may lead to high dust levels in certain areas. For vibration it is more difficult to find the right place, since there is usually no way to completely evaluate the ground conditions. Here the best measuring results might be gained by measuring very close to the foundation of any building of interest. Beside the considerations for the best measurement position with minimal influences on the results, there are also operational aspects that have to be taken into account by choosing the points of interest. For example, the system has to be installed in places, where it does not interfere with the construction/deconstruction work and it has to be accessible for a power line or to change batteries.
Physical build up and setting up the network

The earth screw with the vibration sensor inside is turned into the ground as shown in Figure 8. Then there is a post mounted on the earth screw. All other devices of one node are then attached to the post (Figure 9). The server has to be placed preferably at a dry and secure place. After all systems are turned on, they establish the self-organizing network and start the measurement automatically. Any external device can access the server.

System application and benefits for the different stakeholders

The system information can be interpreted according to the stakeholder interest. Nevertheless, one conclusion from the system results is most important and the same for all stakeholders. This conclusion refers to the compliance with regulations due to pollution limits. As there is no reason or chance to interfere with other participants, if the regulations are met and this compliance is proven by the system results.

Residents:
The major target of residents is not to be affected or harmed by any pollution of the construction site. Health is usually the main reason and also related regulations focus on this topic. There is no possibility to act versus construction works, when the regulations are met, which can be proven by the results of the IMS. The second target of residents is not to be disturbed. In this case the system generally cannot prevent being affected by demolition works, but it can help to meet the impact limits set by regulations. Hence, disturbances usually have to be accepted by residents.

Authorities:
The main target of authorities is taking care that residents and the environment are not affected more than stated in regulations. Authorities are satisfied, when regulations are met, which is proved by the results of the IMS, as mentioned above.

Principal:
In Germany the principal is responsible for meeting the regulation related to construction works. He usually transfers this duty to the contractor. In general, one major interest of the principal is a cost-effective execution of the work. For instance, a delay of the work by authorities’ intervention can be very expensive.

Contractor:
The contractors target is also the major target of the IMS, since this stakeholder benefits most of using the system. The contractor usually agrees to do all work complying with regulations. Therefore, the IMS allows the contractor to adjust his work to the regulations
most beneficially. He can use additional machinery, when limits are not met. Or he can apply protective measures, when limits are exceeded. The meeting of limits can imply a slower progress for the contractor. For instance, different tools have to be used, work has to be stopped in times with high pollution, passive protective measures, like walls, or active protective measures, such as water cannons, have to be applied. Nevertheless, he is also interested in limited interventions due to his working plan. If the contractor can prove complying with regulations, the chance of work interventions and prohibitions is limited. The IMS can provide a sound legal protection to the contractor.

**Conclusion**

The presented IMS is the first integrated monitoring system for construction and demolition, which can be used to meet regulatory limits, related to noise, dust and vibration impacts. The system uses the measured data to calculate the pollution distribution and propagation to warn the contractor and machine operators in real time, when pollutions are too high to comply with legal regulations. The system has been designed and built for the regular use on site. The requirements like low cost sensors, easy to maintain and a secure and stable network are realized.

The IMS helps to meet the demands of all relevant stakeholders of construction and demolition works by meeting the regulations related to noise, dust and vibration pollutions. Additionally, the system can support the cooperation of these stakeholders. For instance, the principal and contractor can guarantee compliance with regulations by applying the system. In case the system will become mandatory for construction/deconstruction works in the future, the principle should be responsible for the application on site. To date the IMS has been successfully tested in laboratory environments which have characteristics of a real construction site. A test on a real demolition site is planned in 2015.

The following basic functions are integrated

- Basic measurement of dust, noise and vibration
- Self connecting network
- Easy set up, easy to maintain
- System to collect and distribute data

All these features are tested on a test site with demolition equipment and are fully operational. Therefore, the system’s state corresponds to the Technology Readiness Level 6 (TRL6), which means its serviceability is given. To reach TRL 7, which would imply it is ready for use in real operation, additional functions have to be integrated and tested. Therefore further tests in rural environment under operational conditions have to be done and the integration of an automated dust, noise and vibration analysis for higher accuracy is needed.

**References**


GA-Based Precast Production Planning System

Chien-Ho Ko¹ and Shu-Fan Wang²

Abstract

Appropriate production plans can make resources utilized effectively as well as minimize waste. However, currently most of the precast fabricators propose production plans depending on the rule of thumb, resulting in the squander of resources and postponed delivery. Computerized scheduling techniques provide more precise outcomes than those made manually. The goal of this study is to develop a GA-Based Precast Production Planning System to assist production managers arranging production plans. This research first establishes a flow-shop sequencing model based on the current production status by considering the buffer sizes between production stations. Then, a multi-objective genetic algorithm is applied to search for solutions with minimum makespan and tardiness penalty. The performance of the proposed system is verified using two examples. The result of which demonstrates that the proposed system can offer appropriate production plans. Furthermore, by taking buffer sizes into consideration, more reasonable and feasible production sequences can be achieved.

Keywords: Precast, flowshop, production planning, genetic algorithms, decision support systems, buffers.

Introduction

The formwork method has been applied in building construction for a long period of time. However, such a traditional construction method can be hardly competitive as the cost of labor and notion of time efficiency rise each year. Precast construction is an enhancement method accomplished by erecting prefabricated concrete elements (Bennett 2005). To support a construction schedule, precast fabricators deliver elements to a site according to its erection schedule. To enhance the competitiveness of a fabricator, production planners face the challenges of satisfying multiple objectives since one may conflict with the others (Chan and Hu 2002). Due to the development in technology and the mutation in the manufacturing industry, traditional simple scheduling cannot be capable of dealing with the current complex production systems.

Leu and Hwang (2001) regarded the three working zones in a precast factory as a flow-shop sequencing model. A genetic algorithm was applied to achieve the solution for this model with minimum makespan. In another research (Leu and Hwang 2002) written by the same authors, a genetic algorithm was tested in several projects for minimizing the time spent on producing precast elements. However, precast fabrication requires a rather large space while manufacturing, previous studies have ignored buffer size between working stations, thereby may result in unrealistic production plans. The objective of this study is to develop a GA-Based Precast Production Planning System to assist production managers

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making appropriate production plans. A limited buffer size between stations is considered in the system.

**Precast Production Practice**

This section explains current practice of precast production. In the process of construction, precast elements are made by a process which can be highly customized. There are two phases within this process, namely the design and the fabricating. In the design phase, designers will translate customers’ demands into physical shop drawings before the precast elements are fabricated. Communications and negotiations are necessary to ensure that clients’ needs have been fulfilled. After confirmed by the clients, the drawings will be used in the second phase in the production of precast elements. The focus of this study is on the fabricating phase, which is conducted after the design phase but before the hoisting construction on building sites.

Elements are fabricated by using various types of steel molds depending on different designs in precast factories. The way how the precast industry uses steel molds is identical to other manufacturing industries. In general, production systems of the manufacturing industry can be roughly divided into two types of method based on different layouts of the plants. One is the comprehensive method, and the other is the specialized method (Warszawski 1990).

With regard to the comprehensive method, all procedures of manufacturing works are conducted by the same team at the same place. After finishing all the procedures for one element, the team will move on to another station to work on the next work piece. The merit of such kind of production is that work flow can be understood easily by the crew. However, resources are not used efficiently and not easily shared among different stations. If the flow path and processing time are similar between each precast element, it will lead to the problem of requiring the same resources at the same time. The layout of this method is sketched in Figure 1.

![Figure 1. Comprehensive Production Method](image-url)


**Precast Production Modeling**

Precast production can be divided into six steps: (1) mold assembly, (2) placement of reinforcement and embedded parts, (3) concrete casting, (4) curing, (5) mold stripping, and (6) product finishing. This process is depicted in Figure 2. In general, fabricators use steel molds for the purpose of reuse. A precast component generally is composed of concrete and steel bars. Reinforcements and embedded parts are placed in their positions after the mold is formed. The concrete is cast when the embedded parts are in their positions. To enhance the chemistry-solidifying concrete, steam curing is implemented; otherwise, the component concrete requires weeks to reach its legal strength. The molds can be stripped after the concrete solidifies. Due to the cost of developing steel molds, fabricators reuse them once they are stripped. The final step in production is finishing. Minor defects such as scratches, peel-offs, and uneven surfaces are treated in this step.

![Figure 2. Precast production process](image)

The traditional flowshop sequencing problem regards production as a continuous flow. The typical equation used to calculate the completion time is shown in Eq. (1):

$$C\left(J_j,M_k\right) = \text{Max} \left\{ C(J_{j-1},M_k), C(J_j,M_{k-1}) \right\} + P_{jk}$$  \hspace{1cm} (1)

where $C\left(J_j,M_k\right)$ denotes the completion time for the jth element in k station and $P_{jk}$ is an operation time for that element ($P_{jk} \geq 0$).

**Production Planning System**

**Searching Engine**

The Multi-Objective Genetic Algorithm (MOGA) has been extensively adopted in numerous multi-objective decision-making analyses. MOGA, obviously, has turned into one of the most eminent solutions for multi-objective scheduling (Montoya et al. 2014). This research proposes a multi-objective genetic algorithm to search for appropriate production plans. The algorithm is adopted from the Multi-Objective Genetic Local Search (MOGLS) proposed by Ishibuchi and Murata (Ishibuchi and Murata 1998). The evolutionary process of the developed algorithm is shown in Figure 3. Each step is explained as below.

- **Encoding**
  
  The factors affecting production makespan include both the resources and the sequence of production. Certain resources such as the number of cranes and the size of the factory cannot be changed by the production planers. Others such as buffer size between stations, number of molds, and working hours can be determined.

- **Initializing population**
  
  To provide an equal opportunity for every state space, a set of initial solutions is randomly generated.

- **Calculating objective function**
The goal of the study is to simultaneously minimize cost and production duration. Scheduling performance is therefore evaluated by its makespan and penalty costs (Ko 2013).

- Updating Pareto solution
  To be sure that the derived solutions conform to Pareto’s definition, every generation should be updated to this solution pool. Chromosomes in the pool which dissatisfy Pareto’s definition are removed.

- Enhancing by elitism
  Elitism has been proven successful in enhancing GA searches (Ko and Wang 2010), surviving a certain number of Pareto solutions to the next generation. By applying this strategy, the fitness increases from one generation to the next.

- Selecting
  A selection operator is used to choose chromosomes according to their fitness. A chromosome with a higher fitness value has a greater chance for survival.

- Crossing over
  A GA extends the searching space by a crossover operator, which produces the next generation by exchanging partial information from the parents. A position-based two-cut-point crossover is used in this study.

- Mutating
  The mutation operator produces spontaneous random changes in various chromosomes and protects against premature loss of important notations. This study uses shift mutation that randomly selects two points.

- Searching local area
  This study searches the local area by using a mutation operator. If the solution obtained through the local search is better than the current solution, the algorithm mutates population again.

- Replacing
  In this process, the previous population is renewed by the generated offspring. The next generation can continuously include new solutions for evolution.

- Terminating conditions
  The terminate conditions provide the criterion for stopping the evolutionary process, which is terminated by iterations in this study.
System Development

A production planning system is developed for managers in precast factories to use the scheduling method proposed in this study. Through graphical user interfaces programmed using JAVA language, users can easily acquire necessary production information. Search engine is programmed using C language for increasing computing efficiency. Two system modules are explained as follows.

Objectives Settings

In addition to the default objectives (i.e. makespan and total penalty cost), this module provides other evaluation criteria, namely idle time, total flow time, and maximum tardiness. This module is shown in Figure 4.
Production Information Input

This module contains two parts. The first encompasses the setting of the number of precast elements and the required mold types. The second includes the inputs of mold types for precast elements, production time, due date, and penalty cost. This module is shown in Figure 5.

Experiment

Previous researches related to the production planning usually assume that buffer sizes between stations were infinite. Nevertheless, precast elements require a lot of space. Production plans might be unrealistic if the real buffer sizes are not taken into account. This study deals with the impact of buffer sizes on production planning. Ten elements are
experienced. Production data, as shown in Table 1, were adopted from Benjaoran et al. (2005). Transportation time is included in the makespan. Related parameter settings are as followed: The population size is 20, crossover rate is 0.9, and mutation rate is 0.005. The evolution over 200 generations is executed in the experiments. The results are demonstrated in Table 2.

In Table 2 the provided buffer size is the greatest capacity in the production system. The maximum buffer size required in the system is two. When the buffer size is larger than two, it has nearly no influence on the makespan (i.e. 126.9) and total penalty cost (i.e. 701.6). The unneeded buffer size not only occupies space, but in practice may increase transportation time and cost that could be referred as waste. However, if the buffer size is smaller than the required buffer size, the makespan and total penalty cost increase responsively. Since only few elements are produced in this experiment, the impact is not obvious.

<table>
<thead>
<tr>
<th>Element No.</th>
<th>Steel mold type</th>
<th>Manufacturing time</th>
<th>Due day (h)</th>
<th>Penalty costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mold assembly</td>
<td>Embedded parts placement</td>
<td>Concrete casting</td>
<td>Mold stripping</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>2</td>
<td>1.6</td>
<td>2.4</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3.4</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>0.8</td>
<td>1</td>
<td>1.2</td>
</tr>
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<td>A</td>
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<td>C</td>
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<td>3.6</td>
<td>2.4</td>
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<td>A</td>
<td>3</td>
<td>3.2</td>
<td>3.0</td>
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<td>C</td>
<td>1.3</td>
<td>0.9</td>
<td>2.4</td>
</tr>
<tr>
<td>8</td>
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<td>1.4</td>
<td>1.1</td>
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<tr>
<td>9</td>
<td>A</td>
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<tr>
<td>10</td>
<td>C</td>
<td>1.6</td>
<td>3.2</td>
<td>2.3</td>
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Table 2. Buffer size experimental results (for 10 jobs)

<table>
<thead>
<tr>
<th>Provide buffer size</th>
<th>Makespan</th>
<th>Total penalty costs</th>
<th>Required buffer size</th>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>126.9</td>
<td>701.6</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>126.9</td>
<td>701.6</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>126.9</td>
<td>701.6</td>
<td>2</td>
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<tr>
<td>3</td>
<td>127.1</td>
<td>706.2</td>
<td>2</td>
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<td>2</td>
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<tr>
<td>1</td>
<td>134.7</td>
<td>729.1</td>
<td>1</td>
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</tbody>
</table>

Conclusions

This study established production models based on the practical production status in precast factories. The multi-objective genetic local search algorithm is applied to search for production plans with minimum makespan and tardiness penalty. At the end, a production planning system with graphical user interfaces has been developed using JAVA and C languages. By applying suitable algorithms in which real situations are concerned, a set of Pareto-optimal solutions can be provided for production managers as the reference when creating production plans.

Two examples are applied to validate the performance of the developed system. Experimental results demonstrate that the multi-objective genetic local search algorithm developed in this study is efficient in offering solutions to complex production planning problems. In addition, considering buffer size between stations is crucial for production planning. The two outcomes mentioned above indicate that the proposed production system is capable of offering feasible solutions to precast production for enhancing decision making.

Acknowledgements

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References


Exploring Transformation Challenges: Limits to the Growth of Building Contractors in South Africa

Fidelis Emuze¹ and Darren Flanagan²

Abstract
Although there are many avenues for transformation, economic empowerment and growth is its cornerstone in the construction industry. The current structure and performance of the construction industry in South Africa is evident of the needed transformation in the sector. While a number of research projects have examined this issue through an objective lens, this paper is based on a phenomenology study. This approach shows that without basic skills, knowledge and capacity, there can be no growth that could change the industry to a high gross domestic product (GDP) contributor to the South African economy. The results of the study shows that although the firms are keen on business expansion, barriers related to capital, skilled labour, late payments, low profit margins, empowerment requirements, competition with larger firms and economic restraints, should be surmounted. It can therefore be concluded that until each firm is open to a new approach to skills acquisition, use of finance and business judgement / decisions, business expansion will be unattainable. Training, education and mentoring that would engender needed construction business skills among SME building contractors is recommended.

Keywords: Bankruptcy, building contractors, transformation, South Africa.

Research Background
Although there are many challenges in South African construction, one of the major issues is the transformation challenge and the limitations that contractors face when they are keen on putting their firms on the growth trajectory. It is well known that the construction industry is a very challenging industry as it is very competitive and at times unstable during economic down turn (De Valence and Runeson, 2011). However, the management dilemma that is the focus of this paper is the inability of emerging or small and medium sized (SME) building contractors to expand their organisational footprint and portfolio without an exposure to business bankruptcy in South Africa. One of the major problems in South African construction is that building contractors do not expand and develop into larger and more prosperous firms with ease (Martin and Root, 2009). The importance of researching this problem lies in the fact that there are many SME construction firms that are owned and managed by Historically Disadvantaged Individuals (HDIs) in South Africa. These HDI owned entities often lack resources that are vital for prosperity in the sector (Martin, 2012). As a result of this, few large firms tend to dominate the landscape and often secure major contracts in the industry. As evident in the construction industry development board (CIDB) register of active contractors, there are so many lower grade contractors

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in comparison to higher grades (Emuze and Smallwood, 2011). This gives a clear indication that the contractual capacity required for high value jobs is dominated by larger firms.

**Research Rationale**

The problem background is rooted in the idea that SME building contractors struggle to transform into larger contracting firms in South Africa. Thwala and Phaladi (2009) acknowledge the poor understanding of broad business issues among emerging contractors. All actors in the construction industry face the same market forces that have implications for different firms. What this means to a small contractor is that they are unable to always respond appropriately to changes in the industry in a fluid situation (Thwala and Phaladi, 2009). According to Martin and Root (2009), main issues that contribute to the pitfalls of contractors that attempt expansion in South African construction include:

- Tendering too low to make a sufficient profit because of the highly competitive nature of the business.
- Lack of managerial skills as well knowledge, in areas of general law, estimation and tender pricing.
- Fronting that tends to act as antithesis of government empowerment initiatives in the sector.

The “fronting idea in South African terms is where the company claims to be managed by HDI, yet it is managed by white South Africans” (Emuze and Adlam, 2013: 139). In a nutshell, it has been observed that SME building contractors often struggle to transform into larger contracting firms in South Africa (Martin & Root, 2009; Martin, 2012). The inability of such contractors to transform limits the available contracting capacity in the industry and then exposes a project to increased numbers of stakeholders that are involved in its delivery.

This in turn has a concomitant cost implications for projects (Emuze & Smallwood, 2011). Thus, the main research problem for this particular study can be said to be “small and medium sized firms willing to expand in South Africa fail to do so timely due to management related challenges. Based on these arguments, it is vital to assist SME building contractors to have a clear understanding of how and when to expand their organisational footprint and minimise the risk of bankruptcy; by so doing, the number of failed contractors should be limited in South Africa since economic sustainability and competitiveness in the market should be discernable (Martin & Root, 2009). The study could also potentially assist firms to note when to embark upon business expansion in the sector as emerging firms are battling to overcome social responsibility, business processes, planning and strategy related challenges (ladzani, Smith and Pretorius, 2010).

**SME Building Contractors: Challenges**

Flooding of the construction market with many contracting entities has been flagged as a major problem. According to Thwala and Mvubu (2008), the construction industry is flooded with empowerment based firms that overcrowd the market in South Africa. The word ‘flooding’ is used in that there are thousands of firms that are on the CIDB register without having appropriate jobs to show for their involvement in the sector. For instance, these firms lack the skills that are vital to the success of contracting firms (Martin, 2012). It is therefore necessary that these firms acquire the
necessary skill for the industry to expand and accommodate them, if economic growth in South Africa is to be obtained (Thwala & Mvubu, 2008).

The study by Thwala and Mvubu (2008) further shows that due to market overcrowding, competition is steep and the tender margins are tough and profit is at a minimal, thus making it difficult for emerging contractors to make it in the industry. In such a situation, SME building contractors would tender for projects even when they are not capable of handling them in areas of finance and experience in order to survive. As a result of the lack of the required antecedents, banks are reluctant to give these building contractors money and if they do, it is at very high interest rates. So many emerging contractors either liquidate or abandon projects due to lack of finance or are disqualified due to the fact that they could not provide construction guarantee.

A further hindrance for the contractors is that of late payment by the client, which causes a downward spiral of events (Thwala & Mvubu, 2008; Maritz and Robertson, 2012). To support this perspective, the study by Tokuori (2010) shows that delay of payment from government departments creates a cash flow problem, due to the fact that SME contractors are already low on capital and they cannot start work without advanced payments and due to this issue – the project and business performance of building contractors suffers. The effects of delayed payment is equally made worse by poor cost and accounting practices found among SME contractors (Thwala and Mofokeng, 2012). The situation is made worse as such contractors often use simple estimation techniques that do not stand a competitive chance (Seeletse and Ladzani, 2012).

In addition, Seeletse and Ladzani (2012) note that SME contractors lack essential resources and skills for competitive tendering because of inexperience. Larger experienced contractors do not experience this difficulty. Apart from estimation and pricing, the management of projects in the early stages is critical to success. Many small enterprise owners tend to manage all aspect of their business alone. This is often because of financial constraints. Because of this pressure and a lack of understanding of the importance of record keeping, bookkeeping is often poor. Inability to access adequate finance and credit, lack of contractual skills and documentation, inability to employ competent workers and lack of skills in the managerial, financial, and technical aspects are also causes of failure to properly manage businesses (Thwala & Phaladi, 2009). Thwala and Mvubu (2008) also found that the relations between emerging contractors and suppliers are not very healthy because most suppliers are reluctant to advance credit towards the emerging contractors because of their project completion related failures and mismanagement of materials.

**Research Method**

Within the qualitative method cluster, the phenomenology approach was adopted. The method was chosen for its ability to effectively obtain information through experiences, and individuals’ perspectives. The primary data stems from face-to-face interviews that were conducted between June and August, 2013. The interviews were conducted in specific locations in order to meet individual representative of the firms that took part in the study. The interviewees were thirteen construction professionals (Table 1). The sample included two classes: seven established contractors and six emerging contractors. The purposively selected interviewees were from different income and geographic areas (Springer, 2010). The interviewees include those who had formal education in the form of diplomas and degrees, while other participants had no tertiary education (Table 1). All the interviewees however had formal
education of at least a matric certificate. There were participants who worked on multimillion rand projects and others who worked on projects amounting to thousands of rand. Some interviewees were based in a single province, and some, the large firms, work in various locations around South Africa - covering a large spectrum of geographical areas in South Africa.

Table 1: Background Information of Interviewees

<table>
<thead>
<tr>
<th>No.</th>
<th>Highest Level of Education</th>
<th>Job Title</th>
<th>Years in Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grade 12</td>
<td>Construction Manager</td>
<td>12 years</td>
</tr>
<tr>
<td>2</td>
<td>National higher diploma</td>
<td>Project Director</td>
<td>38 years</td>
</tr>
<tr>
<td>3</td>
<td>National diploma</td>
<td>Construction Manager</td>
<td>6 years</td>
</tr>
<tr>
<td>4</td>
<td>Bachelor’s degree</td>
<td>Construction Manager</td>
<td>14 years</td>
</tr>
<tr>
<td>5</td>
<td>Bachelor’s (Honours) degree</td>
<td>Construction Manager</td>
<td>4 years</td>
</tr>
<tr>
<td>6</td>
<td>Bachelor’s degree</td>
<td>Company Owner</td>
<td>40 years</td>
</tr>
<tr>
<td>7</td>
<td>National diploma</td>
<td>Company Owner</td>
<td>12 years</td>
</tr>
<tr>
<td>8</td>
<td>Bachelor’s degree</td>
<td>Company Owner</td>
<td>7 years</td>
</tr>
<tr>
<td>9</td>
<td>National diploma</td>
<td>Company Owner</td>
<td>5 years</td>
</tr>
<tr>
<td>10</td>
<td>Matric</td>
<td>Contract Director</td>
<td>32 years</td>
</tr>
<tr>
<td>11</td>
<td>Plummer’s certificate</td>
<td>Company owner</td>
<td>11 years</td>
</tr>
<tr>
<td>12</td>
<td>Matric</td>
<td>Company owner</td>
<td>13 years</td>
</tr>
<tr>
<td>13</td>
<td>National diploma</td>
<td>Company owner</td>
<td>5 years</td>
</tr>
</tbody>
</table>

The information gathered during the interviews was analysed thematically. The data were examined and repetitive information excluded, and the relevant data were grouped into themes and the views on the themes were taken into account (Bryman and Bell, 2003). Experiences were documented as well as the personal and general information. The interview protocol was broken down into themes that reflect the research questions of the study. Barriers prohibiting expansion, bankruptcy in the industry and possible interventions form the major themes that emerged from the transcribed interviews.

Research Findings

Theme 1: barriers prohibiting expansion

Desire to expand

The firms, established and emerging, that were interviewed desire to expand their businesses. However, there were different views about what expansion entails. The smaller firms would like to expand, but they were afraid of the risk of stretching valuable and reliable resources over larger areas. Such resources that were mentioned include management, supervision and finance. Another hindrance to expansion is time and effort, which they require at work. In their mind, additional work time would lead to a loss in family time. The larger firms appeared very keen on the idea of expansion and to quote from one respondent, “there comes a time when expansion becomes inevitable.”
Barriers to expansion

It seems that similar barriers affect both emerging and established contractors. With the expansion of a firm, it appeared that capital, skilled labour, late payments, low profit margins, empowerment requirements, competition with larger firms and economic restraints all played a role in preventing expansion. Capital and cash flow was clearly a restraint to a firm that is keen on expansion. The increase in competition further lowered profit margins and inevitably the cash flow and future capital for possible expansion. Without the cash flow and capital, it is impossible to maintain heavy equipment and pay wages.

It appeared that the large and small firms both struggled with labour issues: lack of skilled labour, foremen and managers who could manage project teams, labour relations and wage uncertainties. An interviewee state that quality of rural education has not prepare labourers for the labour market as they were unable to solve simple problems even after years of training. One of the contracting directors made the statement about employees when he says, “very few employees want to start at the bottom and work their way through middle management, where they can acquire valuable experience, to reach top management.” He further explains that middle management was lacking and this has affected supervision and the quality of the end product. The interviewees further say that the work culture of the modern school graduate is, “I want to be here to earn a salary, but I do not really want to work too hard”.

The data analysis also shows that late payments affect established and emerging firms. This had a greater impact on the smaller firms as their cash flow and capital are limited. The large firms had the capital and cash flow to hold out longer when clients were late with payments. Economic restraint clearly affected emerging contractors as well as established contractors, as most of the interviewees stated it as a reason to be reluctant to expand.

According to the interviewees, the Broad Based Black Economic Empowerment (BBBEE) requirements are difficult to conform to. One of the interviewees explain that the BBBEE partners often lacked the skills to contribute meaningfully within the business and this placed unrealistic demands on the firm. The same respondent said that there were political interventions in the award of tenders, and that sums of money needed to be paid on the side in order to be awarded the tender.

Overcoming barriers

The more established firms definitely had a better understanding than the smaller contractors of how to overcome business obstacles. As an example, the smaller contractors would say that they needed to find better and more skilled labour force when asked how to overcome expansion barriers. The more established firms had a plan and said that they needed to appoint subcontractors and that this would avoid cost increases in areas such as vehicles, tools and salaries. The established contractors said that the turnaround time, after having committed capital and to get a return, was relatively short and thus reduced the risks of expensive financing cost. The more established firms had a way of generating sound management; they recruited students who had academic training and knowledge. The established firms also say that they strive to make the potential middle management employee proud of the firm. Employees were used for their specific strengths, and interest, which motivate the workers to create healthy competition between project sites.

In the area of late payment, the more established contractors tried to negotiate with clients and resolve the issue. However, this was not always successful and
cancellation of the contract could occur. The smaller contractors claim that the cost in trying to win the disputes and get the delayed payment was not worth the high expense and effort. There appeared to be a “success secret” in the fact that the more successful and established firms sought to subdivide their organisation and hire subcontractors.

**Theme 2: bankruptcy in the industry**

*Link between bankruptcy and expansion*

Both emerging and established contractors believed that there is a link between bankruptcy and expansion in the industry. The reasons appeared to be of the same nature.

One respondent went as far as to say that emerging contractors appear to be set up for bankruptcy as they were a times allowed to take out large loans, which gives room for spending money unwisely by purchasing luxury items. He further stated that some people are willing to work for such items, while others are not. Some of the key areas linking bankruptcy to expansion include: taking on projects that they could not handle or ‘grew too fast’ and they found themselves with insufficient capital and cash flow for future overhead payments and expenses related to operations. Another follow up was that jobs took longer than planned for which caused extra unforeseen costs.

The interviewees even noted that management tend to be stretched as the firm expand. People became overloaded and could not manage the work load properly. Expansion required new foremen and workers. Many were unproductive as they still needed training for required skills and this had a negative effect on the cash flow of an organisation at the worst possible time “in the expansion process”.

*Instances of bankruptcy in the Industry*

Every individual interviewee had either heard of or encountered bankruptcy in the construction industry. This gave an indication that this is a real problem in South African construction, especially with emerging contractors.

*Why are contractors struggling in the construction industry?*

Once again, the established contractors had a broader understanding of the issues regarding why contractors fail in the industry. Many had first-hand experience as they had numerous emerging contractors who work with them. Emerging contractors had a tendency to stick to a very narrow field of skills. The industry is very competitive and there was not always work available. Therefore, the contractors were undercutting one another in order to get a tender. The bigger firms were tendering for smaller jobs for the sake of survival, while emerging contractors were struggling to compete with the larger firms.

In another response to the question, “too many projects were awarded to unskilled BBBEE companies because; ‘no sufficient barriers of entry’ exist, was recorded”. The interviewees further say that corruption, poor management and BBBEE transformation issues impacted on the bottom line. One respondent stated that with, “BBBEE you have to share your company”. Poor site and office management meant that there was an overall lack of proper management and financial skills. This leads to poor use of resources. A particular difficulty is that of poor record keeping, which means SME building contractors, would have limited evidence to prove allegations when things go wrong. Other issues that were raised include:

- “Labour was unwilling to work hard for little money”.

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- “Late payments”.
- “ Strikes”.
- “Theft on sites”.
- “Corruption in the award of tenders”.
- “Non-compliance with health and safety (H&S) regulations.

Implications of the Findings

The findings of the interviews identified the contributing factors to SME building contractors’ business failure as most of the data confirmed what has been said in the literature, apart from new insights that should be contextualised as indicated below:

Expansion hindrance amelioration: The study was able to identify barriers that tend to stop contractors from expanding as well as the means to overcome these barriers. In this respect, the aim and objective was only partially fulfilled as obstacles and current challenges were continuously changing among the firms and varied from one respondent to another.

Right time to expand: The research was able to give insights into the advice of when it is the correct time to expand a business portfolio within the sector. Although, there appears to be no absolute strategy that works for all, correct situational analysis in the business environment should provide the right timing for aspiring firms.

Generally, the issues that were examined show that the transformation challenges among SME building contractors in the sector could be reduced by addressing:

- Lack of managerial skills and knowledge.
- Lack of appropriate credit ratings in relation to banking and material supplier services.
- Imprudent use of business funds.
- Non-separation of domestic finance from business finance.
- Poor preparation of tenders due to lack of knowledge and experience.
- Owners trying to manage business unassisted due to cost implications.
- Poor bookkeeping and accounting systems.
- Employment of family members who do not necessarily have the required skills.
- Disparity between capacity and project commitments.
- Tendering for projects with low profit margin projections.
- Usurpation of small jobs by large established contractors.
- Improper award of contracts, especially to unskilled empowerment firms solely on preferential grounds.
- Late payments by client, especially in relation to small contractors that do not have sufficient capital to maintain themselves without clients’ payments.

Concluding Remarks

The literature has shown that the growth outlook for SME building contractors is not promising as their construction related education background is deemed to be either inadequate or non-existent, a situation that is evident in their poor estimation and book keeping competencies. As a result, clients and established businesses are not very keen to take on unreliable SME building contractors due to the possibility of poor performance. Some of the common feature of the SME building contracting business tends to be counterproductive to the long term interest of the owners. Such
feature includes the general perception that the business money is usually used for domestic purposes and the business simultaneously. All these negate the intentions of transformation initiatives in the sector and as such, they limit the growth of non-established building contractors that are still ‘finding their feet’ in the business.

To sum up, as previously noted in past studies, most SME building contractors in South Africa are still ‘living a hand to mouth existence’ and cannot take advantage of tenders as they lack capacity and managerial skills. Suppliers are also unwilling to give credit to them due to ‘performance related stereotype’. This category of firms equally think of survival when making financial decisions so much so that they often employ close associates without required competencies to undertake assigned roles. The common causes of SME Business failure thus pertain to:

- Finance: lack of capital, poor cash flow, poor credit facilities, and spending business money on domestic issues.
- Skills and know-how: lack of managerial skills, especially in relation to accounting systems, labour skills, and tender practices.
- Poor judgment: buying unnecessary items for the firm, undertaking projects that exceed their capabilities, and growing too fast.

The clear trend in terms of challenges has necessitated the use of entry barriers to curtail the flooding of the market by ill-conceived firms that can barely survive for more than a couple of years. The usefulness of mentoring, training and education that would engender necessary construction business skills cannot be overstated. It is good business practice when SME building contractors with the correct ‘ethos’ engage in project execution in partnership with established firm. Their ‘tutelage’ under the established firm should be seen as a precursor to competitiveness and expansion in the industry. When this is done, SME building contractors may be less exposed to the penalties of delayed payments from clients and also, they should be able to upgrade their project capacity.

As this study was based on a small sample of contractors, it has marginally explored the issues. However, the findings should serve as a starting point for future studies that would tackle the dynamics of each challenge and disseminate how to completely eradicate it in the system. The persistence of some of the problems that were identified in the study suggests that ‘the challenges that limit the growth of SME building contractors’ can be considered to be systemic in nature. Future research directions should endeavour to tackle why contractors are unaware of the organisations that could assist them in terms of business expansion; what are the necessary steps to ensure contractors are not involved in projects that could lead to insolvency due to cash flow problems; and most importantly, how can managerial skills and knowledge be leveraged to stem off bankruptcy, and then, encourage growth in the sector.

References


Delays to Mechanical Services-Type Projects Associated with National Culture in Saudi Arabia

Abdullah Alkharmany1, Kassim Gidado2, and Noel Painting3

Abstract
The aim of this paper is to identify the origin of delays in building projects that are associated with the national cultural factors of Saudi Arabia.

In most major building projects in Saudi Arabia, the various mechanical services components, elements and installations are often designed and manufactured abroad by foreign organizations from various countries with sometimes divergent cultures and installed using a workforce that comes from yet more divergent cultural backgrounds. In such projects, the mechanical services package may be in excess of 40% of the overall cost of the project. The work reported in this paper is a literature-based research that forms part of the early stages of a PhD research that aims to investigate the effect of national culture on the occurrence of delays in building projects, particularly in the delivery of the mechanical services packages in Saudi Arabia.

The paper has established that Saudi Arabia is a highly power distance economy (where most of the decisions are centralized) with a high uncertainty avoidance culture. The origins of delays in building projects have been identified from numerous publications and categorized into eight using the Hofstede's national cultural factors. This provides a basis for further research to evaluate the effect of national culture on the delivery of mechanical services-type projects in Saudi Arabia.

Keywords: Saudi Arabia, national culture, mechanical services, delays.

Introduction
Construction delays are very common in the building construction industry (Albogamy et al. 2012). Most of the delays occur in the early stages of the project the initial conception, designing, planning, and resource arrangement activities (Assaf and Al-Hejjii, 2006). Many delays also occur during the construction phase due to problems with contractual and engineering works. Delays in building projects in the Kingdom of Saudi Arabia (KSA) are widespread. A recent study revealed that building services projects worth nearly $719 billion are either delayed or cancelled due to construction delays in 2011 (Al-Awwal, 2012). It is argued by a number of researchers (Assaf and Al-Hejjii, 2006) that such delays are mainly due to socio-cultural factors. The literature on construction delays reveals a range of trigger factors where socio-cultural factors are significantly identified (Al-Ghafly and Al-Khalil, 1999; Assaf and Al-Hejjii, 2006; Albogamy et al. 2012). However, none of the authors make any attempt to categorise these factors into a specific national cultural

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elements such that management can establish appropriate mitigating strategies for successful project delivery in the specified national environment. In Saudi Arabia, there is even a greater need for such categorisation because of the different nationalities and backgrounds of the construction workforce in all stages of the project life cycle. Therefore, the aim of this paper is to identify and categorise the origins of delays in building projects that are associated with the national cultural factors of Saudi Arabia.

**Construction Delay**

A construction delay indicates the difference that occurs between the actual and the planned completion dates. The delay is formally defined by Bramble and Callahan (1987) as “the time during which some part of the construction project has been extended or not performed due to an unanticipated circumstance”. Similarly, Ramanathan et al. (2012) defines delay as “the time overrun either beyond completion date specified in a contract or beyond the date that the parties agreed upon for delivery of a project”. Delays can be classified into three prominent groups: excusable delays, inexcusable delays, and concurrent delays (Bramble and Callahan, 2010; Ibironke et al. 2013). In building projects, delays happen due to either direct or indirect actions of construction stakeholders or because of the external factors that are uncontrollable. Several other studies classify delays into different categories as per their nature or by associating them with the concerned party such as: owner related, consultant related, contractor and sub-contractor related, project manager related, engineering related, and design related etc. (Marzouk and El-Rasas, 2014). Delays can result in cost overrun, disputes, negotiations, lawsuits, litigation, and abandonment of building projects (Haseeb et al. 2011).

**Building Mechanical Services in KSA**

There are three main divisions of building engineering services: electrical engineering, mechanical engineering, and public health engineering. All these categories are classified into further subcategories including: ventilation, air-conditioning, refrigeration, alarm and security systems, fire detection systems, natural and artificial lighting, lifts and escalators, communication mediums such as the telephone and information technology networks, heating systems, electricity and gas renewable sources, switchgear, distribution boards, low voltage, water drainage and plumbing systems etc. (Chow, 2009). In the past two decades, mechanical services have faced challenges and opportunities due to the emergence of new roles in the areas of energy management, low carbon technologies, sustainability, and renewable energy (Tymkow et al. 2013).

Heating, Ventilation, and Air-conditioning (HVAC) systems are the primary components of building mechanical services in the KSA (Fasiuddin and Buddiwi, 2011; Ventures Middle East, 2012; Budaiwi and Abdou, 2013). Saudi Arabia is the third biggest market in the world in terms of HVAC systems. The country has also led in the Gulf Cooperation Council (GCC) HVAC industry and is expected to grow rapidly in the coming years due to its huge investments in mega building projects and development plans concerned with education and social housing between 2010 and 2015 (Ventures Middle East, 2012). The HVAC market in Saudi Arabia accounts for nearly 24 per cent of the entire construction industry. In 2011, the HVAC market in Saudi Arabia was approximately US$ 3.1 billion and its annual growth rate was estimated nearly 3 per cent (Ventures Middle East, 2012). Saudi Arabia is a warm country and this is the reason that ventilation and air-conditioning equipment account for two-third of HVAC market and heating system comprised of one-third.
Culture Dimensions of Saudi Arabia

Hofstede (1991) and Hofstede Centre (2014) identified six cultural dimensions: power distance, masculinity-femininity, uncertainty avoidance, individualism and collectivism, Pragmatic versus Normative, and Indulgence versus Restraint.

Hofstede and Hofstede (2005) define power distance as “an extent to which the less powerful members of society and organisations within a country or community expect and accept that power is distributed unequally” (p. 46). This concept also applies to institutions and organisations where power and decision making are either centralised or decentralised. Hofstede (1991) shows a greater amount of decentralisation in the lower end of the cultural scale to those in more senior positions.

In the second dimension, masculinity describes the perception of members within the society in terms of competition, assertiveness, and achievement. In contrast, femininity (also part of Hofstede’s second dimension) refers to the degree in which relationships, care, traditions, social values, and quality of life are preferred. A “society is called feminine when emotional gender roles overlap: both men and women are supposed to be modest, tender, and concerned with quality of life” (p. 120). “A society is called masculine when emotional gender roles are clearly distinct: men are supposed to be assertive, tough, and focused on material success, whereas women are supposed to be more modest, tender, and concerned with the quality of life.”

The third dimension; uncertainty avoidance is “the extent to which the members of a culture feel threatened by ambiguous or unknown situations” (Hofstede and Hofstede, 2005, p.167). This shows the circumstances where an individual or group of people feel ambiguous, insecure, uncertain, and uncomfortable about something particularly in order to uphold institutions protecting conformity.

The fourth cultural dimension is individualism or collectivism which is described by Hofstede and Hofstede (2005) as “individualism pertains to societies in which the ties between individuals are loose: everyone is expected to look after himself or herself and his or her immediate family. Collectivism pertains to societies in which people from birth onward are integrated into strong, cohesive groups, which throughout people’s lifetime continue to protect them in exchange for unquestioning loyalty (p.76).

In 1991, a fifth dimension was added by Michael Harris Bond, supported by Hofstede, who conducted a further international study among students with a survey tool that was established together with Chinese professors. The dimension was created on Confucian thinking and was originally called Long-Term Orientation (LTO). The Hofstede Centre refers to the fifth dimension as Pragmatic versus Normative (PRA) (Hofstede Centre, 2014).

A sixth dimension was added in the 2010 edition of Cultures and Organizations, based on Michael Minkov’s analysis of the World Values Survey (WVS) data for 93 countries. The sixth dimension is called Indulgence versus Restraint (IND) (Hofstede Centre, 2014).

The Kingdom of Saudi Arabia (KSA) is the thirteenth largest country of the world and has pure Arabic Muslim culture. Religion is the first priority for KSA people and it majorly influences their social behaviour, routine lives, businesses, and even politics. Islamic laws, beliefs, values and customs are more important for individuals and families.

The application of the Hofstede’ six cultural dimension frameworks on Saudi Arabian culture reveals some interesting insights about the Kingdom. Fig 1 shows the score of each dimension and its cultural relevance to other cultures.
Saudi Arabia’s score for Power Distance (PDI) of 95 is extremely high, which demonstrates a hierarchical order system where each individual is placed on their particular position and requires no further justification. In fact, the organisational hierarchy in the KSA often reflects centralisation and intrinsic inequalities. Subordinates are expected to strictly follow the instructions of their bosses in a benevolent way (Hofstede Centre, 2014).

Similarly, the individualism (IDV) score of 25 indicates that Saudi Arabia is a collectivist society. This means that individuals give value to extended family, strong relationships, group settings, and long-term commitments. One of the major features of a collectivist culture is loyalty which overrules other cultural aspects and societal rules and regulations (Livermore, 2009). The society in a collectivist culture develops solid affiliations among members and each member takes the responsibility to take care of other members. Unethical organisational behaviour in a collectivist culture is treated as a serious offence which leads to punishments, and downgrading of employees. Similarly, ethical and formal behaviour throughout a certain period may result in promotions, incentives, or other social and economic benefits (Mitchell, 2008).

A fairly high score of 60 on masculinity/femininity (MAS) dimension indicates that Saudi Arabia embraces masculine culture where men are supposed to work to support their families. From an organisational point of view, managers are usually assertive and decisive and like to take critical decisions without involving other people or subordinates. In masculinity culture, competition is given high importance and conflicts are reduced by finding appropriate solutions (Hofstede, 1991).

The score of 80 on uncertainty avoidance (UAI) index illustrates a high degree of intolerance in Saudi national culture. This shows that in Saudi Arabia, people are rigid in following traditional codes of beliefs, ideas, and in rejecting unorthodox behaviour. In fact, the cultures like Saudi Arabia give great importance to rules, and it does not matter if these rules work or not. In such environments, innovation may be resisted, truth and regularity are the norms, security is important, and people like to work on their own rather than working in teams (Hofstede and Hofstede, 2005).

Pragmatism dimension identifies how a person's past and current situation cannot be clarified. In cultures with a normative orientation, most people have a strong wish to describe as much as possible. In cultures with a pragmatic orientation most people do not...
have a need to describe the whole things, as they have faith in that it is impossible to understand wholly the difficulty of life. The task is not to know the truth but to live a righteous life (Hofstede Centre 2014). KSA scores only 36 in pragmatism, suggesting that it tends more towards normative orientation. People in such cultures have a strong anxiety with seeking the absolute Truth; they are normative in their thinking. They display great respect for traditions, a fairly small tendency to save for the future, and an emphasis on accomplishing quick results.

Indulgence dimension is defined as ‘the extent to which people try to control their desires and impulses, based on the way they were raised’ (Hofstede Centre 2014). Weak control is named “indulgence” and strong control is named “restraint”. Cultures can, consequently, be defined as indulgent or restrained. The KSA score in Indulgence dimension is 52; this indicates that people in KSA have balance between indulgent and restrained orientations.

**How Saudi National Culture Causes Delays**

The term ‘national culture’ is explained by a number of theorists and experts (Hofstede, 1980, 1991; Hofstede and Hofstede, 2005; Shore and Cross, 2005; de Bony, 2010; Rees-Caldwell and). These studies are divided into two groups: firstly single dimensional vs. multidimensional constructs; and secondly heterogeneous vs. homogeneous programming Young and Nie (1996). The single dimensional studies are suitable for organisational analysis only whereas multidimensional constructs can be truly applied on entire national culture for detailed and comprehensive analyses. On the other hand, both heterogeneous and homogeneous concepts are applied to both organisational and national cultural analysis because they both perceive consistency or regularity from the cultural perspective. Heterogeneity is the state of being heterogeneous.

Heterogeneity in any society refers to individuals or a group of people who are different in terms of their cultural backgrounds, ages, sexes, or ethnicities. In contrast, homogeneous assumes that all people or group are similar in qualities and other aspects which are not true in today’s case of national culture. This is the reason that Hofstede considers heterogeneity to conceptualise national culture and then named it as “collective programming” of mind that differentiate people of one society from that of another (Hofstede, 1980). The term collective programming is used by Hofstede to indicate the experiences, values, beliefs, traditions, religious patterns, family structures, legal systems, and languages of the inhabitants and expatriates living in any country.

The first aspect to consider is the language, which is one of the major influencing cultural factors in Saudi Arabia. The language of most of the contracts is Arabic which is often translated into English for foreign employees, consultants and contractors. The dilemma is that engineers and other related professionals wish to communicate in their mother language and they do not employ any qualified translators. This has an impact on the quality and progress of the construction projects (Ren et al. 2008).

In addition, some Islamic traditional words like “In Sha Allah” are quite familiar and most of the local construction participants and site engineers use this word as a promise of finishing work. In English “In Sha Allah” means ‘When God Wants’ and foreign engineers often do not understand such words and take different meanings from it. This develops an uncertain situation which causes disputes during different stages of building projects (Ren et al. 2008). As evidenced when speaking to a number of contractors in Saudi Arabia compared to those of foreign decent. In addition to that many foreign professionals are not aware of Sharia Law which is the backbone of Islamic rules and regulations in Saudi Arabia and Saudis like other Muslims do not compromise on these regulations. The lack of
awareness of these domestic and customary laws in terms of 'do's and don'ts' cause delays in construction projects.

Experience refers to familiarity or unfamiliarity of the environmental envelope, for example: clients in KSA regularly visit sites and instruct contractors to make amendments in design. The construction participants must obey the orders even if the orders are given outside the contractual terms and conditions (Al-Khalil and Al-Ghafl, 1999). Furthermore, the weather of GCC, especially in summer, is extremely hot and more than 95% of the international workforce is not used to living and working in this environment. Foreign engineers and other contractors require some time to understand the local procedures and systems of any project in a foreign country and struggle with dealing with local culture and the conditions they become faced. This results in a reduction in productivity which consequently affects the project’s progress (Al-Momani, 2000). The contractors in Saudi Arabia often employ an international workforce to provide construction and engineering services. People from different countries, religion, and traditions bring their own beliefs, habits, and working methods and are often exposed to conflict during complex building projects (Ren et al. 2008). Similarly, the holidays and festivals of the different nationals delay the process. The consequence of a multinational workforce is a key cultural factor which hinders engineers to provide timely delivery. According to Toor and Ogunlana (2008), the multicultural environment causes several problems where ineffective communication, multiple foreign contractors with mixed nationalities, and the involvement of many foreign professionals in different project phases are rated the highest problematic factor.

The centralised decision making system and red tape culture of the Saudi government delay the processes of obtaining site work permits. For example, working in a free economic zone requires special permits from the government officials; it takes a long time and significant resources to get full access and control of these zones (Ren et al. 2008). Likewise, the visa application processes for foreign nationals and other similar regulations may generate crucial issues which may have critical impacts on the progress of the project. The tradition of working beyond capacity on more than one project at a time is a critical issue. The construction and engineering sector has a shortage of local contractors and this is why existing local engineering firms are over-loaded by working on multiple projects.

The serial sequence nature of traditional procurement method affects speed in projects. Many construction projects in Saudi Arabia adopt traditional procurement methods that are exposed to several shortcomings (Alhazmi and McCaffer, 2000). Companies are reluctant to adopt newly emerging methods that consequently affect the entire process of construction and engineering services. Engaging small contracting firms in Saudi Arabia is common, which often bring delays due to contractors having insufficient capital and little or no experience of working on large projects with complex building services. Their limited resources and abilities hinder them in delivering quality output or to embrace the time schedules.

Construction parties in the KSA do not retain long-term business relationships and this allows construction parties not to follow terms and conditions of the contract with any sense of responsibility (Ali, 2008). Furthermore because there is no proper multitier dispute resolution mechanism there tend to be delays to the construction process if any dispute occurs during the delivery of the project. The blame-culture also causes disputes between the constructions participants. This means that an attempt to evade responsibility is frequent which can adversely affect the project progress.
Table 1. Categorisation of origins of delay in construction projects in KSA

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The aim of this paper is to identify and categorise the origins of delays in building projects that are associated with the national cultural factors of Saudi Arabia. A thorough literature review reverred research on issues to do with delays in construction projects in several countries such as Russia, USA, Kuwait, Nigeria, Egypt, Malaysia, Tanzania, UAE, Hong Kong, Libya, Jordan, Iran and Saudi Arabia. This literature based research identified 175 origins of delay from the various literature and then categorised them into five major groupings established using system thinking methodology: Input (resources); Conversion (technical, managerial, external stakeholders, internal stakeholders); Output (cost, quality, sustainability); Environmental envelope (natural, economic, social, cultural, political, business); and Other (feedback, unknowables). Guided by the Hofstede’s cultural dimensions, further analysis of the identified origins was conducted in order to create a
shortlist of those origins that are specifically associated with the Saudi Arabian national culture. 33 origins have been shortlisted and then categorised into the eight groups using Hofstede’s collective programming factors (Hofstede and Hofstede, 2005). This makes an attempt to create a linkage between the origins of delay with the eight Hofstede's national cultural factors. This is illustrated in Table 1 indicating the literature source and final categorisation of the origins using the cultural factors. It is important to state that some of the origins of delay may intersect between the categories such as international workforce with dissimilar cultural backgrounds categorised under Family structures may also intersect with the Traditions, Languages, and Beliefs categorised. In such cases, the research applied disaggregates system methodology (Gidado, 2004) and used subjective judgment to decide on the appropriate category to place the origin of delay.

Conclusions

It is clearly evident that there are a number of factors influencing delays in construction in KSA. This research has identified the origins of such delays that are influenced by the effect of national culture. Using the six cultural dimensions as a framework, the paper has shown that culturally, Saudi Arabia is a highly power distance economy (where most of the decisions are centralised) and has a high uncertainty avoidance culture (people are rigid in beliefs and religious codes, innovation may be resisted, truth and regularity are the norms, security is important, and people like to work on their own rather than working in teams).

The Hofstede's eight cultural factors, established using collective programming concept, has been used as a framework to categorise the identified origins of cultural delays in building projects. This categorisation will be used in the next stage of this research project as a basis for the evaluation of the effect of national cultural factors in the delivery of mechanical services-type projects in Saudi Arabia. As part of the next stage, primary data will be collected to verify the 33 shortlisted origins of delay and quantify the importance and significance of their effect. Ultimately, the research project aims to develop a model that can be used by project managers to develop suitable strategies to mitigate or manage the effects of national culture on delays in mechanical services packages in the KSA.

References


To Achieve Predictability in Engineering Management

Bo Terje Kalsaas

Abstract

The research question of this paper addresses how to achieve increased predictability in engineering. The research approach is constructive research. It is drawn on theoretical principles and ideas from Last Planner System (LPS) and from production control in software engineering. Experience indicates that LPS is not adequate to achieve the desired predictability in engineering, but the underlying principles of involvement, continuous learning etc. are applied. The paper provides a solution based on a case study. The business of the case company is engineering, manufacturing and construction of mechanical installations for offshore oil and gas extraction and operations. The constructed solution is based on:

- Delivery of drawings from engineering is part of the plan for prefabrication and construction, but controlled in a separate process.
- Engineering is divided into phases.
- Engineering objects are split into sub objects or control areas.
- The control of engineering is based on a combination of control areas and phases.
- A backlog of activities is created, from which tasks are prioritized into sprints lasting for 1-4 weeks. A sprint may be the completion of a control area with a specific maturity in a phase.
- The predictability in the sprint cycles is measured using PPC and causes of deviation.

Keywords: Engineering, offshore construction, mechanical industry, LPS, SCRUM.

Introduction

Offshore projects tend to be large-scale, the financial impact of delays is significant, and the environmental and human consequences of engineering failure are likely to be very serious. Severe accidents offshore have provided the impetus for several improvements of technical safety regulations (Kalsaas 2013). Engineering for these conditions may be bordering on the extremes of previous experiences with drilling depths, climate and wave conditions, and fire risk. Due to the context, a strict QA and QC regime applies to offshore construction projects.

On the production side, the industry seems to use planning strategies inspired by “stage gate” (Cooper 1988) and “waterfall” (Conklin and Weil 1998) models. Christensen and Kreiner (1991) have characterized this linear approach to planning as rationalistic. In their most exaggerated form, such models are based on the machine metaphor with a focus on optimization within the triple constraints of time, cost and quality (Tryggestad 2012). Experiences with rationalistic approaches have shown that they fail to capture the dynamics found in Design Engineering, where knowledge and problem solving develop gradually in learning processes based on experience (Kolb 1984; Kalsaas 2012). Conklin and Weil (1998) illustrate this in what they call “the earthquake”, where problem comprehension and problem

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2 The NORSOK STANDARD S-001 on technical safety applies to the oil industry on the Norwegian continental shelf. The classification society DNV has its own standard (DNV-OS-A101); this is similar to the NORSOK standard, and applies globally.
solving takes place during all four phases of a waterfall model: 1) gathering data, 2) analyzing, 3) formulating and 4) implementing solution.

This is the background against which more iterative and collaborative methods for planning design and engineering must be sought in order to improve the predictability and quality of drawing deliveries. And this is where inspiration from “Scrum” (Schwaber and Sutherland 2011) and “Last Planner System” (Ballard, 2000) comes in as alternatives to the more system rationalistic approaches to organize and manage engineering processes. Scrum is also characterized by some authors as “Agile planning” (e.g. Wysocki 2009). Lean Project Consulting have launched what they describe as “Responsibility-based Project Delivery”, a concept aimed at Design of onshore construction projects that builds on Scrum and agile adaptation (Macomber and Bettler, undated) combined with ideas from Lean. The Scrum methodology is taken from the IT project discipline, whose knowledge processes are claimed to have many similarities to those found within engineering.

Hence, the research question addresses how to develop an integrated project engineering delivery system based on design engineering theory. The fact that we use design engineering theory as our starting point distinguishes our approach from the generic project management approaches, such as stage gate, waterfall, PMI’s model (PMI 2013), etc. Furthermore, our approach accords with Ballard and Koskela’s (2012) idea that the starting point for theory about management should be sought in production, not in management and organization theory. The authors argue that there is a blank area in management science as a result.

Important requirements of such an integrated delivery system is that it must ensure necessary control of quality, progress and cost while including the iterative and collaborative approach adapted to design and engineering understood as learning and knowledge processes. This means integrating not only iterative concepts, but also linear ones, as the latter are considered necessary for the ability to report on progress, cost and quality. The Last Planner System does not include such functionality.

Method

The method is based on a constructive research design for analysing the case (Lukka 2003). The constructive research approach is a research procedure for developing constructions that in turn can contribute to the theory connected to the field of research. In addition, constructive research relates to design science research, which according to Simon (1996) is concerned with devising artefacts, e.g. tools, techniques, materials, and sources of power, to attain goals. Constructive research is a form of prescriptive research aiming at improving the performance of the case being studied. Furthermore, our approach is based on action research (Reason & Bradbury 2008), as the authors are working closely with the case enterprise.

The case enterprise is in the process of developing and implementing an engineering (and fabrication) management system of the kind suggested above, titled “Collaborative Planning Execution” (IPE).

The Case Enterprise

The case company for the IPE development work – described henceforth as “the Vendor” – is a supplier of engineering, fabrication and installation of mechanical constructions for the oil and gas industry. Typical products are various types of modules for drilling rigs and ships, for example mud modules, derricks, drilling floor with sub-structures, and other topside modules.

3 © 2011 Lean Project Consulting
4 Trade mark of Lean Construction Institute
In the following section of the paper we focus on the phenomenon of engineering design before describing and explaining the operationalized integrated engineering project delivery model. This is followed by a presentation of findings from the studied case related to theory on design engineering in general, and findings that are specifically related to the proposed model for integrated engineering project delivery.

**The Nature of Design and Engineering Work**

With the traditional linear planning models in mind, Reinertsen (1997) argues that existing descriptions of the nature of design do not reflect the practical world. This is in line with Austin et al. (1999), who argue that traditional planning techniques are not suitable for design work because they are incapable of dealing with iterations in the design process. Koskela et al. (1997) found clear evidence in their review of the literature that chaos and improvisation are substituted for planning and control, leading to flaws. Ballard (2000) introduced the concepts of “negative iteration” and “positive iteration”. The starting point for positive iteration is that in order for alternative solutions to be understood, good designs must be produced for the incomplete or provisional outputs.

Reinertsen (1997) argues that the due-date delivery problem in design is rooted in the general variability of the design process. Arguing that probability distribution functions should be used to describe the duration of activities, Vatn (2008) follows up on this point. According to Reinertsen’s (1997) data, the design effort ceases when the designers run out of time. This can be interpreted as meaning that the ideal solution is unattainable, and that decisions must be made in terms of what solution can be regarded as good enough (Bølviken et al. (2010).

Male et al. (2007) identify three problems that are particular to design, namely: 1) requirements are often vaguely stated and interpretations of problems are subjective; 2) problems become progressively clearer as solutions evolve; and 3) the process is multidimensional, highly interactive, and represents the interests of many stakeholders.

Winch (2002) describe the challenge in construction projects as the “wicked problems”, these are problems that are uncertain in the sense of being ill-defined and without an optimal solution, which can be linked to the involved dependencies between disciplines. Thompson’s (1967) concepts of dependency and coordination can help create a deeper understanding here. Thompson distinguishes between sequential and reciprocal dependency, identifying the coordination technique tied to the former as planning, and to the latter as mutual adjustment. Kalsaas and Sacks (2012) argue that planning often fails to produce the desired result as a result of failure to understand the qualities of the different dependencies involved. When Smith and Eppinger (1997) describe coordination as negotiation between technical specialists, this exemplifies mutual adjustments, which we regard as a fundamental coordination method in design. At the same time, however, more traditional planning techniques must also be used in order to handle the sequential dependencies.

Ballard and Koskela (1998) argue that design processes should include three perspectives: conversion, flow and value generation. In terms of method and practice, the conversion perspective is associated with WBS (work breakdown structure), CPM (critical path method) and organizational responsibility chart; the flow perspective with rapid reduction of uncertainty, team approach, tool integration and partnering; and the value generation perspective with rigorous requirement analysis and systematic management of customer requirements.
The Engineering Case

The Vendor’s engineering department deals with the disciplines of layout, main steel, outfitting steel, pipes, pipe support, weight control, electricity, IT, HVAC, and technical safety. Main steel is typically the first discipline involved. It depends on information about the machinery to be installed and used on the completed platform, such as winches, rough necks, pipe handling machines, drillers’ cabins with control systems, compressors, pumps, and cranes for drilling operations and handling of materials. Next in line are the major pipes and cable ducts which connect the drilling equipment and the outfitting steal, whereas minor pipes and cables are routed around the main structures. Escape and access routes during the operation phase are an important part of the final layout. Moreover, pipe support constitutes a crucial interface between steel and pipes.

The main case described in this paper is a pure engineering project in which the Vendor engineers modules for a drilling vessel. Decisions are yet to be made as to who will fabricate the designed and engineered products. The Vendor is part of a long supply chain, whose end customer, a Brazilian oil operation company, has contracted out the design work to a specialist naval architecture and marine engineering company. This company has contracted out the equipment design to a drilling equipment supplier with global operations; which has in turn contracted out some of the work to our case company, the Vendor. The Vendor also uses a sub-contractor for some of the engineering work, and along with the Vendor, other companies with fabrication capacity are also engaged in engineering modules for the same project. The engineering work involves close communication between the Vendor, the equipment supplier, and the marine engineering company in the endeavour to find good engineering solutions. The main case has a budget of 76,000 engineering hours (approximately 10 mill US dollars).

The engineering process means that the customer provides the Vendor with a concept and a set of requirement specifications. These include elements such as a rough sketch of the location where the drilling equipment will be used, and functional requirements following from the conditions that will be surrounding its use (ocean depth and geography/climate). Based on the provided information, the Vendor will start to build a 3D model. Fabrication feasibility is an important concern when engineering solutions are chosen by the Vendor. However, this concern must be carefully weighed against user interests tied to the finished product – including HSE solutions – which are determined during the design phase, and encompass the lifespan perspective. These are important aspects of delivering customer value, which is a central concern in Lean Construction.

Operationalization of the Integrated Project Engineering Delivery System

The operationalization is illustrated in Figure 1. The types of plan mentioned in the figure are as follows:

- Level 3 plan: A rough milestone plan that is included in the contract with the customer / the letter of intention
- Level 4 plan: A strategic network plan. Budget figures are linked to the main activities. Used to report back to the customer on progress and financial status, and for internal control of costs and progress.
- Phase Schedule: This is a multi-disciplinary iterative planning process which uses the method of reverse scheduling. The idea of the reverse approach is to generate upstream pull in the value chain, both internally and externally. Milestones and main activities are in focus.
• Lookahead schedule: Its main purpose is to certify that activities are sound before they are implemented. The lookahead schedule is important in that it helps ensure an increasing degree of predictability as the implementation date approaches; and as an arena for registering changes. The schedule is prepared and updated at interdisciplinary meetings, and the focus is on dependencies between different disciplines.

• Action plan: This is a plan for the week during which the work is implemented. Each discipline prepares an action plan – a schedule of activities – for its own employees. The plan is prepared by the head of the discipline in cooperation with his or her team members.

• Quality Control: Engineering has prepared the use of a commissioning system (PIMS) for its detailed follow-up and quality control.

The level 4 plan is a traditional CPM-oriented plan made up of tasks and milestones represented as a Gantt diagram. The Quality Control System, PIMS, is based on using work packages as input, and then applying stage-gate logic to monitor and control these packages throughout all phases of the design process. The phases can also be regarded as a value chain for design objects, and there is quality control of every link in the chain. If aspects are found lacking, the work packages and objects are subjected to amendments, or so-called punch. The iterative and collaborative elements of the operationalized system are the phase plan and the lookahead schedule.

In terms of the three perspectives proposed by Ballard and Koskela (1998), the Level 4 plan and the QC system represent the “conversion” perspective; the phase plan, the lookahead schedule and the action plan represent the “flow” perspective; and the “value generation” perspective is captured in the translation of the customer requirements into engineering method, and in the collaboration with the customer during problem solving. The routines for reporting back to the customer can also be seen as part of this third perspective.

The QC system is not a planning system, and dates for the work packages are derived from the Level 4 plan, which is prepared on the basis of the phase plan. The Lookahead schedule process is used to update the set dates in the QC system in our operationalization. Each engineering discipline reports on its progress in the QC system, and reports from this system are imported into the Level 4 plan, under which periodic reports about progress and costs (time use in relation to budget) are submitted, according to contract, to the customer. Work packages identified in the QC system are declared sound in the Lookahead schedule. Furthermore, buffer activities are identified in the Lookahead schedule, which provides input of sound activities to the Action plan. A comparison between planned and implemented activities is also included, as illustrated in Figure 1.
Findings

This section is divided into two parts. The first of these deals with findings related to the theories on design presented above; the second discusses preliminary findings related to the process of implementing the integrated project engineering system.

Design Engineering

It has been confirmed beyond doubt that understanding of problem scope as well as ideas for possible solutions develop gradually among the participants across the different phases; it thus makes sense to speak of the knowledge involved in terms of different levels of maturity. This confirms the theories referred to above. The implications of this for the declaring of activities as sound will be addressed below.

Furthermore, we find that there is considerable cooperation aimed at solving engineering challenges two tiers upstream in the Vendor’s value chain in this project, which includes the Vendor’s customer, the drilling equipment supplier, and the main contractor for the client. The Vendor’s engineering manager finds the project very engaging since what the customer wants is clearly expressed, comparing it to another project where the customer had few visions beyond wanting a drilling vessel that would be approved by the relevant classification society. In the case project, the perception of the engineers is that they learn a lot from the joint problem solving process. This collaborative process is also very central for value generation; confer the three perspectives on a design process.

As to the point that the ideal solution is unattainable, an experienced project manager claims that in his experience, engineers manage to reduce the weight of the drilling vessel or platform if allowed enough time. This is important for the end product and for the amount of steel eventually used. However, allowing the process to include this weight-reducing stage is not always possible for budget or progress reasons.
Furthermore, this project confirms that customer requirements are often vaguely stated and that for some elements, no scope is provided until far into the project. In a system where everything is mutually connected, this can generate many technical changes at a later stage. Customer failure to work through the problem solving aspects sufficiently to arrive at a mature understanding seems to be the cause when clear definitions are missing. This may in turn be a result of capacity problems in a market with high demand.

In one case the engineering manager refers to a meeting with a customer and the customer’s client that lasted several hours but resulted in few if any decisions, interpreting the problem as a case of Mr X being unwilling to make decisions because he feels that there is too much uncertainty involved. The Vendor’s engineering manager relates that “a full overview is only achieved when the engineering project is virtually ready for delivery”, arguing that the work must concentrate on minor technical matters, temporary decisions must be made on the basis of these, and iterative work must be done on minor as well as more major aspects, systematically removing uncertainty. In addition, there may be commercial interests tied to late decision making on the customer side, as it might saves the cost of having to pay for changes.

It hardly comes as a surprise that reciprocal interdependency is a major aspect of the engineering process. A couple of handfuls of different engineering disciplines are simultaneously working on the same object to gradually ensure that the solutions for its different parts and larger units become more mature, making the mutual adjustments achieved through formal meetings and brief but frequent informal conversations throughout working hours on a daily basis across different disciplines absolutely essential. Especially during the early phases, the engineering work is a matter of trial and error in the search for potential technical solutions to the problems defined by different disciplines, not only one’s own. When this is achieved through mutual adjustment, it can be associated with “positive iterations”.

**Preliminary Experiences in the Effort to Implement the Integrated Project Engineering Delivery System**

Many weeks into the work on the main engineering project studied in this paper, a contract had yet to be established. Combined with numerous delays on the part of the customer, the lack of a contract created a degree of planning uncertainty. An agreement ensuring that the Vendor is paid for the work done was, however, in place.

The engineering project consists of four modules. Initially, a phase plan was made for the engineering of a mud module. The plan had a timeframe of 14 months, and was prepared in the traditional way of establishing milestones and placing activities for the different disciplines sequentially on the timeline. In reality, this plan has collapsed, and could barely be used even as a basis for the Level 4 plan. There are many reasons for this. One reason is that no suitable engineering WBS had been established. This must be understood in light of the fact that the engineering department had no previous experience of managing projects in a detailed manner. Furthermore, it would appear that detailed planning of engineering activities beyond a horizon of a few weeks is impractical due to the inherent variability and the need to take into account that problems become progressively clearer as solutions evolve. In the phase plan we identified a large amount of necessary information that must be collected before the engineering work can begin. We also saw, however, that the work commences even without this case-specific information, building on the experience gathered from past projects, especially by the most experienced engineers.

A phase plan for a Top Side (TP) module has later been prepared. As a basis for this work, the engineering department decided to divide their engineering work into four phases: 1) Layout, 2) Design, 3) Detailing, and 4) Drawing.
In the work of making a phase plan for the TP module, we made changes based on the experiences from the failed first phase plan attempt. We now established a rough milestone plan for the entire project period, concentrating on the nearest milestones. Two maturation levels were defined for the Layout phase: ML1 and ML2. The content of these milestones was also defined. In other words, we answered the question “What engineering must be completed at what maturation level for the different disciplines?” This was done jointly three weeks prior to the deadline for ML1. As it turned out, ML1 collapsed for all of the disciplines except main steel, whose clarifications for continuing the work towards ML2 had been secured. The rest of the disciplines were still waiting for vital information from the customer. This also suggests that there may be good reasons for differentiating the milestones along discipline lines.

Furthermore, it shows that in this type of mechanical engineering, what matters above all is that the main steel engineering work can continue, as it lays the basis for the other disciplines. Release of sections for pipe support can serve as another important milestone of this type.

Another experience from the phase planning for TP module is that when we asked “what must be done in order to succeed at meeting ML1”, the disciplines produced responses that included a series of actions, such as meeting the customer to produce decisions and requirements regarding structural loads, etc. In our model, such items belong to the action plan, not the Level 4 plan.

Despite several attempts, we have not yet succeeded in activating the Lookahead schedule. One reason is that the QC system has not been sufficiently integrated; another is the continuing uncertainty linked to lacking information and decisions from the customer. The designed concept for declaring activities sound in the engineering lookahead rests on four factors: 1) external information, 2) internal information, 3) preceding activity, and 4) staffing. In terms of factor 1, we are faced with the dilemma that we must expect the information to be limited. Thus it is rather a matter of whether sufficient information has been made available for commencement of the work to make sense, and to proceed from there, possibly in collaboration with the customer, to increase the maturity.

We see that engineering is different from fabrication and physical construction in the sense that in those areas, work should not be started until all of the seven flows are in place, in order to avoid the waste-generating mechanism of “making do” (Koskela 2004). In engineering, “making do” can be regarded as part of the normal work process of design engineering, provided that it is a matter of positive iterations.

Thus far into the project, reporting on costs and progress from Level 4 has not yet commenced. This is due to the fact that we have not yet progressed sufficiently in the endeavour to integrate the QC system with the other elements.

The planning meetings are integrated with weekly technical design review meetings, and during discussions between the disciplines of different technical solutions relating to the 3D model projected onto a wall, actions and needs for decisions are simultaneously and collectively identified and written down on a whiteboard. This seems to function adequately.

Conclusion

Based on experiences from implementing the proposed integrated project engineering delivery system so far, we have identified some necessary modifications to the operationalized system. The paper draws up a possible solution for increased predictability and production control in engineering. Key characteristics of the solution are:

- Delivery of drawings is part of the plan for manufacturing and construction.
- How the delivery of drawings is met by the engineering department is controlled and planned in a separate process.
- Dividing engineering work into phases.
- Division of larger engineering objects into sub objects, meaning control areas.
The engineering control process focuses on control areas in the various phases.

A backlog of activities is created, from which tasks are prioritised into so-called sprints lasting for 1-4 weeks. A sprint may be the completion of a control area with a specific maturity in a phase.

The predictability in the sprint cycles is measured using PPC and causes of deviation.

Experiences from the project so far confirm previous findings and theoretical points from the literature – for example that understanding of scope and possible solutions emerge and mature over time; that the reciprocal interdependencies are considerable; and that the ideal solution is regarded as unattainable. This latter point can be exemplified by the fact that the longer the solutions are allowed to be iterated by the different disciplines, the greater the final weight reduction. Moreover, we see that requirements are often vaguely stated, creating a great need for interpretation. Technical solutions are found by the technical experts in negotiations and joint learning processes. The rationalistic and linear models for project execution seem incapable of handling design and engineering as witnessed in the case company during this engineering project. Hence, although considerable changes must be made to the operationalized model, the iterative and collaborate methods will be at the basis of its further development.

References


Costs of Alternative Methods of Acquiring Sandcrete Blocks for Walling

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Abstract

Alternative methods of building material production without compromising on quality have become vital to researchers lately. Site-manufacturing of 225mm hollow sandcrete block for walls was researched on with the aim of comparing its production cost with that of the outright purchase of the block in the market. Two similar twin 2-bedroom bungalows were designed; their cost estimates and the number of blocks required for each of the buildings were got. While blocks were site-moulded for one building on the acquired site, blocks were bought for the second building. This was done for the purpose of comparing costs of alternative methods of acquiring sandcrete blocks and ultimately comparing costs of 225mm thick blockwalls of the same materials. The walls were built between January and March 2013. Records of costs of labour and material were kept. Each of the two buildings used for the research consumed 4,800 blocks. For the site-moulded block alternative, a total cost savings of N182,832 was achieved on the blocks used for the building, resulting in cost savings of 27.21%. This alternative means of acquiring block material for walling is recommended to developers who are interested in cost savings and where time is not of essence.

Keywords: Cost savings, Nigeria, sandcrete block, site-moulded block.

Introduction

As costs of construction are becoming less affordable to average private individuals and organizations in Nigeria, the reason for which can be traced to the global economic meltdown coupled with other complex issues such as the mishandling of the nation’s public wealth, alternative ways of achieving affordable decent housing or office accommodations are being explored by researchers and interested stakeholders. For instance the Nigerian Building and Road Research Institute (NBRRI) over the years has been doing very much work in the area of providing alternative materials for walling among others. The Institute had collaborated with other organizations such as the Federal Housing Authority to put up prototypes on which tremendous savings in costs were said to be made. Also, the Raw Materials Research and Development Council (RMRDC) and the defunct Directorate of Food, Road Rural Infrastructures (DFRRI) made remarkable contributions to construction developments in Nigeria, especially in the areas of alternative ways of sourcing for construction materials.

Wall is an element of a building with the specific roles that it performs. Its functions in a building are so vital that they make the wall an indispensable element of any building. Hence the cost of a wall in a building cannot be overlooked. Most common among the functions of walls include: provision of privacy from the glare view of the public, provision of safety and security from both human and animal intruders including reptiles.

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safety from sun, rain, wind, flood, inclement weather and other elements, partitioning of
the building into convenient space sizes for the use of the occupants and their visitors and
structural functions such as the carrying of the super-imposed loads like the roof members.
Enclosing walls also perform the aesthetic function for the building. Walls can be
subdivided into internal or external walls. They can also be either load-bearing or non-
load-bearing.

Speculations abound in the Nigerian public that there is cost saving in site-moulded
225mm blocks for walls when compared with outright purchase of the blocks. However,
the extent of the likely savings on any type of building has not been established for 225mm
sandcrete block. The available research report closest to this was the cost-saving of 31.65%
established by Lawal (1999) which was for the on-site moulding of 150mm blocks. Other
research publications brought to public awareness on sandcrete block, with or without
additives, include: its comparative cost with that of laterite interlocking blocks (Raheem et
al, 2012); its compressive strength (Wikipedia, (2013); Afolayan et al. (2008), Aho and
Utsev, (2008); Abdullahi, (2005); Adeedeji and Eje, (1998)); its behaviour (Wenapere and
Ephraim (2009)); its quality control (Baiden and Tuuli (2004)). This research is aimed at
ascertaining the quantitative extent to which savings are made in the cost of manufacturing
the 225mm sandcrete blocks on site as compared to the conventional buying of the blocks
from the open market and to sensitize housing developers on a cheaper way of obtaining
sandcrete blocks. The objectives include:

(i) acquisition of a site for erecting two bungalows
(ii) analyzing costs of materials and labour for the blocks required and
(iii) comparing costs of the blocks under each acquisition method.

Related Literature

There are various materials used for walling in Nigeria, sandcrete block being one of them.
Casual observations would reveal that most building accommodations erected in the
country within the past thirty years have their walls made of sandcrete blocks. Other
walling materials include bricks, stone, plywood, earth (laterite also locally called mud)
and the likes. Blocks are of two main types namely; concrete block and sandcrete block.
Unlike concrete block whose components are coarse and fine aggregates mixed with
cement, sandcrete block is made of only fine aggregate (sand) mixed with cement. The
sand and cement mixture is in the proportion of 6:1 (British Standards Institution, 1970).
Specifications for moulding sandcrete blocks stipulates that the block is generally to be
made in accordance with BS 2028.

Sandcrete blocks are made in three sizes in Nigeria. The sizes are 450 x 225 x
225mm (length, width and height) respectively, 450 x 150 x 225mm and 450 x 100 x
225mm. The first size is mainly used for various types of construction such as fencing,
culvert, drainage, abutment, pier, retaining walls and other similar works where it can act
as substitute for concrete. Other binding agents such as ashes of rice husk, sawdust,
coconut shell and the like have been experimented on to partially replace ordinary Portland
cement in the manufacture of sancrete blocks (Aho and Utsev, 2008; Agbede and Obam,
2008; Tyagher et al.; (2011). The focus of this research is on 225mm sandcrete block as a
walling material and without any admixtures or binding agent other than ordinary Portland
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**Materials and Method**

Ilorin, a town in the west midland of Nigeria was chosen for the sighting of the research work. This choice of venue was informed by two reasons, namely the advantage of convenient location for the researchers and the ease of acquisition of site for the experiment. Ilorin is on GPS coordinate N8 29.5038, E4 32.67828 and with a population of 847,582 as at 2007 (Wikipedia, 2013a). The site at Tanke, off the University of Ilorin road, was acquired for the purpose of building two similar houses, each comprising of two bedroom flats and with all walls built of 225mm hollow sandcrete blocks.

Drawings for the two buildings were prepared by an Architect and building approval was sought and obtained from the State Town Planning Authority, see Figure 1). A registered Quantity Surveyor was commissioned to quantify the number of blocks required for each of the two buildings and to supply the current ‘build-only’ rate for 225mm blockwall prevalent in the locality.
Quality of Materials and Workmanship used for Sandcrete Blocks

**Cement**

All cement were Portland Cement of Nigeria or other approved manufacture free from lumps – and conformed in every respect with the latest issue of British Standard specifications for Portland Cement B.S. 12 (British Standards Institution, 1971). Cement was delivered on the site in sound, strong, paper and polythene bags and each bag was plainly marked with brand and name of the manufacturers. The cement on the site was stored in a suitable building approved by the Supervising Officer (S O). Each consignment of cement on the site was kept separate and plainly marked with an approved identification mark.

**Sand**

The sand used in sandcrete block was purchased from local suppliers and complied with B.S.S 882. It was clean, sharp and uniformly graded down from coarse particles not exceeding 5mm in diameter, was free from salt, mica, dirty loam and organic matter and did not contain more than 4% by weight of clay, silt, and fine dust (British Standards Institution, 1992).

**Water**
Water used was clean and free from all impurities either in solution or suspension and a minimum amount was used in mixing for sandcrete block, sufficient only to give a workable mix. No admixture was used.

**Generally**

At least two weeks before starting to deliver the materials on the site the contractor submitted for the approval of the S O samples of the sand that he proposes to use on the work and stated the source of supply of each. No materials were delivered until the S O had approved samples, and the materials as delivered were equal in all respects to the approved samples.

The Quantity Surveyor’s figure of 4,800 blocks per building was used to engage block moulders for the one building while the same number of blocks was purchased for the second building. Two ‘build-only’ construction firms were employed for both buildings at the same contract sum. The constituent costs of moulding the blocks were analyzed and comparison was made with the cost of the outright purchased sandcrete blocks for the other building.

Walls for the two buildings were put up on the site to confirm the Quantity Surveyor’s figure for the number of blocks required for each building (see Figure 2). The total savings made on the site-moulded blocks required for the entire building was also derived. Moulding and buying of the sandcrete blocks and the construction of the walls of the two buildings were carried out during the months of January – March, 2013.

**Figure 2. Twin 2-Bedroom Semi-detached Bungalows**

**Results and Discussions**

From the cost analysis of the site-moulded blocks (see the Appendix), each block was produced at the cost of ₦101.91 whereas a block of the same size was selling at the prevailing market price of ₦140 (transport cost inclusive). This gives a difference of ₦38.09 or a 27.21 % savings on each block. The reduction of ₦38.09 on a sandcrete block implies a savings of ₦182, 83 on the total number of blocks (4800) required for the complete 1No. Twin 2 bedroom semi-detached bungalow

**Implications of the Findings**
The research findings add to the knowledge that value for money on blockwalling can be optimized by using the site-moulded block alternative. With the savings of 27.21% on the cost of sandcrete hollow block as walling material, direct moulding of blocks on site brings relief to potential house owners who might not have sufficient fund to embark on conventional buying of blocks for the project. A savings of about ₦183,000 on blocks alone of a typical twin two-bedroom semidetached bungalow is an encouragement to build.

Precautions

To produce site-moulded sandcrete blocks of desirable strength and other characteristics that are favourably comparable to the sandcrete blocks in the market, the production environment must be properly under control. Specifically, on removal from the machine on pallets, the blocks are to be matured in the shade in separate rows one block high with a space between for at least 24hrs and sprayed with water. They may then be removed from the pallets but not stacked or removed from the shade for a further 4 days and sprayed with water at intervals. Following this the blocks may be stacked not more than 5 blocks high in the shade for a further 14 days and allowed to dry out. No blocks are to be built into any part of the building until they have matured in the manner described for at least 21 days.

It is worth noting that if the above stated conditions of curing the blocks are not satisfied, the 27.21 per cent savings cannot be achieved. Deviations from adhering to the stated procedures are most likely to end up in big financial loss as the moulded blocks may not properly cure. For instance, rain falling on the freshly moulded blocks affects the soundness of the hollow blocks negatively. Likewise the space and shade under which to spread and store the blocks for the required number of days should be readily available on the site. A minimum buffer period of 21 days should be available before the need to incorporate the blocks into the building arises.

Conclusion and Recommendation

From the results of the erection of the walls of the two buildings and the cost analysis carried out, the following conclusions can be drawn:

(i). Cheaper alternative means of achieving value for money in sandcrete blockwall construction without compromising quality is by site-moulding of the required blocks.

(ii). Proper control and monitoring of the production process of site-moulding blocks are necessary in order to avoid deviation from the set objectives and also to forestall big financial loss on the long run.

(iii). To further achieve the strength objective of the site-moulded blocks, a minimum setting period of 21 days is required before incorporating the blocks into the building.

For building procurers who have sufficient time and shaded space on site and desire to save costs on sandcrete block, the option of site-moulded sandcrete hollow block is recommended. This option was found to save cost on sandcrete block material to the tune of 27.21% and without compromising on the aesthetic and strength quality of the block.

It is to be noted that developers who do not have sufficient space to keep the blocks during the first five days of production (first day on pallet followed by four days of wetting) should not embark on site-moulded block alternative. Where time is of essence, site-moulding of block is not advised as a minimum period of three weeks is required for the curing of the blocks before they can be incorporated into the work. There are other challenges associated with site-moulding of blocks. These include: compromising quality due to diversion of materials (especially cement), running after operatives to bring them to site, racking (rough/non-linear) of blocks due to uneven site topography, controlling weather condition especially casting during heavy rain downpour, and other contingencies
beyond control. Due to lack of sufficient fund, the experiment which was to be repeated on other sites for proper validation was carried out on only one site. This makes the research a special case.

The site-moulding of blocks is further recommended on the basis of global economic advantage. It allows for employment of more craftsmen (engagement of block moulding specialists) and yet the total expense on the sandcrete blockwall is less than when the conventional method is used.

Areas for Further Research

This experiment was conducted during dry season where curing of the blocks was not having interference from the rain, moulding of blocks during wet season should be carried out and the financial implication of provision of protection of the blocks against direct rainfall in their first five days of moulding could be investigated. Cost implication of close monitoring of the quality of blocks produced on site can be investigated as well.

References


Appendix

Analysis of Cost of a 225mm Hollow Block

For the period January-March 2013

Moulding of 225mm sandcrete blocks.

Materials:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 bag of 50 kg portland cement on site</td>
<td>₦1700.00</td>
</tr>
<tr>
<td>1 lorry load (3 cu.m) of sharp sand</td>
<td>₦6000.00</td>
</tr>
<tr>
<td>1 tanker load of water</td>
<td>₦5000.00</td>
</tr>
</tbody>
</table>

No of 225mm sandcrete blocks that can be moulded from 1 bag of cement = 35

Cost of cement in 1 No 225mm sandcrete block = ₦1700/35 = ₦48.57

Labour costs:

Charges (+ overhead, profit & tools) by the ‘Specialist’ for moulding

1 No 225mm block = ₦14.00

Cost of wetting, lifting and stacking blocks.

Wetting

Consider 1000 blocks – wetting at 4 different periods (a period takes 1 hour)

4 hours unskilled labour at ₦1000/8hr day = ₦500

Labour cost of wetting 1 block = ₦500/1000 = ₦0.50

Lifting

Consider 1000 blocks. 1 hour of unskilled labour at ₦1000/8hr day = ₦125

Labour lifting 1 block = ₦125/1000 = ₦0.125

Stacking

Consider 1000 blocks

3 hours of unskilled labour at ₦1000/8hr day = ₦375

Labour cost stacking 1 block = ₹375/1000 = ₹0.375

It takes 1 lorry load of sand to mould 200 No sandcrete blocks

Each of the two buildings takes 4800 sandcrete blocks to build (the QS figure).

Thus to mould 4800 blocks, it takes 24 lorry loads of sharp sand at ₦5000 per load = ₦144000

Cost of sand per block = ₹144000/4800 = ₹30.00

It takes 8 tankers of water to mould and wet 4800 blocks at ₦5000 per tanker = ₦40000

Cost of water per sandcrete block = ₹40000/4800 = ₹8.33

Adding all costs 1 – 7. cost per block gives ₦(48.57+14.00+0.50+0.13+0.38+30.00+8.33) = ₦101.91

Cost of 1 No 225mm sandcrete block throughout the period in the area (3 local government areas) was ₦140. Therefore Cost of commercially produced block – cost of site-moulded block = saving/loss made.

Thus ₦(140 - 101.91) = ₦38.09 (saving made)

38.09/140 = 27.21% savings.
A JIT Algorithm for Offshore Rig Assembly Sequencing

Ernest Abbott1 and David Chua2

Abstract
Lean principles in production are synonymous with the Toyota motor company, probably the most productive and innovative car manufacturer in the world. However, in a construction environment Lean principles are not so easy or obvious. The major difference between a production and a construction environment is the synchronicity of the work and the longer time horizons. In the production environment the product stages are often short, whereas in the construction environment they are long.

Constructing offshore rigs is a long process involving many stages where the correct assembly sequence is paramount. Offshore rigs are composed of units, referred to as blocks. The building of the block involves sub-blocks; each sub-block differs in size, shape and construction time. At the block level, with more than one team of workers constructing the sub-blocks, it is possible to apply Lean principles to the sub-block work so that they arrive at the block assembly point with the minimum of waiting time.

A number of Greedy based sequencing algorithms have been developed by way of a compare and contrast. The Greedy sequencing algorithm augmented with back-tracking coupled with post schedule allocation reordering has proved to be a good one within the bounds of the random nature of the data.

Keywords: Assembly sequence, lean construction, offshore rig, sequencing algorithms.

Introduction
Lean principles in production have been successfully applied in a number of industries, most notably the car industry and consumer electronics industry. Toyota has been credited with developing the modern Lean production approach. Toyota identified seven areas of waste in manufacturing, overproduction, defective product, high inventories, non-value action, unnecessary or superfluous processes, transportation of materials and idle time for material and people (Lang et al., 2001). These concepts of Lean production have permeated other sections of industry. This present work is to apply, as far as possible, lean principles to the construction of off-shore rigs, and in the process derive a just-in-time algorithm.

Lean production has an emphasis on efficiency with the aim of eliminating waste at all stages of the production process. The aim of Lean production is to add value to the produce at every stage of its process. Waste, in Lean manufacturing, increases the time of production or increases the cost of production, but does not add value to of the product (Liké & Lamb, 2002). Lean production is not an end in itself (Womack, James. P. & Jones, 1994), but part of a process that stretches the full length of the value chain.

One characteristic of Lean production is the continuous supply of parts; this eliminates time wasted in waiting for parts to arrive. This continuous supply is better known as Just-in-Time. This approach differs from the traditional method of supplying parts in a

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continuous production process, where parts are produced at one stage of the process for the next, irrespective of the requirement of the next stage. This is called a push system and leads to high levels of inventory (Womack, J. P. et al., 1991).

Lean principles, in part, have been applied in the Japanese shipbuilding industry leading to an improvement in productivity of 150% in the 30 years from 1965 to 1995 (Liker & Lamb, 2002). Liker and Lamb do advocate organizing a shipyard by “product line”. A similar approach has been adopted by Lang et al. (2001) in a theoretical simulation of a Lean shipyard.

In the construction of offshore rigs, the Lean principle of continuous supply, along the lines of those identified by Liker and Lamb (2002), are not easily implemented. In shipbuilding blocks are standard, whereas for offshore rigs, block repeatability is at the best rare and often unique in construction. However, in the final assembly of the block, some progress can be made towards reducing waste in terms of waiting time and double handling of sub-assemblies.

**Block Assembly**

Liu et al. (2011) recognizes the inherent challenges of having long production lead times for a product, such as blocks for Offshore rigs. They use aggregate production planning in the area of workforce levelling as well as inventory usage. They achieve their objective using a multi-objective genetic algorithm. Their work deals with smoothing the work flow of block construction, and as with Liker and Lamb (2002), their objective is to construct a grand block just-in-time. The work of the present research is to deal, not at the macro level as is being done by Liu et al. (2011) and Liker and Lamb (2002) but with the micro level of the sub-assembly construction so that it arrives at the final assembly point just-in-time, or close to just-in-time.

To have a better grasp of the issues involved a brief description of the block parts and construction is given. The Offshore rigs are constructed of units called blocks. The blocks are composed of a number of different part types: plates, brackets, stiffeners, flanges and bulkheads. The plate is the foundation for the other parts. A plate with one or more other parts welded to it is called a sub-assembly. Two or more sub-assemblies welded together is called a sub-blocks. Sub-blocks (& sub-assemblies) are welded together to form a block.

The first stage of building a block is to create a base panel from the various plates. These panels are cut out from a much larger sheet of steel using a laser cutter. The laser cutting process is fast compared with welding of the seams, so does not present a problem in ensuring that the plates arrive just-in-time at the location where they are welded together in a processes known as union melt.(see Figure 1).

![Figure 1. Creating a Base Panel](image-url)
The next step in the construction process is the welding of stiffeners to the base panel. Stiffeners are special steel profiles sourced from an outside supplier which are cut to the required length in the shipyard. The shipyard has amply stock of these standard parts. As the only process required here is the cutting to length, there is no problem in ensuring that these arrive at the point of requirement just-in-time.

![Figure 2. Stiffeners Add to Base Panel](image)

The next stage of the construction process is the assembling of the various sub-assemblies. The order of assembly has already been determined, for example Abbott and Chua (2013) for an outline on how this is achieved. The welding of the sub-blocks to the base panel is in two parts. The sub-assemblies are fitted and tack welded into place. The final welding only takes place after all sub-blocks have been fitted and tack-welded into place. The fitting sequence is not the same as the welding sequence. The fitting sequence of a sub-block and/or sub-assembly is determined by a number of factors, size, weight, position within the block, being some of them. (The actual details are beyond the scope of this paper.) The final welding is from the centre of the block outwards. This is done so as to minimize the distortion caused by the welding process.

![Figure 3. Completed Block](image)

The work content of each sub-block/sub-assembly differs, yet they have to arrive in a particular predetermined assembly sequence. This research is concerned in developing
some algorithms with a number of objectives, to minimize the makespan, to minimize the waiting time at the final assembly point and to minimize double handing of parts.

**Block Assembly Sequence and Just-in-Time**

The basic requirement for a just-in-time block assembly is that the sub-block/sub-assembly arrives at the assembly point the moment they are required. The construction time of the sub-block/sub-assembly is considerably longer than the assembly time. The fitting and tack welding of a sub-block in its final location takes from 30 to 60 minutes. Even if this is extended, it is multiple times faster than the construction of the sub-block/sub-assembly. A sub-block/sub-assembly can take several hours to several days to complete.

The construction of a sub-block/sub-assembly is the task of a team, which usually consists of a couple of workers. There are a number of reasons for this: the size of the component being constructed and safety during the welding process. With a limited number of teams and a large number of sub-blocks/sub-assemblies all of which have different construction times, it is impossible to achieve just-in-time assembly.

A computer simulation was performed to demonstrate this point. The simulation consist a number of sub-blocks ranging from 10 to 300. The construction time for each sub-block was randomly generated in the range 2 to 30 time units. The longest construction time was taken as the limiting value. All other sub-blocks were grouped so that no group of sub-blocks had a total construction time greater than the longest sub-block construction time. This grouping does not take into account the required assembly sequence, since the purpose of the simulation is to get the minimum number of teams for JIT assembly. For each set of sub-block the process was repeated 60 times, this should remove any ‘freak’ values that could occur from using the randomly generated values. The average of the 60 repetitions was recorded; the results are in Table 1.

<table>
<thead>
<tr>
<th>No. of Sub-Blocks</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. No. Teams</td>
<td>6.93</td>
<td>12.73</td>
<td>18.43</td>
<td>24.30</td>
<td>29.22</td>
<td>34.63</td>
<td>40.80</td>
<td>46.23</td>
<td>51.23</td>
<td>57.92</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.69</td>
<td>0.64</td>
<td>0.61</td>
<td>0.61</td>
<td>0.58</td>
<td>0.58</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of Sub-Blocks</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
<th>160</th>
<th>170</th>
<th>180</th>
<th>190</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. No. Teams</td>
<td>62.88</td>
<td>67.92</td>
<td>73.40</td>
<td>78.57</td>
<td>83.93</td>
<td>89.27</td>
<td>94.62</td>
<td>100.15</td>
<td>106.25</td>
<td>111.52</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.57</td>
<td>0.57</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of Sub-Blocks</th>
<th>210</th>
<th>220</th>
<th>230</th>
<th>240</th>
<th>250</th>
<th>260</th>
<th>270</th>
<th>280</th>
<th>290</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. No. Teams</td>
<td>117.62</td>
<td>122.00</td>
<td>127.92</td>
<td>133.38</td>
<td>139.20</td>
<td>143.28</td>
<td>150.07</td>
<td>155.18</td>
<td>160.87</td>
<td>166.08</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.56</td>
<td>0.55</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.56</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
</tbody>
</table>

The simulation results demonstrate that with a small number of teams JIT production is not achievable. However, a measure of JIT assembly is possible; it is that it will not be 100% JIT.

**Developing the Algorithm**

As has been mentioned, the task of constructing a sub-block/sub-assembly is assigned to a team. This naturally leads to scheduling the work among the teams treating each team as parallel machine. For this research each team is considered to possess an identical skill set.

---

3 The notation used here is that of Graham et al. (1979) which is now the standard notation.
The work is carried out without pre-emption. Each sub-assembly/sub-block is completed before work begins on the next.

It has been pointed out (Blazewicz et al., 1983; Chen et al., 1988; Karger et al., 2010) that scheduling with parallel identical machines without pre-emption is an NP-hard problem. It has been suggested (Mosheiov, 2001), however, that flow-time minimization on parallel identical machines, albeit only two parallel identical machines, is polynomial solvable. The solution is far too problem-specific for this research, since it posits a learning effect, which may be possible in construction environments that deal with repetitious units, which is not the case in the construction of the offshore rig. Further, the computation resource required to resolve this for only two parallel machines is $O(n^4)$. The focus here will be on an algorithmic approach. The problem under investigation in this research is quite constrained in that there is a predefined output sequence; hence the choice of work allocation is more limited which makes it possible to use an algorithm to resolve the problem. Further, this is not really a shop-flow issue, as the various sub-blocks are confined to one process, as it were, on any ‘machine’, and then is ready for assembly.

The most obvious method is the use a Greedy algorithm to allocate work among the teams. Other algorithms used for identical parallel machines in a machine shop environment, such as Longest Processing Time First (LPT), are not suitable here as this algorithm is more focussed on the minimization of the makespan. For LPT the completion order of the jobs is of no relevance, however, in the assembly of sub-assemblies for blocks for Off-shore rigs the order the jobs are completed in is of great importance.

Each algorithm that is developed depends on the objective, although one objective is to adopt Lean principles, minimizing the makespan for the schedule is clearly an important objective.

**Makespan** is defined as $C_{\text{max}}^S = \max_j C_j^S$ of a schedule $S$ to be the maximum completion time of any job in $S$, where $C_j^S$ is the completion time of job $j$ in schedule $S$.

For $m$ machines where the processing time for job $j$ is $p_j$, then $C_{\text{max}}^* \geq \frac{\sum_{j=1}^{n} p_j}{m}$ where $n$ is the number of jobs, $C_{\text{max}}^*$ is the makespan of the optimal schedule and $C_{\text{max}}^* \geq p_j$ for all jobs $j$. That is makespan for the whole assembly process cannot be less than the sum of the average processing time for all the individual jobs.

A greedy algorithm for identical parallel machines assigns the next available job to the next free machine. The sub-blocks are ordered in their required assembly sequence. **Figure 4** and **Figure 5** illustrate the process. Job 10 is successively assigned to each machine and the completion time, $C_{10}^S$, of the schedule is calculated. The machine with $\min C_{10}^S$ is the one to which the job is assigned. **Figure 5** illustrates the machine that job 10 is finally assigned to.
More formally, the $i^{th}$ job is added to the machine with the minimum completion time, i.e. the $i^{th}$ job is added to $\min mC$, where $C^m$ is the completion time for machine $m$. Since the $i^{th}$ job is added in this wall, the overall schedule is always going to be a minimum.

There is a possibility of improving the algorithm by applying a back tracking technique. With back tracking the job is added to the minimum machine schedule, provided that when it is added to the minimum machine schedule the maximum schedule is not exceeded. If the maximum schedule is exceeded the job is swapped with the previously added job, provided the overall schedule is now earlier than when the new job was added to the minimum machine schedule.

If $i$ jobs have been added to the schedule, using the greedy algorithm, the $i^{th}$ job was added to the machine with a completion time earlier than $C_i - p_i$ . Similarly for the $i+1^{th}$ job it is added to the machine with a completion time earlier than $C_{i+1} - p_{i+1}$.

When the $i^{th}$ job was added to the schedule, it was added to the machine with the shortest completion time, $\min mC$. This machine is chosen irrespective of the work content of job $i$.

The $i+1^{th}$ job is added to the schedule. If $C_{i+1} \leq C_{\text{max}}$, the addition of the job to the assigned machine is accepted. There is no change in the expected waiting time between the completion of job $i$ and job $i+1$, i.e. $C_{i+1} - C_i$. If, however, $C_{i+1} > C_{\text{max}}$ then back tracking is tested with $i^{th}$ job being replaced by $i+1^{th}$ job in the schedule. Following the replacement of the $i^{th}$ job by the $i+1^{th}$ job, the $i^{th}$ is added to the schedule, which will be a different machine, provided that $C_i' \leq C_{i+1}$, where $C_i'$ is the revised completion time for job $i$, otherwise job $i+1$ is added as per the greedy algorithm.

The waiting time, if the $i^{th}$ and $i+1^{th}$ jobs are not swapped is given by

$W_i = C_{i+1} - C_i$ if $C_{i+1} > C_i$

$= 0$ if $C_{i+1} \leq C_i$

The waiting time, if the $i^{th}$ and $i+1^{th}$ jobs are swapped is given by

$W_i' = C_{i+1} - C_i'$ if $C_{i+1} > C_i'$

$= 0$ if $C_{i+1} \leq C_i'$

When swapping $i^{th}$ and $i+1^{th}$ jobs, the condition for the swap was that $C_i' \leq C_{i+1}$. The waiting time is zero time units. Without the swap the waiting time is $C_{i+1} - C_i \geq 0$.

This is illustrated in Figure 6 and Figure 7. There are 10 sub-assemblies P1 to P10, with varying construction time, shown in parenthesis. Sub-assembly P1 has a construction time of 10 days. In the greedy algorithm the completion is at day 49, the total work is 91 days. In Figure 7, sub-assembly P9 is constructed by team 1. This leads to a completion on day 46, thus a saving of 3 days over the normal greedy schedule.
Backtracking with post sequence reordering is when all the jobs have been allocated to the machines. The completion time of each job is compared to its required time. Job $i+1$ is required after the job $i$ has been assembled, but its construction completion may be earlier. Figure 8 and Figure 9 serve as an illustration. Examining team 2, it can be seen that jobs P2, P3 and P4 will be completed before job P1 is completed. This leads to a problem of double handling. Jobs that are completed ahead of their required assembly time are placed in a stack. In this example the stack would consist of jobs P2, P3 and P4. After P1 is completed, jobs P3 and P4 would have to be removed from the stack in order to retrieve job P2. This is inefficient work where the jobs are double handled. If job P3 is placed in a new stack and job P4 is placed on top of it, the same situation arises when job P3 is required.

To remove this double handing of jobs in line with lean principles, the sequence of construction for jobs P2, P3 and P4, is reordered, as may be seen in Figure 9. With this reordering, the stack now has job P2 on the top, so there is no double handling of previously completed jobs when P1 is completed and P2 is required.

It needs to be noted that this reordering of the queue does not change the makespan for the jobs; rather it improves the work flow and reduces the overhead of double handling of the jobs.

Each job has a start time, construction duration and required time. The start time and construction duration need no explanation. The time a particular job is required is defined as when the job is required at the assembly point. As here lean principles are being applied, the job is required at the same time the previous job is required with the addition of the fitting time. Since the construction time for a sub-assembly is comparatively long compared with the fitting time at the assembly point, for scheduling purposes the fitting time is ignored, hence the required for $(i+1)^{th}$ job is deemed to be at the finish time of job $i^{th}$.

Figure 8 shows P1 finishing at time 12. P2 finishes at time 1, but is not required until time 12; the same is true for Jobs P3 and P4. The jobs in team are ordered so that those with the same requirement time are order in reverse required assembly sequence. Figure 9 shows the sequence of P2, P3, and P4 reordered as P4, P3, and P2.
An assembly has 2 time values: its completion time (CT) and its required time (RT). The completion time is the point the assembly is completed, whereas the required time is the point at which the assembly is required to be just-in-time.

For a part \( i \), if \( RT_i > CT_i \) then the part is early. If \( RT_i=CT_i \), the part is on time. \( RT_i<CT_i \) the part is late.

The sub-blocks are order into their required assembly sequence. Then the algorithm is processed:

```
Begin:
For \( i = 1 \) to \( n \)
    If \( RT_{i+1} \leq CT_i \)
        set \( RT_{i+1} = CT_i \)
    Endfor
End
```

The sub-assembly is now ordered as follows:
- Team Number - Ascending
- Required Time – Ascending
- Original required sequence – Descending

**Testing the Algorithm**

To test the algorithm four computer models were developed in C#, the sub-block construction times were randomised using a seed of 42, with range of 1 to 8 days. The models were (a) greedy algorithm, (b) greedy algorithm with post reordering, (c) greedy algorithm with backtracking only and (d) greedy algorithm with backtracking and post reordering.

The following tables all have 30 items with a total work time of 99 days. The results are shown for 2, 3, and 4 teams working on the construction.

**Table 2. Greedy Algorithm Only**

<table>
<thead>
<tr>
<th># Teams</th>
<th># in Stack</th>
<th>Max in Stack</th>
<th>Total Stack Time</th>
<th>Avg. Stack Time</th>
<th>JIT Items</th>
<th>% JIT Items</th>
<th>Total Waiting Time</th>
<th>Avg. Waiting Time</th>
<th>Sequence Changes</th>
<th>Optimum Makespan</th>
<th>Makespan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7</td>
<td>2</td>
<td>12</td>
<td>1.71</td>
<td>11</td>
<td>36.67</td>
<td>45</td>
<td>1.5</td>
<td>0</td>
<td>49.5</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>4</td>
<td>28</td>
<td>2.15</td>
<td>16</td>
<td>53.53</td>
<td>30</td>
<td>1.0</td>
<td>0</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>6</td>
<td>37</td>
<td>2.47</td>
<td>21</td>
<td>70.00</td>
<td>22</td>
<td>0.73</td>
<td>0</td>
<td>24.75</td>
<td>27</td>
</tr>
</tbody>
</table>

**Table 3. Greedy with Post Reordering**

<table>
<thead>
<tr>
<th># Teams</th>
<th># in Stack</th>
<th>Max in Stack</th>
<th>Total Stack Time</th>
<th>Avg. Stack Time</th>
<th>JIT Items</th>
<th>% JIT Items</th>
<th>Total Waiting Time</th>
<th>Avg. Waiting Time</th>
<th>Sequence Changes</th>
<th>Optimum Makespan</th>
<th>Makespan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7</td>
<td>2</td>
<td>15</td>
<td>2.14</td>
<td>17</td>
<td>56.67</td>
<td>45</td>
<td>1.5</td>
<td>4</td>
<td>49.5</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
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<td>2</td>
<td>32</td>
<td>2.46</td>
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<td>4</td>
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<td>1</td>
<td>35</td>
<td>2.33</td>
<td>24</td>
<td>80.80</td>
<td>22</td>
<td>0.73</td>
<td>7</td>
<td>24.75</td>
<td>27</td>
</tr>
</tbody>
</table>
### Table 4. Greedy with Backtracking Only

<table>
<thead>
<tr>
<th># Teams</th>
<th># in Stack</th>
<th>Max in Stack</th>
<th>Total Stack Time</th>
<th>Avg. Stack Time</th>
<th>JIT Items</th>
<th>% JIT Items</th>
<th>Total Waiting Time</th>
<th>Avg. Waiting Time</th>
<th>Sequence Changes</th>
<th>Optimum Makespan</th>
<th>Makespan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8</td>
<td>2</td>
<td>17</td>
<td>2.13</td>
<td>13</td>
<td>43.33</td>
<td>45</td>
<td>1.5</td>
<td>0</td>
<td>49.5</td>
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<td>2.62</td>
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<td>0</td>
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<td>35</td>
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<tr>
<td>4</td>
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<td>5</td>
<td>22</td>
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<td>60.00</td>
<td>21</td>
<td>0.7</td>
<td>0</td>
<td>24.75</td>
<td>26</td>
</tr>
</tbody>
</table>

### Table 5. Greedy with Backtracking and Post Reordering

<table>
<thead>
<tr>
<th># Teams</th>
<th># in Stack</th>
<th>Max in Stack</th>
<th>Total Stack Time</th>
<th>Avg. Stack Time</th>
<th>JIT Items</th>
<th>% JIT Items</th>
<th>Total Waiting Time</th>
<th>Avg. Waiting Time</th>
<th>Sequence Changes</th>
<th>Optimum Makespan</th>
<th>Makespan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8</td>
<td>2</td>
<td>21</td>
<td>2.63</td>
<td>18</td>
<td>60.00</td>
<td>45</td>
<td>1.5</td>
<td>18</td>
<td>49.5</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>2</td>
<td>41</td>
<td>3.15</td>
<td>23</td>
<td>76.67</td>
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<td>35</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>1</td>
<td>24</td>
<td>2.18</td>
<td>23</td>
<td>76.67</td>
<td>18</td>
<td>0.6</td>
<td>32</td>
<td>24.75</td>
<td>26</td>
</tr>
</tbody>
</table>

The column headings in the table have the following meaning:

- #Teams = number of teams.
- #in Stack = the total number of items that were ready early and placed in a waiting stack.
- Max in Stack = the maximum number of items in the stack at any one time.
- Total Stack Time = sum of the times all items spent in the stack.
- JIT Items = items that were ready when required.
- % JIT Items = the percentage of items that were JIT.
- Total Waiting Time = amount of time waiting for an item.
- Avg. Waiting Time = average waiting time for all items.
- Sequence Changes = number of items whose sequences were changed.
- Optimum Makespan = total amount of work divided by number of teams.
- Makespan = number of days taken to complete all work for the team.

### Analysis of Results

With this particular set of random data, it may be seen that backtracking &/or post reordering has an advantage in terms of increasing the number of JIT items. Comparing Table 2 with Table 3 (Greedy only and Greedy with Post Reordering) there is an increase in the number of JIT items. Further, with Post Reordering, there is a reduction in wasted time since there will not be double handling of items. Similarly, the same can be said in comparing Table 2 and Table 4 and Table 2 and Table 5 data. There is a clear increase in the JIT Items. The highest number of JIT items is when the Greed algorithm is augmented with backtracking and Post Reordering.

### Conclusions

Identical parallel machine theory from scheduling has been adopted to resolve the sequencing of the construction of sub-assemblies with a limited number of work teams.
As good as the greedy algorithm is in this constrained problem, it may be improved in many circumstances with the addition of backtracking. While it has been shown that JIT may not be fully realised with a limited number of teams for work, some lean principles may be applied to the construction process by using reordering following the completion of the assignment of the construction sequences of the sub-assemblies. Although this does not improve the makespan for the schedule, it does remove the need for double handling of the sub-blocks and thus makes a step towards a better implementation of lean principles in the construction of offshore rigs.

As with all algorithms and random input, there is no guarantee that it will give an acceptable result on all occasions. The algorithms developed here may be seen as an arsenal, in that the best one for the set of data may be chosen.

References
Automated Master Project Schedule for Construction Incorporating Building Information Model and IFC

David Cheng¹, Ernest Abbott², David Chua³, and Ahmad Tashrif⁴

Abstract

At the end of a predesign phase of a building design, it is essential for the consulting firm to be able to generate from the BIM design, take-off quantities and construction activities durations efficiently at a short timeframe to derive the cost budget estimates and schedule for project tendering purpose. However, these efforts require prior construction site experience and knowledge together with their association to the BIM and IFC construction component data to automate a Master Project Schedule. The research and development of the automated master project schedule is the focus of the project which will read IFC data from a BIM application and display the model while the data are distributed to a database repository. The automated project schedule can then be generated with the activities and timeline of each building component presented by floor levels and component types. Finally, the challenges in changes in the construction methods such as precast and/or cast in-situ, and the additional building component information from BIM to IFC that provide a set of data to derive a practical project schedule are discussed while these data can also be used to estimate the bill of materials of building components. The aim of this research project is thus to enable planners to use a platform that holds and manages construction knowledge and applying BIM and IFC standards to generate a master project schedule automatically.

Keywords: automated project schedule, building design, construction activities, short timeframe, BIM, IFC data

Introduction

The Architecture, Engineering and Construction (AEC) industry today is faced with many software tools that offer to provide an integration platform to manage various aspects of planning, design and construction activities. In today’s state of such an integration, it is still evolving in the industry under the direction of BIM (Building Information Model) and IFC (Industry Foundation Classes) (buildingSMART 2014) initiatives.

Many of the BIM software are developed based on their former 3D CAD environment and there are others on new programming methodology. IFC data as a text-based neutral format for interchangeability between BIM and IFC compliant systems is the current international standard in the industry for its intended purpose. There are already a number of public software developed by research institutions as IFC data checkers, readers and viewers; these are used mainly to check if the IFC data generated by different BIM systems if the format is compliant to the format specified in the standard’s specification and version.

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BIM software also needs to keep up-to-date progressively with the higher version of the IFC data specification. These are challenges that the BIM software have to accommodate especially when IFC data interchangeability is concerned.

The IFC data are used for re-construction of the BIM model in another platform, for example, an Architectural design, Structural components’ model and others in the AEC discipline where besides geometrical information there are information such as sizes, area, material descriptions, height as found in the IFC data standard specification that one can derive many other information needed for engineering and quantitative calculations.

These objectives of this paper are (1) to demonstrate that the use of IFC data in a BIM software can be applied to perform a project schedule construction knowledge computation with the use of a database system and (2) to generate a master project schedule from the IFC data / database. As the BIM software used in the prototype is a development platform, many programming algorithms can also be applied to achieve its purpose such as intelligent design analysis to check for compliance to building codes and public authorities’ requirements such as boundary’s setback and as fire escape route.

The focus here is on the planning stage of a building development project where a master project schedule derivation using IFC data, project management time duration precedence and database system can support the building developer and its consultant with a cost budgeting estimates’ expectation and over an estimated duration to complete a proposed building project. As the prototype is at its current stage to prove this approach, the coverage is thus limited to structural building components.

The logistics in assembling the BIM model in this paper are EyeShot (EyeShot 2014) software (a development software and modeler that is coded in C# object programming to manage BIM classes and entities), IFC data convertor to EyeShot (http://www.devdept.com/ where an IFC convertor had been developed to accept specific IFC data object type and property information), MySQL (a database system to store and manage IFC data and construction knowledge), C# programming within MS Visual Studio 2012 (to provide algorithms for computing that re-organize the database) and extracted data to generate the project schedule using a developed software MyPlanDo (David Chua 2013) and .NET framework 4.5.

**Industry Review**

A number of literature reviews had shown that most BIM software had their own IFC importer. The IFC data after importing are usually reference models that one has to select and incorporate into the BIM 3D model environment before more work can be carried out such as modeling the model from the IFC data.

There are many IFC Viewers and Readers which are published in the public domain to support users to verify if the IFC data file is compliant to specific versions. Some are black-boxes and there is no further work can be done on them by adopters. Some provide IFC libraries for adoption by programmers to develop an IFC importer but specific programming language has to be used in order to make the IFC libraries work properly in the development environment. Unfortunately the original developer response to any queries is usually slow.
It would be good for companies in the BIM and IFC industry to develop IFC libraries and other IFC Viewers and Readers and share them in a common repository so that the AEC industry can move quicker into BIM with interchangeability between BIM software.

The Approach

The prototype is developed using industry standards’ tools and data format that are acceptable by the AEC industry. In this respect, BIM concept and IFC data specifications were studied and applied through the adoption of a BIM development platform (EyeShot) by the university and importing IFC data and re-organizing the data to database, in this case, MySQL is adopted. The theory behind the approach is no stranger to many as in project management there is a need to understand precedence network and the calculation of the dates of activity sequences and time duration.

The approach is modeled in the diagram as shown in Figure 9 which is self-explanatory. The IFC import routine was developed in EyeShot and it is configured to read and filter out non-essential information. The IFC data files were generated by other BIM software such as Revit. This is intentional as it was from here that the appropriate IFC data format version IFC2X3 was based on for importing to EyeShot and according to the widely used industry BIM tool Revit. After several tests to convert IFC data to BIM software, the IFC importer developed under EyeShot was observed to work as intended after minor enhancements to it when better understanding of the way the properties are organized.

The IFC Data Importer

The IFC Data Importer, at the current moment, reads in the following main building component types and their properties are briefly described below:

<table>
<thead>
<tr>
<th>a) Component Type: Beam, BeamStandardCase, Column, ColumnStandardCase</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Name</td>
</tr>
<tr>
<td>- Description</td>
</tr>
<tr>
<td>- IsDefinedBy</td>
</tr>
<tr>
<td>o IfcRelDefinesByProperties</td>
</tr>
<tr>
<td>• RelatingPropertyDefinition</td>
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<tr>
<td>• Name</td>
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<tr>
<td>o BASEQUANTITIES</td>
</tr>
<tr>
<td>• NOMINALLENGTH</td>
</tr>
<tr>
<td>• LENGTH</td>
</tr>
<tr>
<td>• CROSSECTIONAREA</td>
</tr>
<tr>
<td>• OUTERSURFACEAREA</td>
</tr>
<tr>
<td>• TOTALSURFACEAREA</td>
</tr>
<tr>
<td>• GROSSVOLUME</td>
</tr>
<tr>
<td>• NETVOLUME</td>
</tr>
<tr>
<td>• GROSSWEIGHT</td>
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<tr>
<td>• NETWEIGHT</td>
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<tr>
<td>o PSET_REVIT_DIMENSIONS</td>
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<tr>
<td>o DIMENSIONS</td>
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<td>• L</td>
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<td>• V</td>
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<tr>
<td>• LENGTH</td>
</tr>
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<td>• BREADTH</td>
</tr>
<tr>
<td>• HEIGHT</td>
</tr>
<tr>
<td>• VOLUME</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Component Type: Wall, WallStandardCase</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Name</td>
</tr>
<tr>
<td>- Description</td>
</tr>
<tr>
<td>- IsDefinedBy</td>
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<tr>
<td>o IfcRelDefinesByProperties</td>
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<td>• Name</td>
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<tr>
<td>o BASEQUANTITIES</td>
</tr>
<tr>
<td>• NOMINALLENGTH</td>
</tr>
<tr>
<td>• LENGTH</td>
</tr>
<tr>
<td>• NOMINALWIDTH</td>
</tr>
<tr>
<td>• NOMINALHEIGHT</td>
</tr>
<tr>
<td>• GROSSFOOTPRINTAREA</td>
</tr>
<tr>
<td>• CROSSECTIONAREA</td>
</tr>
<tr>
<td>• NETFOOTPRINTAREA</td>
</tr>
<tr>
<td>• GROSSSIDEAREA</td>
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<td>• NETSIDEAREARIGHT</td>
</tr>
<tr>
<td>• GROSSVOLUME</td>
</tr>
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<td>• NETVOLUME</td>
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<td>o PSET_REVIT_DIMENSIONS</td>
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<td>• LENGTH</td>
</tr>
<tr>
<td>• BREADTH</td>
</tr>
<tr>
<td>• HEIGHT</td>
</tr>
</tbody>
</table>
c) Component Type: Slab, SlabStandardCase
- Name
- Description
- IsDefinedBy
  o IfcRelDefinesByProperties
    - RelatingPropertyDefinition
    - Name
      o BASEQUANTITIES
        - NOMINALLENGTH
        - LENGTH
        - PERIMETER
        - GROSSFOOTPRINTAREA
        - NETFOOTPRINTAREA
        - GROSSVOLUME
        - NETVOLUME
        - GROSSWEIGHT
        - NETWEIGHT
      o PSET_REVIT_DIMENSIONS
      o DIMENSIONS
        - L
        - B
        - H
        - V
        - LENGTH
        - BREADTH
        - HEIGHT
        - VOLUME

d) Component Type: Stair, StairFlight
- Name
- Description
- IsDefinedBy
  o IfcRelDefinesByProperties
    - RelatingPropertyDefinition
    - Name
      o BASEQUANTITIES
        - NUMBEROFRISERS
        - RISERS
        - NUMBEROFTREADS
        - RISERHEIGHT
        - TREADLENGTH
      o PSET_REVIT_DIMENSIONS
      o DIMENSIONS
        - L
        - B
        - H
        - V
        - LENGTH
        - BREADTH
        - HEIGHT
        - VOLUME

Other property types in the IFC file are scanned and pre-processed at the same time while others such as component types as in ramp, curtain wall, door, roof, footing, pile, plate, railing, space, windows and others, would be used in future enhancement.

After importing the IFC data into EyeShot, the 3D BIM model can be viewed, inspected and accepted for writing to the database tables named under each of the component types including their GUIDs, elevations, levels, component types and physical detailed properties. So basically the IFC model is now stored in the database. The database is further described in the next section “Database Preparation”.

Another module of the prototype is the Construction Knowledge (CK) application which is developed to assign construction methods to the building component types such as Prefab or/and Cast In-situ methods and these are maintainable through a Maintenance module.

When the CK module is launched, EyeShot is also launched to provide the 3D BIM model view on selection of a project model of interest to the user. The project model is then retrieved via the database and its 3D graphics are then re-constructed in its 3D viewport. At the same time, a tree-view window presented on the side of the interface maps the graphic 3D entities in a hierarchical graph form where one can traverse to identify the component and its location in the 3D viewport and vice versa for more object details.

Database Preparation
Preparation of the database was required so that the imported IFC data can be distributed to the respective database tables in MySQL.

A database “IFCBUILDINGDATA” was created with 14 tables and 1 view to store and re-organize the IFC dataset.
A database “CONSTRUCTIONKNOWLEDGE” was created with 10 tables as activities template for which on acceptance of the set of activities they are written onto one of the columns in table “ifcconstructionknowledge” located in the database “IFCBUILDINGDATA” such as <A, Activity <n>, Duration;> format. The construction method that goes by the notation in-situ <building component-type> or prefab <building component-type> can be re-sequenced as required. <Building component-type> is either beam or slab or column or wall or stair.

A database “SCHEDULEDB” was also created with 3 main tables for formatting the IFC and construction knowledge data that are consolidated to one of its tables to enable a project schedule application to retrieve, manage and plot the project schedule (Gantt chart). This will be described in another section “The Project Schedule Generated Automatically”.

The IFC Importer and Modeler

Figure 1. IFC data file loaded and viewed

Figure 2. Construction Knowledge table

In the viewport as shown in Figure 2, each building component type can be assigned different construction methods such as prefab or cast in-situ as a group for walls, slabs, columns, beams and stairs. Even the individual component such as “Concrete-Rectangular-Column: 300 x 450mm:300 x 450mm:147467” can also be assigned specific construction method (Figure 3). As for this prototype example, the building component types are grouped as prefab “Column” (shown in one color type) within a specific floor level. However if some columns within this floor are required to have a different construction method such as in-situ, one can select the component and change the columns from prefab to in-situ. Because of the construction methods ranking setup, the project schedule will place the construction sequence according to the ranking rule.
Maintenance of the Activity Sequence

The Activities for each building component types can be modified and set up according to the project planner’s experience on construction site. The activity sequence that describes them using the <A, Activity <n>, Duration;> format can be easily maintained and even change to practical activity descriptions which are currently used in a typical construction project. The term A or Q was reserved for future purpose although it may change. ‘A’ is active that denotes active activity in the process.

Assignment of Construction Methods

Before assignment of construction methods to each of the building component types, the pre-defined construction methods in the preceding section on Maintenance are set up according to prefab or in-situ, and their activity sequence planned for.
After assignment of construction methods to the building component types, the 3D BIM model and its construction methods can then be written to the “SCHEDULEDB” tables with project schedule data format in mind such as MS Project. The computation consideration before writing to the database tables is to consolidate the total number of activities to construct each building component and which construction methods to start first that is ranked accordingly in the database table.
The database “CONSTRUCTIONKNOWLEDGE” together with the programming of Winforms in C# allows users to re-organize the construction activities sequence to reflect the practical experience in construction. The application (MyPlanDo) which is a project resulted from another university researcher’s work reads directly from the scheduledb table “MSPACTIVITY” which had already stored the project schedule activities data and retrieve and plot as a project Gantt chart. The MyPlanDo works with MS Project or any other project software that generates the mpp file format. What happens here is that the mpp data are actually been distributed to the scheduled table “MSPACTIVITY” after it is loaded into MyPlanDo.

The Project Schedule Generated Automatically

What the project prototype has done is incorporating IFC Importer into EyeShot for planners to assign construction methods and detail activity sequencing after which the planner can compile all these data by generating a set of data that is ready for MyPlanDo to read and construct the Project Schedule Gantt Chart layout for further planning though MyPlanDo has many other offerings such as PPC (Production Planning & Control), Constraint Management, Tracking and management of activities and others that are not covered in this paper. The prototype is also enhancing the usage of MyPlanDo as a Project Schedule generator via the BIM/IFC approach with interfacing between the BIM software EyeShot and MyPlanDo. The automated project schedule derived from the database is plotted as a Gantt Chart is shown below:

![Gantt Chart Image]

Figure 7. MyPlanDo – Project Schedule Generated

In the EyeShot platform, the Quantity take-off for the number of columns, beams, walls, stairs and slabs can be easily calculated and presented by floor levels and grouped under
each building component type. From the tree-view, one can also observe the quantities involved for each of the building components.

**Quantity Take-off from the Project Model**

More details such as costs estimation and component descriptions can be included in the quantity table. A sample output is presented below for a simple quantity take-off. With this table, the proposed project cost estimates for the structural components can be derived. If the IFC data with regards to geometry data are accurate the bill of materials derived from the system would be useful for cost calculation and analysis, determining the number of precast components, calculating the volume and weight of components, and so forth.

It is also extendable to include filtering of the information report types to provide different views of quantitative reports. An example is shown in Figure 8.

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Description</th>
<th>Method</th>
<th>Length</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1000 + Block 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 500 x 450mm</td>
<td>Precast Column</td>
<td>5000</td>
<td>1</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 300 x 450mm</td>
<td>In-Situ Column</td>
<td>3000</td>
<td>11</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 300 x 450mm</td>
<td>In-Situ Column</td>
<td>2700</td>
<td>20</td>
</tr>
<tr>
<td>Slab</td>
<td>Floor Generic 300mm</td>
<td>In-Situ Slab</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Wall</td>
<td>Basic Wall Generic - 200mm</td>
<td>In-Situ Wall</td>
<td>3000</td>
<td>16</td>
</tr>
<tr>
<td>Wall</td>
<td>Basic Wall Generic + 200mm</td>
<td>In-Situ Wall</td>
<td>2700</td>
<td>16</td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam</td>
<td>Concrete-Rectangular Beam 500 x 600mm</td>
<td>Precast Beam</td>
<td>5000</td>
<td>56</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 500 x 450mm</td>
<td>Precast Column</td>
<td>5000</td>
<td>12</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 300 x 450mm</td>
<td>Precast Column</td>
<td>2700</td>
<td>20</td>
</tr>
<tr>
<td>Slab</td>
<td>Floor Generic 300mm</td>
<td>Precast Slab</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Level 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam</td>
<td>Concrete-Rectangular Beam 500 x 600mm</td>
<td>Precast Beam</td>
<td>5000</td>
<td>56</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 500 x 450mm</td>
<td>Precast Column</td>
<td>5000</td>
<td>12</td>
</tr>
<tr>
<td>Column</td>
<td>Concrete-Rectangular-Column 300 x 450mm</td>
<td>Precast Column</td>
<td>2700</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 8: Bill of Quantities for Precast and Cast-In-Situ Concrete Component Types
Practical Application

The prototype was modeled using the workflow diagramming and presented in Figure 9:

Figure 9: Prototype workflow diagram

It is established that this workflow can govern how the project can be routed from one stage to another providing a quick approach to establish a proposed project with a master project schedule generated automatically, to perform and compute quantity take-off for its building components, to analyze the costs for the project main building components taking into account the pre- and post-construction activities, and to consolidate the number of precast components to order or make. Any other project schedule analysis can be carried out within MyPlanDo.

Research Project’s Strengths and Weaknesses

The research carried out in this paper has shown that its strength is its flexibility to use a platform such as EyeShot where an IFC read module is developed to read IFC data. This extracted data becomes the heart of the BIM model in EyeShot as the building components can be assigned to construction methods (precast or cast in-situ) if the original source of the IFC data source does not include them. As a development platform the programming codes can be easily customized to suit the requirements in reading and manipulating IFC data and project scheduling. The research overall strength is the ability to integrate developed modules and connectivity to IFC database as in MySQL or any other database brands. It is also not the purpose in this project to develop a project management software. Thus an export routine to project software such as MS Project via CSV format is developed as part of the environment although not discussed in the paper. MyPlanDo which retrieves the master project schedule is used to verify the schedule generated by the EyeShot platform.

The module developed for the reading of IFC data was integrated by adopting a third-party IFC DLL engine, and adapted in this research with own codes integrating the DLL. After
understanding the philosophy of the DLL, its usage became easier than the initial stage of using it.

The research also enables the bill of quantities to be easily consolidated and various reports can be derived such as total and sub-total number of precast elements, for example.

It is not the intent of the research to compete with commercial BIM software and project management software. Instead it demonstrates the usage of an “open” platform to enable planners to apply, hold and manage construction knowledge and applying BIM and IFC standards to generate a master project schedule automatically.

**Conclusion**

It has been shown that for an IFC data file of a proposed project, the planner can adopt the workflow process to view, inspect and accept the BIM 3D model. Following this the assignment of construction methods that contain their specific activity sequence can be carried out for the building components. This is an important stage as it allows the project planner to assign methods and activity sequence according to their prior or current site experience for setting up as construction knowledge provided by the knowledge and experience of site managers.

These set of construction knowledge and the IFC data can be analyzed and computed with the transformed dataset and write into the database.

As a result, when using a project schedule application (developed or commercial) that reads project data from the database, an automated master project schedule can thus be derived. For further work, the following enhancement can be implemented in the future:

Future work to increase its functions are:
- Enhancement to construction knowledge and precedence diagram concept to provide better project scheduling as currently only the finish-to-start and start-to-start relationships are implemented.
- Importing more IFC data types such as ifcram, ifccurtainwall, ifcfooting, ifcpile, ifcspace and others for wider scope of coverage.
- Importing IFC data for other engineering disciplines such as MEP, QS and Architecture.
- Comprehensive quantity take-off.

**References**


Rita Obiozo¹ and John Smallwood²

Abstract
With the understanding that ‘happy workers are productive workers’, research findings indicate that the extraordinary construction management needs of megaprojects such as ECOPARK Hanoi Vietnam require a new set of construction management strategies such as the biophilic construction site model (BCSM). The BCSM is a greening construction site model that derives its relevance from the biophilia hypothesis and a proven track record for improving the social intelligence of the workplace, worker wellbeing and performance towards cost-effective applications. The study involves an exploratory research survey aimed at examining the impact of the BCSM in eliminating the toxicity of psychosocial stress and establishing a nourishing environment on the worksite derived from nature. The methodology involves a focus group study of workers and management on construction sites which includes triangulation. The findings indicate that the ‘informal dynamic rock garden’ is a suitable form of ‘healing garden’ adaptable to construction sites including the specific recommendation for the inclusion of plants within the site offices, welfare facilities, and worksite in order to improve worker wellbeing and performance.

Keywords: Biophilia, ergonomics, health and safety, mega projects, social intelligence.

Introduction
The vision of creating a healthier and more sustainable society gives rise to the ‘research question’ of how not to design workplaces / worksites that minimize human wellbeing in furtherance of the construction management body of knowledge (CMBOK). The aim is to achieve the cost benefit of megaprojects by applying the inherent benefits of nature on construction sites, which include the psychotherapeutic influence on the H&S and wellbeing of workers. The objective examines the impact of the BCSM in eliminating the toxicity of psychosocial stress and establishing a nourishing environment on the worksite derived from nature. Empirical data drawn from the biophilia hypothesis, states that ‘humankind has an innate emotional affiliation to all organisms in nature’ (Wilson, 1984; Kellert and Wilson, 1993). This is indicative of the need for re-energizing human symbolic values with nature in a green environment such as a ‘landscape inspired construction site’ according to the biophilic construction site model (BCSM). This is arguably one of the most pressing and potent needs facing the management of construction projects / mega projects in recent times (Obiozo et al., 2011; Obiozo and Smallwood, 2014). Flyvberg (2014) indicates that megaprojects are in dire need of such an innovative construction

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management strategy in order to overcome the inherent problems associated with the four sublime factors classified as technological, political, economic, and aesthetic. The research findings also emphasized the need to integrate the values and benefits of mega projects alongside the Triple bottom line (TBL) in harmony with the local communities and environment that benefit from it in a manner that is sustainable and cost-effective (Flyvberg, 2014). These are attributes that are associated in this research with the term ‘happy workers’. The various parameters and structure of the research design include the following aspects:

- **Independent variables**: the construction site environment is identified as an independent variable that would have a decisive influence on the performance of workers and their productivity on project;
- **Dependent variable**: the performance and productivity of workers on the project is a dependent variable that is measured by the cost effectiveness and timeliness of a project that is within the scheduled timeline for delivery;
- **The methodology applied**: is the exploratory greening construction site survey method which includes the Biophilic Construction Site Model (BCSM) strategy. It involves an exploratory research survey and comparative analysis of construction sites in progress; Case Study 1 (CS-1): ECOPARK, Ecological City, Hanoi, Vietnam, and Case Study 2 (CS-2): BHP Billiton Wessel’s Mine Central Block Project, specifically the M&R Cementation Construction Project Site, located at Hotazel in the Northern Cape Province of South Africa. The findings derived from CS-1 are validated and measured against the findings on CS-2. The method of data collection and analysis includes triangulation, which is both qualitative and quantitative. It includes a focus group study of construction workers and management; interviews, observations, a formal and an informal questionnaire survey, photo elicitation, and a review of historical and technical data, and
- **Validation of findings**: A generalizable model was derived from which recommendations and suggestions were made for the inclusion of an informal dynamic rock garden design on construction sites with particular reference to the inclusion of plants within construction sites, site office premises, welfare facilities, and material sheds.

**Mega Projects and the Four Sublime – the Case for the Innovative Strategy of the BCSM**

Flyvberg (2014) defines megaprojects as large scale complex ventures that typically cost one billion US Dollars or more and take many years to develop and build, involve multiple public and private stakeholders, are transformational and impact millions of people. Kallianpukar and Browning (2013) states that workplace, wellbeing, and performance are not independent but are more or less complimentary and dependent components of a financially and psychologically healthy workplace which is in alignment with contentions from Snow (2010). Wellness is defined as a set of organised activities and systemic interventions offered through corporations / worksites, in corroboration with Hedge (2000), which states that healthy comfortable employees are invariably more satisfied and productive.

**The Biophilic Design Concept of the BCSM and ‘Green Ergonomics of Tranquillity’**
The theory of ‘biophilia’ addresses the ‘innate emotional affiliation of humankind to all organisms in nature’ (Wilson, 1984). It is substantiated with empirical findings from different supportive and scientific fields covering a wide spectrum of scientific fields and researchers from the built environment articulated in the edited book Kellert and Wilson (1993). One of the driving objectives of the ‘biophilia’ theory referred to as ‘nature in space’ states that access to actual nature such as live plants and animals has the strongest positive effect on people’s physiologies. By implication, there is every indication that the incorporation of human access to nature into the built environment such as the construction site can improve H&S, ergonomics, wellbeing, and happiness of workers to a large extent (Obiozo et al., 2011; Kallianpukar and Browning, 2012).

Another aspect identified as the ‘nature of the space’ includes a spatial design that evokes the natural landscape and advocates for the development of interiorscapes within interior spaces such as site offices, welfare facilities; lunch break retreats, material sheds; on construction sites, by the inclusion of indoor plants. This factor also includes the development of a landscape inspired construction site that evokes the feelings of a savannah; grassland with a cluster of bushes or trees that evokes the H&S factor of prospect and refuge, and ‘green ergonomics of tranquility’ (Miyake, 2003; Kallianpukar and Browning, 2012). Miyake (2003) indicates that the factor known as the ‘green ergonomics of tranquility’, substantiated with a range of empirical evidence, is defined by the International Ergonomics Association (IEA) as addressing a comfortable living space / environment whose content exudes a truly peaceful and relaxed environment.

The natural solution of ‘green ergonomics of tranquillity’ include stress reduction through the impact of nature; nature-psychophysiology; construed as a process by which a person responds psychologically, physiologically and very often with behaviour to a situation that is demanding or threatens H&S and wellbeing (Hedge, 2011; Finneran and Gibb, 2013). Miyake (2003) identifies nature-psychophysiology in its concept and futuristic prospect for the furtherance of CMBOK to include the following: visual elements – nature view; auditory elements – sounds of nature; and olfactory elements – smell and aroma from nature. Miyake (2003) substantiated this fact with corroborative evidence from a range of recent empirical findings which include: effects of wooden odours; negative ions, nature sounds and favourite music using psychophysiological measures, and effects of indoor foliage plants. Miyake (2003) also cited Miyakzaki (1991) as having identified a kind of wooden odour associated with the Japanese Cypress which softened some negative emotions such as tension, anxiety, fatigue, and confusion in stress conditions in corroboration with the relaxation effect of wooden odour.

Research Methodology

The BCSM Strategy / Greening Construction Site Survey

The empirical determinant in the realization of the objective is modelled on the recommendation of EU-OSHA (2012) derived from a report given by European Survey of Enterprises on New and Emerging Risks (ESENER) on the analysis of the management of psychosocial risk stated as follows: In the management of psychosocial risks the same analytical strategy is applied relative to the management of general risks to H&S, namely:

- Employing the conceptual framework of OSH management to investigate the possibility of generating an empirical construct which will efficiently summarize
features of OSH management within a particular area of psychosocial risk. Such an empirical construct will be, effectively, a single variable capturing the scope of the management of psychosocial risks, and

- To model the relationship between that variable (in the status of dependent variables) in a multivariate setting. Thereby, there is a need to identify the significant predictors of OSH management in the area of psychosocial risks and provide the policy makers with options for intervention (EU-OSHA, 2012).

CS-1; ECOPARK Ecological City, Hanoi, Vietnam

Ecopark is reputed to be the largest green township development in Northern Vietnam covering a total development area of 499.9 hectares as shown in Figure 1(a), and is located within 10km from the center of Hanoi and 20min drive from the city [Figure 1(b)]. The project is divided into 9 phases and as a mega project has a total estimated investment capital of up to 8.2 billion US Dollars (Savills, 2011). It has over 110 hectares in green areas and lakes interspersed with ongoing construction processes of the various facilities and with various aspects of interior space within the reception / front office locations, site offices, and welfare facilities. The encounter of the green construction site / BCSM element of study has deep and lasting impressions on visitors as testified by participants of the CIB W107 Conference who visited the Ecocity construction site (Savills, 2011). It presents a harmonious integration of a network of trees, lakes, gardens, and quiet pathways forming a beautiful landscape which according to Than (2011) and Savills (2011) is intended to intertwine daily life and nature at all stages of the project life cycle; design, construction, and end user / occupant [Figure 1(a)]. For this reason, the construction of the Ecocity being true to its concept began with the infrastructure and landscape phase, which according to Than (2011) was intended to enable the construction workers to operate in a holistically green environment deriving the benefits thereof for enhanced health, wellbeing and productive performance [Figure 1(c) and (d)].

Photo elicitations

Figure 1. The ‘green construction site’ and location map of the ecological city (under construction November, 2011).

Figure 1: (a) presents a model of Ecopark showing the trees, rivers, lakes, gardens, and quiet pathways forming a beautiful ‘landscape inspired construction site’ weaving through the facilities, infrastructure and tree lined road network; (b) presents a location map of Ecopark, showing the Ecocity as being within 10km from the center of Hanoi, and connected by six direct access routes; (c) shows an island with a developed tree at a road intersection and in clear view of the building under construction enveloped with green shade netting, and (d) shows the ongoing construction site within a fully developed green wooded area (Source: Field survey; during the CIB W107 Conference in 2011).
Observation and Comments

Client’s perspective

Tuan (2011) identifies the client’s perspective in the position paper presented at the conference which states the following:

“…the construction workers are regarded as intrinsic not exclusive in the determinant of a productive construction management program and control of complex mega projects. In this case, the greening and landscaping of the construction site is considered the primary focus of the master plan from the conceptual design stage, through the construction processes, towards the final realization of the end product / finished project; a green environment for the end users and the local populace / nation and the global community. For this reason, the construction processes began with the landscaping and infrastructure as shown in Photos 1 and 2. This vision was implemented as articulated in the government proposal and policy for the masterplan developed into a ‘green construction site’. It has a laudable and generalizable ‘green ergonomics of tranquility’ as its theme in giving priority and consideration also for the H&S and wellbeing of workers (Tuan, 2011).

CIB W107 participants and scientific committee

The scientific committee of the CIB W107 adjudged the vision and mission as effective on all aspects. The chairman stated: “This is a featured case of innovation and sustainable construction….to transform from planning into being is a difficult process. We highly assess the achievement of Ecopark. The green city deserves to be a featured study model for many countries (Dang, 2011)”, and has fulfilled the aim of an innovative strategy in green building design and construction that is cost effective; an eventual payback on investments on the immediate and futuristic bottom line, and sustainable according to the TBL considering the size, magnitude and impact of the Ecocity as a megaproject of its kind.

Validation of Research Findings at CS-1

CS-2: BHP Billiton Wessel’s Mine Central Block Project; M&R Construction Site

The measurement of this variable is validated with the similarity of a comparable case study, namely CS-2: the BHP Billiton Wessel’s Mine Central Block project site of M&R and Synntech Project management. The greening construction site survey conducted during the peak of the summer season of the arid interior climate of the Northern Cape Province of South Africa revealed the application of the BCSM strategy. In this case, the biophilic design concept includes both the theory of biophilia and feng shui principles of wellness intervention as shown in Figure 2.

The BCSM Whole Construction Site Element of Study

Photo Elicitations

![Photo Elicitations](a) ![Photo Elicitations](b) ![Photo Elicitations](c) ![Photo Elicitations](d)

Figure 2. CS-2, M&R Cementation Construction Site.
Figure 2: (a) shows the courtyard including the four cardinal trees surrounded by rose bushes and the giant water jug fountain located at the entrance to the construction site presenting a welcome ambience to the workforce and visitors; (b) shows the giant water jug fountain as the focal point of the landscaped garden with walkway radiating from it and connecting the different sections within the site office premises from the entrance location at the initial phase, with provision for future expansions during the setting out of the construction site as a ‘green performance index’ and an aspect of ‘green ergonomics of tranquility’ by the M&R H&S Department; (c) shows the warm glow radiating from the sunny shading device over the site office containers and shading the walkways connecting the different containers as the workers moved from M&R to Synntech Project management offices and to the project site and other parts of the Wessel’s mine central block project, and (d) shows the workers’ extension exhibiting the impact of the ‘green performance index’; the grass lawn was planted and maintained by the workers in appreciation of the management effort, and maintained with grey water from their washing even in the height of the summer season and with the existing reticulation problem (Source: Field Survey).

The Questionnaire Survey

The BHP Billiton greening construction site survey comprising M&R, Synntech Project Management, and Bashewa and Olivier Construction firms; constituting 68 respondents; 33, 9, 10 and 15 respectively. A Likert type scale was used for the self-administered questionnaire, which ranges from 1 to 5, 1 being strongly disagree and 5 being strongly agree. A mean score (MS) based upon the percentage responses to the five-point scale was computed to enable the result to be ranked (R) as shown in Tables 1 and 2.

Table 1 indicates the respondents’ degree of concurrence with respect to the cost effectiveness of the psychotherapeutic value of the BCSM element of study. It is notable that only one (20%) of the five functional values, namely ‘increased work effectiveness’ has a MS > 3.00, which indicates that there is agreement as opposed to disagreement. However, four (80%) of the functional values have MSs ≤ 3.00 i.e. disagreement as opposed to agreement – ‘improved comfort’, ‘greatly reduced turnover’, ‘rapid payback in investment’, and ‘absenteeism cut in half’. ‘Rapid payback in investment’ and ‘absenteeism cut in half’ with MSs = 2.63 are ranked joint third, however as the former has a lower standard deviation it is ranked third. In terms of the various ranges four (80%) of the functional values; ranked first to fifth; have MSs > 2.60 ≤ 3.40, which indicates that the agreement is between disagree to neutral / neutral. Included in this range are, ‘increased work effectiveness’, ‘improved comfort’, ‘greatly reduced turnover’, and ‘rapid payback in investment’.

Table 1. Measure of cost effectiveness of the psychotherapeutic value of the BCSM element of study

<table>
<thead>
<tr>
<th>Psychological well-being attribute (Psychological factor)</th>
<th>Unsure</th>
<th>Strongly disagree...Strongly agree</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased work effectiveness</td>
<td>0.0</td>
<td>4.4</td>
<td>7.4</td>
<td>27.9</td>
</tr>
<tr>
<td>Improved comfort</td>
<td>4.4</td>
<td>5.9</td>
<td>7.4</td>
<td>20.6</td>
</tr>
<tr>
<td>Greatly reduced turnover</td>
<td>2.9</td>
<td>10.3</td>
<td>11.8</td>
<td>27.9</td>
</tr>
<tr>
<td>Rapid payback in investment</td>
<td>4.4</td>
<td>10.3</td>
<td>13.2</td>
<td>22.1</td>
</tr>
<tr>
<td>Absenteeism cut in half</td>
<td>5.9</td>
<td>8.8</td>
<td>14.7</td>
<td>33.8</td>
</tr>
</tbody>
</table>

Source: Field Survey.
Table 2 indicates the measure of ‘green ergonomics of tranquility’, which includes the socio-psychotherapeutic value (psychosocial factors: ergonomics, communication, H&S and wellbeing) of the BCSM element of study as a motivational factor toward cost effective performance as indicated in Table 1.

Table 2. Measure of ‘green ergonomics of tranquility’ - socio-psychotherapeutic factor towards cost effective performance

<table>
<thead>
<tr>
<th>Emotional factors – organisational value and team spirit</th>
<th>Unsure</th>
<th>Strongly disagree...Strongly agree</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced aesthetic appeal of the construction site</td>
<td>1.5</td>
<td>4.4 8.8 17.7 33.8 26.5</td>
<td>3.44</td>
<td>1</td>
</tr>
<tr>
<td>Improved job satisfaction</td>
<td>1.5</td>
<td>0.0 4.4 25.5 42.7 17.7</td>
<td>3.40</td>
<td>2</td>
</tr>
<tr>
<td>Enhanced fraternal communication / interaction</td>
<td>1.5</td>
<td>1.5 7.4 39.7 26.5 17.7</td>
<td>3.31</td>
<td>3</td>
</tr>
<tr>
<td>Enhanced sense of personal wellbeing</td>
<td>1.5</td>
<td>2.9 11.8 19.2 44.1 13.2</td>
<td>3.27</td>
<td>4</td>
</tr>
<tr>
<td>Increased organisational pride / mission</td>
<td>1.5</td>
<td>4.4 07.4 22.1 44.1 11.8</td>
<td>3.22</td>
<td>5</td>
</tr>
<tr>
<td>Reduced and healing of work / environment stress</td>
<td>0.0</td>
<td>10.3 8.8 25.5 35.3 14.7</td>
<td>3.13</td>
<td>6</td>
</tr>
<tr>
<td>Satisfied with management health / welfare concerns</td>
<td>4.4</td>
<td>5.9 7.4 22.1 38.2 13.2</td>
<td>3.10</td>
<td>7</td>
</tr>
<tr>
<td>Reduced stress and fatigue</td>
<td>0.0</td>
<td>10.3 11.8 29.4 32.4 8.8</td>
<td>2.95</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: Field Survey

It is notable that seven (86%) of the socio-psychotherapeutic values have MSs > 3.00, which indicates that in general there is agreement as opposed to disagreement. These values are ranked first to seventh – ‘enhanced aesthetic appeal of the construction site’, ‘improved job satisfaction’, ‘enhanced fraternal communication / interaction’, ‘enhanced sense of personal wellbeing’, ‘increased organizational pride / mission’, ‘reduced and healing of work / environment stress’, ‘satisfaction with management’, and ‘health and welfare concerns’. However, eighth ranked ‘reduced stress and fatigue’ has a MS ≤ 3.00 indicating disagreement as opposed to agreement. In terms of the various ranges first ranking ‘aesthetic appeal of the construction site’ also has a MS > 3.40 ≤ 4.20, which indicates that the agreement is between neutral and agree / agree. Thereafter, the rest of the functional values ranked second to sixth have MSs > 2.60 ≤ 3.40, which means that the agreement is between disagree to neutral / neutral. Included in this range are, ‘improved job satisfaction’, ‘enhanced fraternal communication / interaction’, ‘enhanced sense of personal wellbeing’, ‘increased organizational pride / mission’, ‘reduced and healing of work / environment stress’, ‘satisfaction with management health and welfare concerns’. Only one of the values, namely ‘reduced stress and fatigue’ has a MS > 1.80 ≤ 2.60, which indicates that the extent of the agreement is deemed to be between strongly disagree to disagree / disagree.

Results and Analysis

The findings from the questionnaire survey corroborate with the management report, personal observations, and the formal and informal interviews as expressed in the photo elicitations, namely that the whole construction site BCSM element of study at CS-2 is a cost effective and a motivational incentive towards ‘green ergonomics of tranquility’. This
indication is significant in terms of the following findings: The MSs of the functional values in Table 1 significantly indicate that the psychotherapeutic measure of the BCSM element of study has contributed between a moderate to a major extent to generally improved cost effectiveness and successful delivery of the project, with ‘increased work effectiveness’ (MS = 3.07) ranked first. In Table 2, nearly all the values have MSs > 3.00, which indicates that generally there is agreement as opposed to disagreement in terms of the impact of the implementation of the BCSM on the ‘improved socio-physiological wellbeing’ factor towards enhanced performance and cost effective project delivery. The ‘green performance index’ as a motivational incentive was established in Table 2, with first ranked ‘enhanced aesthetic appeal’ (MS = 3.44) being among the socio-psychotherapeutic values.

**Analysis and Discussion**

**The BCSM and sustainable sites initiative**

In reflection:

“Hidden away as flowing from an unknown source, tucked away and mysterious, appeals to the sense of mystery, addressing the superstitious in mind, and healing of the distortions, by creating a sense of a heavenly dimension on earth – that is healing and soothing – because it attacks the fear of the unknown. Soothes frayed nerves, music addresses bottom line, better invisible than visible, mysterious dimension, source of mystery, sense of heaven – the construction person is not just a rational person, but also an emotional person.”

(Derived from McCallum, 2005; Goleman, 2006).

The above reflection summarizes the fact that the empirical findings derived from CS-1 and validated by CS-2, unequivocally indicate that it is no longer enough to set up a construction project site without an innovative construction management strategy such as the BCSM in order to achieve the TBL in sustainable sites initiative, in fulfillment of the Brundtland commission of 1987 (Haslam and Waterson, 2013). A range of evidence from empirical studies have indicated that EI / SI advise that rational thinking has to be supported by emotional development to achieve the necessary balance towards self-satisfaction / actualization and effective optimal performance (Goleman, 2006). The corroborative evidence from the salient research findings and related sources indicate that if the right environment exists in a particular workplace, the rest of the challenging issues such as the problem of the four sublime factors of mega projects as articulated by Flyvberg (2014) will resolve itself in favor of successful cost-effective performance on construction projects (Joye, 2007, Goleman, 2006; Joye, 2007; McCallum, 2005; David, 2009; Rogers, 2012; Jones, 2011; Obiozo and Smallwood, 2014).

**Suggestions for ‘Informal Dynamic Rock Garden Design’ on Construction Sites**

In furtherance of further research related to the CMBOK, various suggestions are provided for the application / adaptation of ‘informal dynamic rock garden design’ on construction sites with particular reference to the inclusion of plants within construction site premises, site offices and welfare facilities; lunch break retreats, changing rooms; and material sheds as shown in Figure 3. In addition colour-physiological could be achieved with colour dynamics and indoor plants and a trellis with climbing plants as partitions within site offices and welfare facilities. A simple outdoor shelter could also be created enhanced with
shade nets between site office containers under existing trees and furnished to create a lunch break retreat and site office.

Figure 3. Recommendations for adaptation of the BCSM on construction sites – water features, pot plants, and colour-psychophysiology.

Figure 3: (a) shows nature settings created with a natural fish pond for either ornamental / food fish on construction site premises with artificial birds; (b) shows an indoor table top water fountain within site offices and welfare facilities; (c) shows a simulation of water likened to a ‘Zen garden’ that could be achieved with raked sand including rocks positioned at strategic locations among green lawns and trees, which is also adaptable as a miniature table top rock garden contained in boxes within site offices and indoor spaces, and (d) shows an existing dump yard on construction sites converted into a green area as shown by the inclusion of plants and vegetation in a beneficial manner among the rocks to create an ‘informal dynamic rock garden’ respectively (Source: bubble design).

Conclusion / Recommendation

The empirical findings significantly define the factors involved in determining the objective of the research, which is to investigate the notion that ‘happy workers are productive workers’ in relation to the elimination of the hazard of psychosocial risk factors on construction sites based on the methodology; ‘greening the construction site’ or the BCSM strategy drawn from the ‘biophilic design concept’ that impacts on H&S, wellbeing and cost effective performance. To achieve this aim, the development of systems and products that use less energy were emphasized, relative to understanding and promotion of positive and sustainable behavioral changes in the exploration of corporate sustainability and ‘green ergonomics of tranquility’ interventions in construction (Miyake, 2003). The findings recommend the greening of construction sites and the BCSM as a cost effective solution to the problems of mega projects as highlighted by Flyvberg (2014) and as a site specific measure (Hedge, 2000). The recommendation indicates that this factor as applied in the BCSM strategy should be factored into the initial cost considerations and design of facilities such as construction worksites, as a determinant of increased user productivity, wellbeing, and H&S. Although gains in productivity are financially significant, empirical data relative to the study indicates that it is summarily a factor of beneficial investment in people’s wellbeing, H&S, and ergonomics which concurs with contentions from Heerwagen (2006).

References


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RIBA Plan of Work Model and Classification of Constraints to Cost Performance of Construction Projects

Sunday Odediran¹ and Abimbola Windapo²

Abstract
The trend of construction cost performance is under scrutiny because huge amount of public funds and resources go into construction projects. Performance of construction cost in recent time is not satisfactory and has connection to certain project factors. These factors have been identified and evaluated by many studies who fail to classify and standardize these factors according to Royal Institute of British Architect (RIBA). RIBA plan of work is a universal document that classifies building construction into various stages of operation. However, this paper employs RIBA plan of work model in classifying constraints to cost performance of construction projects with a view to grouping these factors under appropriate sections of the document. Pertinent literature relevant to the study was reviewed and primary data were collected by means of stratified random sampling. Both descriptive and inferential statistics were employed in data analysis. The paper reveals that the most significant stages of RIBA model in the classification of factors influencing performance of construction cost are construction and design/pre-construction stages. The paper recommends a careful consideration of the most significant stages by construction professionals and other stakeholders as outlined in RIBA document for improve construction cost performance.

Keywords: Construction cost constraints, cost performance, factors classification, project factors, Royal Institute of British Architects (RIBA).

Introduction
The measurement criteria of a construction project performance are multi-dimensional. The most widely examined and significant are cost, time and quality; eventhough the optimum achievement of these often seem impossible to most project (Odediran and Windapo, 2014). However, cost of construction is a basic criterion and driving force of project success (Azha et al., 2008). Moreover, completing project within estimated cost is receiving much attention (Ali and Kamaruzzaman, 2010; Bello and Odusami, 2010). Construction projects final cost globally are known for overshooting their initial cost budget (Ogunsemi and Aje, 2005). This is often described as cost overrun (Choudhry, 2004; Al-Najjar, 2008) and the trend is more severe in developing countries where overruns exceed the anticipated cost of the project (Angelo and Reina, 2002). Construction industry in Nigeria is faced with the problem of cost overrun as one of the prevailing factors influencing construction cost performance (Balogun, 2005).

The incidence of cost overrun on construction projects is due to influence of many project factors on construction performance (Kaming et al., 2006; Azhar et al., 2008; Otunola, 2008; Ameh et al., 2010; Ali and Kamaruzzaman, 2010; Mahamid and Bruland, 2011; and Kasimu, 2012). These project factors are stakeholders’ (clients/consultants)

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obligations and uncertainties during the execution of construction project; and these factors occur at different stages of project. Previous studies have reviewed these factors based on their level of influence on construction cost performance and did post-analysis classification of these project factors (Odediran and Windapo, 2014; Abdul-Aziz, 2013; Kasimu, 2012; Ali and Kamaruzzaman, 2010; Ameh et al., 2010) but limited number examined and classify these factors according to Royal Institute of British Architects (RIBA) outline plan of work for building/construction project. RIBA (2007) makes a comprehensive outline plan of work which explicitly organizes the process of designing and managing building/construction projects and administering building/construction contracts into a number of key work stages. RIBA classified work stages into five (5) key components including preparation, design, pre-construction, construction and use. Projects factors or activities are grouped under each stages of construction project. However, this paper examines project factors influencing performance of construction cost and classifies these factors according to RIBA work stages. The RIBA work stages were grouped into three (3) stages and these are preparation, design and pre-construction and construction stages while use stage was excluded for the purpose of this paper. These classifications were ranked by the construction professionals.

Review of Literature
Cost Performance of Construction Projects
Performance of cost of construction projects has been documented and this among numerous researches includes that undertaken by Flyvbjerg (2002) which uncovered trends of cost overrun in global construction. Flyvbjerg (2002) found out that 9 out of 10 projects had cost overrun; overruns of 50 to 100 percent were common; overrun was found in each of the 20 nations and five continents covered by the study; and overrun had been constant for the 70 years for which data were available. Al-Momani (1996) in a study of construction cost prediction for public school buildings in Jordan established that in the developing countries, cost of construction projects exceed original contract price by 30%. Mahamid and Bruland (2010) study on 169 road construction projects in West Bank in Palestine between 2004-2008 found out that 100% suffer from cost divergence, 76.33% have cost over estimation while 23.6% have cost underestimation and discrepancy between estimated and actual cost has averages of 14% ranging from -39.27% to 98.04%. Pickrell (1990) carried out a study for the US Department of Transportation covering US rail transit projects with a total value of US$24.5 billion. The total capital cost overrun for eight of the projects was calculated to be 61% ranging from -10 to +106%. Also, the study by Auditor General of Sweden (1994) covering 15 road and rail projects revealed that the average cost overrun of eight road projects was 86%. The cost overrun for road projects ranged from -2 to +182%, while the average cost overrun for the seven rail projects was 17%, ranging from -14 to +74%.

Furthermore, a study by Fournac et al. (1990) for the UK Transport and Road Research Laboratory (TRRL) which covered 21 metro systems in developing countries showed that six metro projects had cost overruns above 50%. Two of these projects had cost overrun of up to 500%, three had cost overruns in the range of up to 100%, and the remaining four had cost overrun of up to 50%. Skamris and Flyvbjerg (1996) conducted a research in Denmark which compared the accuracy of cost estimates on large-scale infrastructure projects (seven tunnels and bridges) before the decision was made to build concluded that cost overrun of 50–100% was common for larger transportation infrastructures and that overruns above 100% were not unusual. Akewusola (2007) reported that the mean cost overrun in Nigeria was 46.76% during the prosperity period of 1972-1978, 65.83% during the recession period of 1979-1983 and 23.39% during the
depression of 1984 to 2007. Chindo et al. (2012) in an empirical study in Nigeria established that initial and final provisional sums differ averagely by 18.41%, of which inflation accounted for 61.5% of the difference. The study also revealed that of the 40.54% increase between initial and final contract sums, differences between initial and final provisional sums accounted for 45.41%.

Factors Influencing Cost Performance of Construction Projects

The performance of construction projects are influenced by many project factors and there are also significant factors influencing the cost performance of construction projects (Odediran and Windapo, 2014a,b). Through a review of previous studies on factors influencing the performance of construction cost, a list of thirty-five (35) factors were obtained as shown in Table 1. The result of industry survey on the most significant constraints to cost performance of construction projects in the Nigerian construction industry is also outlined in Table 1.

RIBA Model of Work Stages

RIBA Outline Plan of Work 2007 is a universal document which makes a comprehensive outline of work stages for building/construction project; and explicitly organizes the process of designing and managing building/construction projects and administering building/construction contracts into a number of key work stages. RIBA classification was in five (5) key stages which include preparation, design, pre-construction, construction and use. Projects factors or activities are grouped under each stages of construction project. Preparation stage covers project appraisal and design brief. Project appraisal identifies client’s needs and objectives, business case and possible constraints on development. This also includes preparation of feasibility studies to assess the available design options to enable the client decide whether to proceed. Design brief ensures the development of initial statement of project by confirming key requirements and constraints; identifies procurement method, procedures, organizational structure and range of consultants and others to be engaged for the project.

Design stage covers three key sub-stages; concept, design development and technical design. Concept is the process of implementing design brief and preparation of additional data. It also include preparation of outline proposals for structural and building services systems, outline specifications and preliminary cost plan, and review of procurement route. Design development includes structural and building services systems; updated outline specifications and cost plan while technical design provides information on specification sufficient to co-ordinate components and elements of the project and information for statutory standards and construction safety. Pre-construction stage also outlines details on production information, tender documentation and tender action. Production information provides sufficient detail to enable a tender or tenders to be obtained; application for statutory approvals and preparation of further information for construction requirement under the building contract. Tender documentation is the preparation and/or collation of sufficient details to enable tender/tenders to be obtained for the project. Tender action is the process of identification and evaluation of potential contractors and/or specialists for the project; obtaining and appraising tenders; submission of recommendations to the client.
### Table 1. Significant Constraints to Total Cost Management (TCM) of Construction Projects

<table>
<thead>
<tr>
<th>S/N</th>
<th>Constraints to Total Cost Management (TCM)</th>
<th>Significance (SNCI)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variation orders</td>
<td>0.5953</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Material price fluctuation</td>
<td>0.6932</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Unstable market trends and conditions</td>
<td>0.5202</td>
<td>5</td>
</tr>
<tr>
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<td>31</td>
<td>Use of poor quality of materials</td>
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<tr>
<td>35</td>
<td>Incessant dispute occurrences</td>
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</tbody>
</table>

Source: Odediran and Windapo (2014b); Note: SNCI= Significance Index

Construction stage covers mobilization and construction to practical completion. Mobilization is the of process of letting the building contract, appointing the contractor, issuing of information to the contractor and arranging process handing over of site to the contractor. This stage also ensures the administration of the building contract by making
provision to the contractor further information as and when reasonably required; and reviewing of information provided by contractors and specialists. Use stage is the administration of the building contract after practical completion and making final inspections. It also involves assisting building user during initial occupation period and review of project performance in use. This captures the outline of what is expected of construction professionals at every stages of construction projects; and as a standard document will form the foundation for classifying those factors influencing the cost performance of construction projects.

Methodology
The aim of this research is to classify constraints to the cost of construction projects according to RIBA outline plan of work stages. Review of literature was made to highlight the top rated constraints which form the constructs of the instrument (questionnaire) used in the study. A list of thirty-five (35) factors influencing cost overrun of construction projects was made (Table 2). RIBA outline plan of work was also obtained and evaluated for the purpose of this study to highlight content of each work stages which was adopted in line with the aim of this paper. The study population comprised of construction professionals working in the public sector (Government ministries, departments and agencies) and private sector (consulting and contracting practices) in South Western zone (Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states) of Nigeria. The study employed stratified random sampling technique in the selection of respondents from the registers of various professional bodies. This is because the professionals are grouped in form of state chapters representing the population of the professionals. A sample size of two hundred and five (205) respondents was obtained from the zone out of which one hundred and eight (108) responded to the survey. Seventy-four (74) responses were found suitable for analysis in term of completeness and timely response to the questionnaire.

This represents a response rate of thirty-six percent (36%). The survey questionnaire was structured into two (2) sections. The first section focused on the general background of the employers/firms and the respondents. Information requested from the employers/firms include their location, years of establishment and type of organization; and information about the responding officers include their positions in the firm, professional designation & registration, academic qualification, year of work experience within the organizations/firms and construction industry. The second section addressed the classification of factors influencing the cost performance of construction projects in Nigeria. The professionals were asked to score the identified factors on the scale of three (3) stages of construction projects which include; 1-preparation (conceptual/feasibility), 2-design (planning) & pre-construction and, 3-construction (execution) stages using RIBA outline plan of work model. This shows that the rating scale was 1, 2 and 3 respectively. The values of mean score (MS) were calculated using SPSS 20 as follows:

\[ MS = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{(n_5 + n_4 + n_3 + n_2 + n_1)} \]

Where:
- \( n_5 \) = number of respondents who picked 5
- \( n_4 \) = number of respondents who picked 4
- \( n_3 \) = number of respondents who picked 3
- \( n_2 \) = number of respondents who picked 2
- \( n_1 \) = number of respondents who picked 1
Findings and Discussion

Test of Sample Adequacy and Appropriateness

The list of the factors influencing cost performance of construction projects highlighted as shown in Table 1 were subjected to factor analysis with each item treated as a variable with the aim of reducing them to few significant factors which will be used in the description of closely related factors and those sharing the same features. The adequacy and appropriateness of the factors influencing performance of construction cost was tested using Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) and the Bartlett’s test of sphericity. The result presented in Table 2 shows that KMO value was 0.631. Field (2005) established that the KMO value of a set of scores should be close to 1 for factor analysis to yield distinct and reliable factors and Wiki (2007) also stated that Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) should be greater than 0.5 for satisfactory factor analysis to proceed.

Hence, from these propositions, it could be concluded that factors analysis is appropriate for the data collected for this study. Also, Bartlett’s test of sphericity showed that the result was highly significant ($\chi^2 = 1.064E3, p< 0.05$). The result agreed with Field (2005) recommendation and therefore confirmed the adequacy and appropriateness of factor analysis carried out for this study.

RIBA Model Classification of Constraints to Cost Performance of Construction Projects

From the result of factors analysis of 35 factors influencing cost performance of construction projects identified from literature and adopted from Odediran and Windapo (2014b), Table 3 shows how construction professionals score and classify influence of these factors on construction cost performance. The classification was done based on RIBA outline plan of work stages which include preparation (conceptual/feasibility), design (planning) & pre-construction and construction (execution) as below outlined. Table 4 shows that there are more factors influencing construction cost performance at construction stage followed by design/pre-construction stage and with least (1) factor at preparation stage; which implies a need for better mechanisms to manage every components of construction process.

i. Preparation Stage

The result shows that the only factor influencing cost performance of construction projects at preparation (conceptual/feasibility) stage was high design inaccuracy. This shows that accuracy of construction cost depends on the accuracy of design and when designs are deficiency, estimated cost will be inaccurate.

ii. Design/Pre-Construction Stage

The factors influencing construction cost performance at design/pre-construction stage are poor financial/cost planning, high design accuracy, inaccurate estimation of quantities of works and inadequate cost estimating method. Other factors include inadequacy of cost estimating method, poor financial/cost planning, inadequate project planning and monitoring, inadequate project decision making, poor materials and equipment procurement strategies, inadequate construction cost data and inaccurate contractor's pricing strategies. The design/pre-construction stage classification is related to the inaccuracy in the quantification of works, construction cost estimation and pricing, cost planning and financing, and materials and equipment procurement.
<table>
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<tr>
<th>S/N</th>
<th>RIBA Work Stages</th>
<th>Constraints</th>
<th>Significance Index</th>
<th>Rank</th>
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<tr>
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<td>Poor leadership style on construction projects</td>
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<td>0.4627</td>
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<td>Adverse weather conditions</td>
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<td>Poor contract documentation</td>
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<tr>
<td></td>
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<td>Incessant dispute occurrences</td>
<td>0.3896</td>
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</table>
This finding to a significant extent agrees with findings and classifications of Le-Hoai, et al. (2008), Ameh et al. (2010), Kasimu (2012) and Abdul Azis et al. (2013) who classified factors influencing cost performance of construction projects into issues related to construction cost estimating, pricing, financing; construction and site management.

### Table 2. KMO and Bartlett’s Test

<table>
<thead>
<tr>
<th>KMO and Bartlett's Test</th>
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<tr>
<td>Kaiser-Meyer-Olkin Measure</td>
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<td>Approx. Chi-Square</td>
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<td>Bartlett's Test of Sphericity</td>
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<td>df</td>
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<td>Sig.</td>
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</table>

This RIBA classification shows that for effective construction cost to be achieved at pre-construction stage; adequate effort should be made by the estimators to ensure that quantities of works are accurately taken to represent design because the top rated factor at this stage is inaccurate cost estimation of quantities of works. After quantities of construction works are taken, accurate pricing and estimating of unit price is another significant milestone for effective construction cost performance. Moreover, establishing the actual project cost is not enough than a good cost planning and adequate procurement system. These were supported by previous studies (Long et al., 2008; Nega, 2008; Peeters and Madauss, 2008; Squire, 2008; Kaliba et al., 2009; Gatlin, 2013; Odediran and Windapo, 2014b; Odediran and Windapo, 2014b). This will provide a platform by which a cost check is made at the construction stage of a project; but when this fails possibility of construction cost performance is in doubt.

### iii. Construction Stage

Factors influencing cost performance at construction stage of a project are variation orders, material price fluctuation, unstable market trends and conditions, additional works, high inflation rate and technical/construction errors and omissions. Other include irregularity in cash flow, poor contract/site management, client' changing requirements and experiences, incessant project delay, poor leadership style on construction projects, frequent contractual claims, high material wastage on site, inaccurate labour cost and requirements, poor financial/cost control and monitoring, shortage in material supply, instability in exchange rate, adverse weather conditions, incessant payment delay, poor project information dissemination and management, use of poor quality materials, project complexity, poor site conditions, poor contract documentation and incessant dispute occurrences. These factors according to RIBA classification shows that factors influencing construction cost performance during construction process are associated with instability in market conditions, construction and design errors, poor site/construction management, hostility of project/site characteristics. This finding agrees with previous studies (Lee et al., 2008; Azhar et al., 2008; Ameh et al., 2010; Kasimu, 2012; Rahman et al., 2013; Shanmugapriya and Subramanian; 2013; Abdul-Aziz et al., 2013).

This shows that for effective construction cost performance to be achieved, understanding of the effect of forces of demand and supply in construction markets by the estimators and project managers is necessary in achieving an effective construction cost performance. This finding is in support of previous studies (Long et al., 2008; Odediran and Windapo, 2014b; Odediran and Windapo, 2014b).
Conclusion and Recommendation
This paper through previous studies evaluates factors influencing cost performance of construction project and classifies these factors according to RIBA plan of work model. The classification according to RIBA model includes preparation, design/pre-construction and construction stages excluding use stage in this paper. The result shows that out of thirty-five (35) factors identified, there are 1, 9 and 25 for preparation, design/pre-construction and construction stages respectively. This implies that there are many factors influencing the performance of construction cost at construction stage than design/pre-construction or preparation/feasibility stages. The top rated factors at construction stage are material price fluctuation, variation orders, technical/construction errors and omissions, high inflation rate, unstable market trends and conditions, and additional works. These are associated with market conditions and design inaccuracy. However, the top rated factors at design/pre-construction stage are inaccurate estimation of quantities of works, poor financial/cost forecasting, inadequate project planning and monitoring, and inadequate cost estimating method.

This paper concludes that the most significant stages in the RIBA model classification of the constraints to the performance of construction cost are construction and design/pre-construction stages. The pertinent issues raised at the significant stages of the model are market conditions, design inaccuracies, deficiencies in method(s) employed in cost estimation and project cost/financial forecasting, planning and monitoring. These are associated with the professional/contractual responsibilities, duties and obligations of designers (architects and engineers), estimators (quantity surveyors) and constructor (contractors/builders) on a construction project. However, giving adequate attention to these factors at various stages of construction project by every concerned stakeholders is an essential step in achieving cost performance of construction project and efficient project delivery.

References


Effect of Organisational Justice in Motivating Construction Workforce Towards Improved Work Productivity

Ogwueleka, Amaka Chinweude¹ and Maritz, Marthinus Johannes²

Abstract
Work productivity has remained a major concern for all employers at different industrial sectors. Keys to financial success and profitable businesses are not basically on the firm’s strategies or systems but rather on human element (workforce). The literature scan reveals that construction employees play a dominant role in work productivity and there is a correlation between workforce behaviour and organisational culture (justice). This paper assesses the effect of organisational justice in motivating employees towards work productivity in the South African construction industry. The study adopts the constructs of organisation justice and their attributes to assess their impact on work productivity of construction employees. Responses are transformed into RII values and Cronbach’s α reliability test is conducted to measure consistency of each factor. Pearson’s correlation coefficient is used to measure the strength of linear association between the three dimensions of organisational justice and organisational commitment. Thereafter, multiple linear regression analysis was performed to examine independent variables that are statistically significant for predicting organisational commitment. Results of the analysis reveal that distributive justice and interactional justice are highly significant in predicting regression model of organisational commitment while procedural justice is moderately significant. Research findings provide a guide for management personnel in the construction industry on how to improve their organisational culture and commitment in order to promote work productivity.

Keywords: Organisational justice, distributive, procedural, interactional and construction industry.

Introduction
Employees who are committed in any organisation are most likely to meet customers’ needs and are motivated to maximise their abilities (Fatt et al., 2010). Zaman et al. (2010) advocate organisational justice as a strong predictor of organisational commitment. Organisations are social systems where human elements (workforce) are basically the driving force for effectiveness and efficiency. Perceptions of employees can affect their levels of commitment in any organisation. Thus, Saks (2006) emphasises that the degree of an employee’s commitment can be improved by increasing and strengthening his/her perception on the support from the organisation. The perception of an employee regarded his/her duties and the organisation in which he/she works influences the degree of job satisfaction. Employee’s job satisfaction and performance are two major parameters that effect project performance. This is in line with the study conducted by Iqbal (2013) which emphasises that the employee’s job satisfaction has a direct impact on his/her behaviour, performance and also job satisfaction.

Employees, being human beings are motivated by different stimuli; the organisation provides an environment in which they can interact socially. One major concept that is important to human social interaction is justice. Justice influences an employee’s behaviour

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² Professor, Head, Department of Construction Economics, University of Pretoria, Pretoria.
wherefore perceiving injustice will affect employee’s job satisfaction and also create negative effect on performance (Iqbal, 2013). Kontakos (2007, citing Beugre, 1998) states that ‘in studying justice, what is important is not the reality but the subject’s perception of reality’. People are naturally responsive to the justice of events and situations in their everyday lives across a variety of contexts (Owolabi, 2012, citing Gopanzao, 2009). As previously noted, perceptions of employees towards organisational justice can be measured against the degree to which the organisation provides its employees with appropriate, fair and respectful treatment, adequate and accurate information, resources and rewards. Most employees feel more motivated when they are rewarded fairly for their genuine contributions to their organisations in accordance to organisations’ policies. It is essential to note that the perception of fairness in organisational justice is not limited to rewards but also respect for people. Unfair perception leads to dissatisfaction with outcomes or decisions thus there is a need to examine employees’ perceptions in relation to organisation justice.

This paper assesses the effect of organisational justice in motivating employees towards work productivity in the South African construction industry. In order to achieve this purpose, the following objectives are considered: a) to identify and evaluate construction workforce’s perceptions in relation to the three dimensions of organisational justice: distributive, procedural and interactional and b) to examine and model for the relationships between the three dimensions of organisational justice and organisational commitment. The following hypothesis is developed to investigate the significance of the three dimensions of organisational justice on organisational commitment.

H0: The three dimensions of organisational justice (distributive, procedural and interactional) cannot significantly predict the change in organisational commitment.

H1: The three dimensions of organisational justice (distributive, procedural and interactional) can significantly predict the change in organisational commitment.

Related Literature Review
Justice instigates integrity while organisational justice initiates an environment for individuals to work together to achieve a common goal. The perception of injustice in an organisation can undermine the morale of employees which might reduce their spirit of effort and activity. Thus, we can rightly say that the level of perceived fairness of an employee is determined by the level of perceived justice. Murtaza et al. (2011) define organisational justice as the perception of employees about fair treatment in an organisation. The individual’s perception of decisions taken can influence his/her subsequent attitudes and behaviours. The principle of organisational justice is anchored on the perception of inequity in distributive issues. The equality of the type of decisions taken and how they are implemented regarding rewards can significantly affect the motivation of construction workforce towards achieving clients’ goals (Bierhoff et al., 1986). There are three key theories of organisational justice namely: distributive, procedural and interactional justice (Colquitt, 2004).

Distributive Justice
Distributive justice refers to the treatment on an equal basis of employees in terms of salary, working hours, promotion and other rewards (Adams, 1965). The “Adam’s equity theory” quotes ‘employees are satisfied when they feel that the rewards have been equally given according to their input and there is no difference as compared to others’. This relates to fairness of decision outcomes where the reward is fair enough to motivate recipients and does not exceed the value of benefits to providers. This is required to set an appropriate intensity to fairly compensate for providers’ risks and to promote efforts (Rose and Manley, 2010).
higher intensity increases providers’ margins in response to their increased efforts (Rose and Manley, 2010, citing Zenger, 2000). The literature scan reveals numerous factors influencing distributive justice; they were compiled as possible factors of distributive justice for this study (Tang et al., 1996; Cohn et al., 2000; BPI, 2013).

**Procedural Justice**
Procedural justice focuses on the employee’s perception of fairness of managers’ decisions based on the rules and procedures that regulate a process (Folger and Konovsky, 1989; Nabatchi et al., 2007). This involves decision-making processes that can lead to decision outcomes. For example, there is a need to express fairness in the performance measurement process which will determine the reward allocation. Most employees are interested in knowing which decisions have been made and how they have been made (Cropanzano and Floger, 1991). For example, if managers’ exercises regarding the evaluation of an employee’s performance are perceived to be unfair according to the rules and regulations thus may lead the employee presuming that there is no justice and become frustrated (Murtaza et al., 2011). It is important to have equality in dealings with employees in order to attain motivation and commitment of employees towards achieving project goals (Colquitt, 2004). Murtaza et al. (2011) further differentiate procedural justice as the process or means of taking decisions while distributive justice deals with ends or outcomes of the decision taken. Possible factors of procedural justice are identified and compiled for this study (Tyler and Bies, 1990; Tang et al., 1996; Baldwin, 2006).

**Interactional Justice**
Interactional justice refers to the treatment that an individual receives when decisions are made and can be promoted by providing explanations for such decisions and communicating the decisions with sensitivity and respect (Bies and Moag, 1986). This implies that the communication process between reward providers and recipients which involves honesty and respect, will significantly impact on work motivation. The study of Rose and Manley (2010) stipulates that negative reactions from recipients occur as a result of poor treatment received by a service provider or a client. The concept of interactional justice is closely supported by economic reciprocity theory which states that an agent prefers an environment of fairness with an honourable intention for good reward (Fehr and Falk, 2002). Interactional justice does not pertain to the outcomes of procedures associated with decision making but rather focuses on whether or not people believe that they are treated fairly when decisions are implemented. Fair interpersonal treatment necessitates that employers communicate truthfully and treat people with courtesy and respect.

A construct validation study by Colquitt (2001) proposes that interactional justice should be split into two components, namely: a) interpersonal and b) informational. Interpersonal justice is the perception of respect and propriety in one’s treatment. This reflects the degree to which people are treated with politeness, dignity and respect by the service providers in executing procedures or determining outcomes. Informational justice involves the adequacy of explanations given in terms of their timeliness, specificity and truthfulness. It focuses on the explanations provided to people who convey information about why procedures are used in a certain way or why outcomes are distributed in a certain fashion. Baldwin (2006, citing Bies and Moag, 1986) identifies key factors of interactional justice which can enhance people’s perceptions of fair treatment under interactional justice. Other similar studies on factors of interactional justice were reviewed and the identified factors are used this study (Randeree, 2008; Usmani and Jamal, 2013).
Research Methods
Data Collection
The exploratory nature of this study requires a combination of both quantitative and qualitative methods of data collection. The use of a mixed methods approach is to allow for the mixture of both quantitative and qualitative data at some stage in a research process within a single study and also to understand a research problem more completely (Ivankova et al., 2007). This approach operates within the pragmatic paradigm by adopting deductive and inductive reasoning. Quantitative method enables the relationships between variables to be studied and the results are generalised for the whole population while qualitative method gives an in-depth understanding of an individual’s experiences through an inquiry process. For quantitative approach, surveys through questionnaires were found effective because of the relative ease of obtaining standard data appropriate for achieving the objectives of this study. A questionnaire survey was used to collect information from respondents in order to evaluate construction workforce’s perceptions in relation to the three dimensions of organisation justice, namely: distributive, procedural and interactional within the South African construction industry and also to examine and model for the relationships between the three dimensions of organisational justice. A validity test was conducted on questions to ensure that the identified parameters cover the constructs to be measured. Amendments were made on the drafted questionnaire based on suggestions from research experts in the related field of study. According to Farrell (2011), the use of qualitative method for data collection may be difficult to get an answer but the data captured are rich. Personal interviews were conducted with some respondents to clarify their answers.

Characteristics of Respondents
The study population comprises of project stakeholders who are involved in both building and civil engineering works in the Gauteng Province of South Africa. Gauteng is the smallest of the nine provinces in South Africa but with the highest population of about 12.3 million. It is regarded as the economic centre of South Africa, which accounts for over 34.8 per cent of the country’s total GDP. Most of the construction companies have their headquarters in the Gauteng province, and the province has recorded the largest infrastructural development in South Africa. Kothari (2003) stipulates that the survey protocol of random sampling procedures allows for a relatively small number of people to be used to represent a much larger population. Target population are mainly construction participants who are involved in the execution of both commercial and public infrastructure projects in Gauteng. The study targeted project stakeholders comprising of clients, consultants, contractors, sub-contractors, and construction researchers. First, the questionnaire was administered using face-to-face method to the targeted population, a total number of 25 recipients have completed the questionnaire manually. Second, the questionnaire was sent through open access media to the targeted population and 35 construction professionals have participated in the survey. The survey was carried out from June, 2014 to mid-August, 2014 with a total number of 60 responses, which was used for data analysis (refer to Table 1)

Measures
The questionnaire is classified into three parts. Part one focuses on the demographic data of respondents, this is revealed in Table 1. Part two assesses the extent to which the three dimensions of organisational justice influence work productivity of construction employees, the respondents are asked to rank their responses using a 5-likert scale of: no effect (1), minor effect (2), neutral (3), moderate effect (4) and major effect (5). Part three evaluates the organisational commitment based on hypothetical statements, the respondents are asked to
rank their responses using a 5-likert scale of: very low (1), low (2), moderate (3), high (4), and extremely high (5).

Data Analysis
This section presents the analysis of collected data using administered questionnaires. Table 1 reveals the cross-tabulation of profession of respondents against their demographic information. The results are presented using descriptive statistics of frequency count and percentage. For the purpose of this analysis, the profession of respondents is further classified into three groups, namely: client, consultants and contractors. Consultants comprise of construction researchers, designers, consultants, and project managers while contractors include both subcontractors and suppliers. This analysis shows a well-representation of different sectors in the construction industry, therefore their responses can be used to generalise for the industry. The majority of respondents (68 percent) are fully engaged in managerial positions at their various organisations, this reveals that a high percentage of respondents are experienced in decision making in construction projects. A percent of 38 respondents has between 1 to 9 years of work experience followed by 33 percent of respondents with more than 10 years’ work experience in the construction industry and 30 percent of respondents have more than 19 years’ work experience. This implies that their responses can be regarded as of a great value for the research findings. This analysis shows that more than average of respondents (53 percent) has participated in 15 or more construction projects. This reveals that the majority of respondents have both high level of work experience and participation in construction projects. A percent of 50 respondents has obtained formal education in various Bachelor degrees while 33 percent of respondents have obtained formal education in postgraduate studies.

Data collected for independent variables are ranked based on the relative importance index (RII). Their responses are transformed into RII values using the following formula:

$$\text{RII} = \frac{\sum w}{A \times N}$$

Equation (1)

Where ‘w’ is the weight assigned to each attribute by the respondents and ranges from one to five, ‘A’ represents the highest weight and ‘N’ is the total number of respondents. Using the RII, rank values are assigned to each factor. Ranking their responses was deemed appropriate to reveal perceptions of respondents and this paper further calculates the Cronbach’s alpha reliability test for their responses to measure the internal consistency of each factor. Pietersen and Maree (2007) stipulate that alpha values greater than 0.7 are considered as acceptable in research. According to Wang et al. (2013, citing Jaccard and Becker, 1997), Pearson’s correlation is used to determine the extent to which two variables of the same respondents are linearly related. This paper adopts Pearson’s correlation coefficient to measure the strength of linear association between the three dimensions of organisational justice and organisational commitment. This technique is used to explore the nature of underlying causal relationships between organisational justice and organisational commitment. Thereafter, multiple linear regression analysis was performed to examine the independent variables that are statistically significant for predicting organisational commitment (Y). This is in line with similar studies conducted by Cheung et al. (2004), Iyer and Jha (2005) and Fatt et al. (2010). The regression equation used for this analysis is expressed as follows:
\[ Y = a + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_n x_n \]

Where \( Y \) represents dependant variable, \( a \) represents intercept (constant), \( \beta \) is regression coefficient of each independent parameter and \( x \) is independent parameter.

**Table 1. Cross-tabulation result of profession of respondents against their demographic information**

<table>
<thead>
<tr>
<th>Level of position</th>
<th>Clients</th>
<th>Consultants</th>
<th>Contractors</th>
<th>Frequency count</th>
<th>Per cent %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managerial</td>
<td>2</td>
<td>14</td>
<td>25</td>
<td>41</td>
<td>68</td>
</tr>
<tr>
<td>Middle management</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Operational (skilled/unskilled)</td>
<td>-</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>27</td>
<td>28</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Working experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 1 year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 to 9 years</td>
<td>3</td>
<td>6</td>
<td>13</td>
<td>22</td>
<td>37</td>
</tr>
<tr>
<td>10 to 19 years</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>Above 19 years</td>
<td>-</td>
<td>12</td>
<td>6</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>27</td>
<td>28</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Number of participated projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 5</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>6 to 10</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>11 to 15</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Above 15</td>
<td>-</td>
<td>18</td>
<td>14</td>
<td>32</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>27</td>
<td>28</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Highest formal education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matric</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Diploma</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>B.Sc./B.Tech/B.Com</td>
<td>1</td>
<td>10</td>
<td>19</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>M.Sc./M.Tech/MBA</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>PhD/D.Tech.</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>27</td>
<td>28</td>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

**Findings and Discussion**

In order to evaluate construction workforce’s perceptions in relation to the three dimensions of organisation justice: distributive, procedural and interactional, the respondents are asked to rank their variables on a 5-likert scale. The analysis of the results is presented in Table 2. The dimension score shows that “Interactional justice” has the highest average ranking of “0.844”, followed by “Distributive justice” with ranking of “0.832”, then “Procedural justice” is ranked “0.788”. This implies that interactional justice has the highest level of importance amongst the three dimensions of organisational justice. “Respect for people” and “Effective communication values” are rated highest in interactional justice, although “Respect for people” and “Rewarding employee’s effort” are ranked first and second respectively, in the overall organisational justice factors. Reliability analysis is conducted and Cronbach’s alphas for the three dimensions of organisational justice are higher than 0.7, which indicates an acceptable level of internal consistency for measuring each variable. The overall Cronbach’s \( \alpha \) for organisational justice is 0.957 (N of items = 3), which also indicates a high level of internal consistency for the scale with this specific sample.
### Table 2: Rating of three dimensions of organisational justice in construction projects

<table>
<thead>
<tr>
<th>Code</th>
<th>Dimensions of organisation justice</th>
<th>Variables</th>
<th>All groups (RII)</th>
<th>Rank</th>
<th>α for each dimension</th>
<th>Dimension score</th>
<th>α for organisational justice</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_1a</td>
<td>Distributive justice</td>
<td>Basic needs</td>
<td>0.787</td>
<td>15</td>
<td>0.836</td>
<td>0.832</td>
<td>0.957</td>
</tr>
<tr>
<td>X_1b</td>
<td></td>
<td>Fairness in pay to staff</td>
<td>0.863</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1c</td>
<td></td>
<td>Recognition of merit performance</td>
<td>0.863</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1d</td>
<td></td>
<td>Appropriate rewards/compensation based on productivity</td>
<td>0.863</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1e</td>
<td></td>
<td>Rewarding employee’s effort</td>
<td>0.887</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1f</td>
<td></td>
<td>Proportional equity in reward distribution</td>
<td>0.820</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1g</td>
<td></td>
<td>Maximise the employee contributions</td>
<td>0.817</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_1h</td>
<td></td>
<td>Reward/compensate for voluntary services</td>
<td>0.753</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2a</td>
<td>Procedural justice</td>
<td>Involvement of employee’s opinion before decisions are taken</td>
<td>0.773</td>
<td>18</td>
<td>0.914</td>
<td>0.788</td>
<td></td>
</tr>
<tr>
<td>X_2b</td>
<td></td>
<td>Standard criteria for measuring employee performance</td>
<td>0.793</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2c</td>
<td></td>
<td>Logical decision making</td>
<td>0.767</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2d</td>
<td></td>
<td>Use of appropriate information</td>
<td>0.780</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2e</td>
<td></td>
<td>Appropriate correctability procedure</td>
<td>0.783</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2f</td>
<td></td>
<td>Considering employee’s concern in decisions</td>
<td>0.813</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_2g</td>
<td></td>
<td>Morality and ethicality</td>
<td>0.807</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3a</td>
<td>Interactional justice</td>
<td>Truthfulness</td>
<td>0.837</td>
<td>8</td>
<td>0.928</td>
<td>0.844</td>
<td></td>
</tr>
<tr>
<td>X_3b</td>
<td></td>
<td>Respect for people</td>
<td>0.890</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3c</td>
<td></td>
<td>Socially appropriate behaviour</td>
<td>0.837</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3d</td>
<td></td>
<td>Taking justifiable actions</td>
<td>0.843</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3e</td>
<td></td>
<td>Effective feedback process</td>
<td>0.853</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3f</td>
<td></td>
<td>Effective communication values</td>
<td>0.877</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3g</td>
<td></td>
<td>Timeous response to feedback</td>
<td>0.857</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3h</td>
<td></td>
<td>Good interactive environment</td>
<td>0.833</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_3i</td>
<td></td>
<td>Psychological firmness of employees</td>
<td>0.773</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Correlations between the three dimensions of organisational justice and organisational commitment

<table>
<thead>
<tr>
<th></th>
<th>Distributive justice</th>
<th>Procedural justice</th>
<th>Interactional justice</th>
<th>Organisational commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributive justice</td>
<td>1.000</td>
<td>0.741**</td>
<td>0.749**</td>
<td>0.821**</td>
</tr>
<tr>
<td>Procedural justice</td>
<td>0.741**</td>
<td>1.000</td>
<td>0.882**</td>
<td>0.864**</td>
</tr>
<tr>
<td>Interactional justice</td>
<td>0.749**</td>
<td>0.882**</td>
<td>1.000</td>
<td>0.903**</td>
</tr>
<tr>
<td>Organisational commitment</td>
<td>0.821**</td>
<td>0.864**</td>
<td>0.903**</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed)
Pearson’s correlation analysis reveals that organisation commitment is correlated to distributive justice at 0.821; procedural justice at 0.864 and interactional justice at 0.903 (see Table 3). This indicates that there is a strong correlation between organisational commitment and the three dimensions of organisational commitment. There is no sufficient evidence to support H0 since the p-value is less than 0.05 at each of the three dimensions of organisational justice therefore we conclude that distributive justice, procedural justice and interactional justice can significantly predict the change in organisational commitment at confidence levels of 95%.

Results of the regression analysis reveal that the value of R is 0.933 and the value of R² is 0.871 which implies that 87 per cent of variation in organisation commitment can be explained by variables in distributive justice, procedural justice and interactional justice. The ANOVA reveals that the p-value of regression model is less than 0.05 therefore it confirms that the three dimensions of organisational justice can significantly explain the variance in organisation commitment. Thus, it implies that the regression model is suitable to explain the relationships between the three dimensions of organisational justice (distributive, procedural and interactional) and organisational commitment. From the coefficients output as presented in Table 4, the value of the t-test for “distributive justice” is 3.909 and the p-value is 0.00 which is less than 0.05 thus “distributive justice did contribute significantly to the regression model”. The value of the t-test for “procedural justice” is 1.861 and the p-value is 0.06 which is a bit greater than 0.05 thus “procedural justice did not contribute significantly to the regression model”. The interactional justice reveals the t-test statistics of 4.785 and the p-value of 0.00 which is less than 0.05 thus “interactional justice did contribute significantly to the regression model”.

The multiple linear regression equation (model) for organisational commitment can be presented as:
Organisational commitment = (-0.030) + 0.340 [distributive justice] + 0.157 [procedural Justice] + 0.492 [interactional justice]

Based on this model, significance of independent variables can be predicted by comparing the weights of coefficients ($\beta$) for each variable. From this equation, distributive justice and interactional justice are highly significant in predicting organisational commitment while procedural justice is a moderate predictor.

<table>
<thead>
<tr>
<th>Coefficients (β)</th>
<th>t</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant )</td>
<td>-0.030</td>
<td>-0.121</td>
</tr>
<tr>
<td>Distributive justice</td>
<td>0.340</td>
<td>3.909</td>
</tr>
<tr>
<td>Procedural justice</td>
<td>0.157</td>
<td>1.861</td>
</tr>
<tr>
<td>Interactional justice</td>
<td>0.492</td>
<td>4.785</td>
</tr>
</tbody>
</table>

**Conclusion**

This paper assesses the effect of organisation justice in motivating employees towards work productivity in the South African construction industry. As previously noted, the perception of injustice can undermine the morale of employees which might reduce their spirit of effort and activity. Meyer and Smith (2000) emphasise the need for managers to gain knowledge of justice climate in order to ensure that all of their employees perceived fair treatment. The study adopts a mixed methods approach for data collection which includes questionnaire survey and interviews. Data collected for independent variables are ranked based on relative importance index (RII) and the overall Cronbach’s $\alpha$ indicates a high level of internal consistency for the scale. Relative importance index, Pearson’s correlation and multiple linear regression analyses reveal “interactional justice” as the
dimension of organisational justice with the highest value and did contribute significantly in predicting organisational commitment. Research findings for this study contradict the results of the survey conducted by McFarlin and Sweeney (1992) in Midwestern bank where distributive and procedural justice are identified as dimensions of organisational justice with significant positive effects on organisational commitment. A plausible explanation for this discrepancy is that the settings in a construction sector differ from a banking sector while other factors may include country context and economic system. This study further develops a regression equation (model) for organisational commitment where interactional and distributive justice play significant roles in prediction while procedural justice did not. Thus, the research findings provide a guide for management personnel in the construction industry on how to improve their organisational culture and commitment in order to promote work productivity.

References


Murtaza, G., Shad, I., & Shahid Malik, W., 2011, Impact of organizational justice on employees job satisfaction: evidence from Pakistan, International conference on management, 1123 - 1135


Improvement Initiatives to Benefit Rural Communities in Pottery Making

Nthabiseng Mahumapelo¹

Abstract

Mintek’s Small Scale Mining and Beneficiation division supports government’s initiative to alleviate poverty and create employment by providing skills to previously disadvantaged communities. The division uses Mintek’s high-technology facilities and resources to support small, medium and micro enterprises in mining, extraction and value addition to minerals through beneficiation. This paper outlines the operations conducted in setting up of pottery projects especially in rural areas. Key activities include sourcing of funds, project scheduling, infrastructure development and management of funds. An average of ten to twenty people will be employed per project through this initiative.

Keywords: Beneficiation, pottery project and rural development.

Introduction

South Africa is faced with a challenge of helping poorer communities to alleviate poverty and unemployment through programmes which will equip them with skills. Mineral endowment on its own is not enough if it cannot be converted into any competitive advantage. Government through Department of Mineral Resources has identified some cross cutting constraints such as limited access to raw materials, shortage of critical infrastructure, limited exposure to research and development, inadequate skills and limited access to markets. (Parliamentary Monitory Group, 2013)

Mintek’s Small Scale Mining and Beneficiation division

Mintek is a Science Council enacted by an act of parliament; Mineral Technology Act, No. 30 of 1989. One of the strategic objectives of Mintek is to play a significant role in second economy interventions, by developing technologies appropriate to the local jewellery, artisanal and small scale mining industries. The aim is to expand the mineral industry, lower entry barriers, initiate poverty alleviation programmes and support the growth of small, medium and micro enterprises (SMMEs) in the sector. (Paul, 2011)

Mintek’s Small Scale Mining and Beneficiation (SSMB) division uses high technology facilities and resources to conduct research related to poverty alleviation programs. The division has set up the Timbita Pottery Incubator to assist previously disadvantaged communities with skills to manufacture pottery.

Objective

The objective of setting up pottery projects in rural communities is to create employment through beneficiation programmes

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Deliverables

The following are key deliverables:

- Employment creation
- Identification of minerals / raw material with economic potential or potential for sustainable community projects
- Providing groups with quality pottery equipment that is suitable for the manufacture of a variety of products
- Be able to operate the supplied equipment correctly and safely
- Be competent to manufacture saleable pottery products and
- Be able to control quality processes.

Methodology

A literature review was undertaken to develop a deeper understanding of the rural pottery in South Africa and project management processes.

Mintek personnel participated in site visits to different rural villages in South African provinces such as Kwa-zulu Natal, Limpopo and Eastern Cape to interview community members or potters about their knowledge of forming traditional pottery. Meetings with the potters were planned in advance, and interpreter was co-opted to facilitate communication, particularly through interpretation and understanding of local customs. All the interviews were conducted at the local municipality offices. In some cases approval has to be sought from local Chiefs where traditional customs are still observed. As authorities they are also interested in both preservation of custom and economic development for communities that they lead.

Data gathered during the initial interviews assisted in learning about different pottery making techniques used by potters. The questionnaires were designed by Mintek personnel to capture the following data:-

- Personal details of the potters, their family background, and living circumstances
- Types of pots made, their purposes, and prices
- Techniques used for making and firing pots, and problems experienced
- Number of pots made and sold, to whom they were sold, and production capacity
- Details with respect to clay and other resources required for pot making
- Issues relating to marketing and selling pots, as well as thoughts on traditions and new products

In addition, meetings were held with potential funders to find out their requirement to apply for funding of pottery projects. The project manager requests equipment quotations from reputable suppliers. Then equipment is procured in accordance with the commercial procedures. Discussions are then held with the municipality to secure a building to be used as a pottery workshop. The contractor is appointed to renovate the building based on safety and practical considerations. Ceramic trainers and marketing personnel research about the easy method of training potters.

The project management processes of (Project insight, n.d.) initiation, planning, execution, monitoring, controlling and closure were applied to improve the skills of rural potters to form good quality pottery, fundamentals of running a small business, setting up of pottery workshop and marketing of products.

Results
Literature Review on Rural Pottery

Pottery

History shows that South Africa (Ceramics and African art, n.d.) and the rest of the African continent have always turned to pottery for their utilitarian needs in cooking, storing food items, eating, drinking, and as ritual vessels. Over time, South African tribes learned to decorate their pottery items with motifs that blend in with their homes and tribal patterns.

African pottery has always used raw materials easily found in the environment like clay. Clay is found in abundance everywhere on the African continent and South Africa is no different. Most potters in villages were women because they were the ones who needed the pots for cooking and for their homes. When the potters were men, they only did it for ceremonial vessels. Furthermore, women potters were not allowed to decorate their pots and utensils with animal or human figures. This is because these figures were generally reserved as art done by men potters.

As the European settlers arrived, there was a shift in the design and artwork as well as in the involvement of men in pottery. Now that it was a money-making venture because of the growing demand from foreign settlers and their visitors, men potters began to increase, and it became a means of trade.

Pottery Techniques

In most tribal villages, the art of pottery and the products produced had to have ancestral approval. This meant that potters were not allowed to venture away from what were the general acceptable standards in design, artwork, and use.

The techniques used were handed down from older generations. These were simple and hand-made. Before the settlers arrived, no such pottery equipment was known. Potters would collect clay from river beds and termite pits. They would clean the clay of impurities and grind it to a fine dust. With a mix of water and sand, they were able to come up with good consistency for forming objects.

Some of the techniques used were coiling and scraping. The tools were anything easily available like plastic, wood, mussel shells, small stones, leather, cotton fabric, and lids for the base turntable. To create colour, natural materials were used like ochre, graphite, and chalk which were either rubbed or painted on the surface. Sometimes, hair, twigs, and bones were used to decorate the pots. For instance, the Pedi or Sotho tribe potters would use combs to create patterns while the potters from the Zulu tribe in KwaZulu-Natal would use a small nodule.

The firing techniques would also be different. Zulu potters would use aloe leaves and reduce exposure to oxygen to blacken their pots. For a shiny effect, they would brush vegetable fat or juice on the object prior to firing.

Field Visit

The objective of the field visits is to gain an understanding of the area, collect clay samples to be tested, where it is mined, to be introduced to the community groups who are potential beneficiaries.

The findings from interviews conducted were recorded and where applicable additional information was collected telephonically at a later stage. The findings from the field visit were as follows:

- In rural areas most people are unemployed and depend on social grants for a living.
- Old or traditional methods are still used to form pottery.
- Local clay is used as a raw material to form products.
- Pottery pots are used for cooking, storing food and beer.
- Potters produce few products because most of the products formed crack after firing.
- Products are sold for local users.
- Potters don’t know about marketing of products.
- The rural potters in most cases do not have any formal education and cannot read or write.

Based on the above findings Mintek through its SSMB division committed to assist beneficiaries by managing projects from initiation to closure. This is done through the following main interventions:

- Research and feasibility studies
- Securing and sourcing funding options
- Training and technical support
- Marketing

The following section highlights the process followed in implementing a pottery project.

**Project Initiation**

The project initiation phase is the critical phase within the project life-cycle. To successfully initiate a project, you need to clarify which basics steps are required to carry out to develop a business case, undertake a feasibility study, develop a project charter, and assign project team, project review. (Project Management Association, n.d.). Mintek personnel compile a detailed business plan for the group which specifies the project vision, goals & objectives, scope & boundaries, deliverables & expectations, project organization and an implementation plan. The basic equipment and services required to set up a pottery project are listed in table 1 (Van Niekerk, A, 2014)

**Planning**

Project planning is part of project management, which relates to the use of schedules such as Gantt charts to plan and subsequently report progress within the project environment. The project schedule should reflect all of the work associated with delivering the project on time. Without a full and complete schedule the project manager will be unable to communicate the complete effort, in terms of cost and resources, necessary to deliver the project. (Project insight, n.d.)

A Gantt chart (Smith C) is used to outline all the tasks involved in a project and their order will be shown against a timescale. This gives you an instant overview of a project, its associated tasks and when these need to be finished. The figure 2 indicates the Gantt outlining all tasks involved. The approach that will be adopted to undertake the proposed project will include the following:

- Inform beneficiaries about the project objective
- Obtain quotes from different suppliers
- Site visit, assess the condition of the building
- Draw safety plan
- Learning material ordering
- Arrange with suppliers to purchase equipment
- Purchase raw material
- Purchase training consumables
- Facilitator preparing for training
- Ordering and delivery of PPE
- Equipment delivery
- Commission of plant
- Testing equipment
- Conduct training and technical assistance

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>Furnace, bats, set of props, blunger, pottery wheels, decorating wheels, bats, tools</td>
</tr>
<tr>
<td><strong>Delivery</strong></td>
<td>Transport of equipment</td>
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<tr>
<td>Raw materials for three month's production</td>
<td>Clays and glazes</td>
</tr>
<tr>
<td><strong>Personal Protective Equipment (PPE)</strong></td>
<td>Safety boots</td>
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<td></td>
<td>Safety glasses</td>
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<td></td>
<td>Overalls</td>
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<td></td>
<td>Dust masks (boxes)</td>
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<td><strong>Working capital</strong></td>
<td>Beneficiaries working capital for three months</td>
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<tr>
<td><strong>Incentives</strong></td>
<td>Stipends for trainees (3 months)</td>
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<tr>
<td><strong>Marketing</strong></td>
<td>Brochures</td>
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<td></td>
<td>Marketing research</td>
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<tr>
<td><strong>Commissioning of plant</strong></td>
<td>Commissioning</td>
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<tr>
<td><strong>Training by Mintek</strong></td>
<td>Pottery training</td>
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<td></td>
<td>Quality training</td>
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<td>Safety training</td>
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<tr>
<td><strong>Travel</strong></td>
<td>Return trips</td>
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<td>Facilitator accommodation (days)</td>
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<tr>
<td><strong>Assistance</strong></td>
<td>Project administration and technical assistance for six months</td>
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</table>

Figure 1. Gantt chart for pottery project
**Execution**

This is a critical phase to ensure that the project plan is put into action. In order to achieve positive outcomes the following activities are carried out in consultation with different stakeholders such as beneficiaries, local economic development officers, local government officials and Mintek personnel.

*Identifying appropriate facility*

When funds are available the infrastructure will be developed (which often involves securing a building and ensuring that it is in a good safe condition, establishing access to water and electricity). Equipment and raw materials will also be purchased. After commissioning of the workshop pottery training will commence.

*Safety induction*

Before any practical work will commence, learners will be educated about:
- The dangers of fine clays and the safety measures that have to be in place
- The safe use and handling of pottery equipment and
- Proper utilisation of PPE

*Technical training*

During training students will be involved in group activities. The course breakdown is seventy percent (70%) practical and thirty percent (30%) theoretical. The training program covers the following activities:
- Identification and preparation of materials, tools and equipment for craft production
- Manufacture of marketable craft products
- Producing sequences of the same craft product and
- Review and finishing of craft products for a market

*Control*

The monitoring and controlling process oversees all the tasks and metrics necessary to ensure that the approved and authorized project is within scope, on time, and on budget so that the project proceeds with minimal risk. This process involves comparing actual performance with planned performance and taking corrective action to yield the desired outcome when significant differences exist. Monitoring and Controlling process is continuously performed throughout the life of the project. (Best Practices, n.d.)

The funds are transferred into Mintek’s account and managed by a project investigator. The project investigator ensures that activities planned are done on time and monitors the progress. For example, equipment must be delivered on time, appropriate raw materials purchased and learners are informed about training dates. Progress reports are written and submitted to funders. Technical assistance will be provided for a period of six months to ensure that the correct procedures are followed, technology transfer is continuous and safety requirements are adhered. Technical assistance deliverables include the project administration, regular visits to the site to monitor quality of work and giving feedback on markets i.e. popular products currently in demand.
Quality control processes

The beneficiaries will be taught that after manufacturing the quality of the product should be assessed and they should consider the following:

- Does the piece have a pleasing shape?
- Are the shapes, decoration, clay type and size of the product adapted to its function?
- Is the product well manufactured and finished?

In addition, when producing products they had to do the following to ensure that there are no defects:

- Continually inspect their product during production
- Mend defects in the early stages of production and
- If your product had defects downgrade it or scrap it.

To ensure that wastage is kept to a minimum, the facilitator will demonstrate the process of recycling clay to the learners. This is a process, whereby dry clay is made reusable, by crushing and mixing the clay with water or soaking the clay in two hundred (200) litre drums, filled with water for a week.

Closure

A detailed report is written by the project investigator, stating how the money was spent on infrastructure development, raw material purchases and training. The closing phase includes all the activities necessary for the project office to close the project. Project close may be signified by system acceptance and transfer to the support organization, or by official system retirement or replacement. It is important that lessons learnt during the project are captured and that project information is properly archived. This phase marks the end of the project’s operation, including transferring operations and/or data to a follow-on system (as applicable) and retirement of any legacy system. This phase includes archiving project data and documenting final lessons learned. (Best Practise, n.d.)

Challenges

The project leader must assess the obstacles that may arise when planning and implementing the project. A risk management plan should be developed to address uncertainties and challenges which might arise during and after the project. Some of the more common challenges in pottery project include:

- It is expensive to build a workshop. Normally we rely on municipalities to provide unused buildings to be used as project workshops. Some municipalities do not have unused buildings and this can cause delays in implementing the project.
- Delays from suppliers and contractors renovating a building
- Electricity and water installation is expensive and depending on the infrastructure challenges this may take a while
- Transport of equipment can be expensive because most villages are far from suppliers and access to the areas is compromised by the quality of roads
- Sometimes the learners speak an African language that the facilitator is not familiar with. For example, the learners only speak and understand Venda, but the facilitator can only speak Sotho and/or Zulu and there is lack of available interpreters
- Some members of the group lack discipline and willingness to learn
- Securing funding for these projects is a huge challenge
Literacy is still a challenge in rural communities

Marketing

Marketing is an important step in the process because it is aimed at securing the market and ensuring sales for the products made by beneficiaries. Beneficiaries are taught about brand development, corporate identity and selling of products. The SSMB marketing personnel design brochures and banners for the project. SSMB collaborate with other government departments such as the department of trade and industry and small enterprise development agency to develop beneficiaries in various skills transfer programmes which involve business and soft skills.

Collaboration is also done in various marketing projects. These include:

- Promotions
- Local and international exhibitions, advertorials, etc.
- Distribution of products both locally and internationally
- Product development from design to prototype development and
- Brand building to increase the awareness and footprint of the brands associated with the various SMME’s.

Conclusion

The SSMB division supports government’s initiative to alleviate poverty and decrease unemployment by providing skills to the previously disadvantaged communities through training. This paper outlined the activities conducted to manage a pottery project. Different funders are approached for funding. A Gantt chart is used to ensure that the project is implemented according to the timeframes planned. Pottery training is offered for twenty one days. SSMB provides technical assistance for a period of six months to ensure that the correct procedures are followed and technology transfer is continuous. Progress and final reports are written and submitted to the funders. Basic marketing is offered to the learners so that they can be able to sell their products. Ten to twenty people will be employed, that means ten to twenty families will benefit from this project.

A project of this nature provides a framework for the development of the rural sector.

This project also talks to the following national priorities:

- Skills Development
- Creation of SMME’s

References


Stakeholder Perspectives on the Use of Satisfaction Metrics in Large Engineering Projects

Abimbola Windapo¹, Sunday Odediran², Luqman Oyewobi³, and Gcinulwazi Qamata⁴

Abstract
This paper examines stakeholder perspectives on the use of satisfaction metrics in large engineering projects and asks whether there is a significant difference in the perception of the stakeholders on the use of satisfaction metrics. The rationale for the examination stems from the view by scholars that difficulty experienced by project managers on projects is as a result of the different perception of project performance criteria within the stakeholder group. The study makes use of existing literature in identifying the satisfaction metrics used by stakeholders on construction projects. A mixed method research approach incorporating both objective and subjective paradigms was used in the study to collect empirical data from stakeholders working on four large construction sites being procured by a South African State Owned Company (SOC). The data was collected using a structured questionnaire and focused group interviews. The study established that there are significant differences in the views of participants on important satisfaction metrics. The level of use of this form of success criteria was found to be more important to the client followed by the consultants – engineers and architects, while the project management team perceived it as being of less importance. The paper recommends that clients of large engineering projects should put in place strategies that will bring about explicit communication between the different stakeholders and an avenue for softening the boundary relationships that may exist between them. The research conducted is restricted to one SOC in South Africa and its four sites. Non-disclosure by the SOC of the performance of the projects under construction also brought about difficulties. Therefore, a future research, which would explore the validity of these research findings with another comparable SOC project, is recommended.

Keywords: Large engineering projects, perception, project success and satisfaction.

Introduction
The construction industry is project-based and no two projects are exactly the same. Projects differ in terms of requirements, complexities and are surrounded with uncertainties which make it difficult to manage and satisfy stakeholders (Loosemore, 2006). Projects require planning and efficient management of its stakeholders to be successful, and satisfaction of stakeholders’ need is key to achieving desired outcome (Bourne, 2006). Traditionally, projects’ success was tied to the three criteria of meeting the cost, schedule and quality of projects. In construction today, successful projects cannot only be viewed from the angle of meeting the three criteria but also in meeting stakeholders’ satisfaction.

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⁴ Electricity Supply Company of South Africa (ESKOM), South Africa.
Though, stakeholder satisfaction depends on information concerning the three success criteria combined with accuracy and reliability of the data and information (Nguyen et al., 2009).

To meet these requirements, project organisations are becoming more sophisticated and several approaches have been instituted to deliver construction projects on schedule, cost and meet the desired quality. However, in spite of these developments all types of projects still experience high degree of failure which constitutes a dent on the reputations of project stakeholders (Bourne, 2006). It is however not known whether this failure is linked to how a stakeholder views satisfaction on projects which is subjective and their use of objective measures of satisfaction. What makes the concept of project success difficult and complicated in practice is because stakeholders have conflicting interests and goals (Hillman and Klein, 2001), which according to Frödell et al. (2008) results in different perceptions of success and in the different ways of measuring success.

This paper thus examines the perception of project stakeholders on the use of satisfaction metrics to measure project success on four large infrastructure projects procured by a State Owned Company (SOC) in South Africa. It also examines whether there are significant differences in their perception of stakeholders’ on the performance metrics used. The rationale for this study is hinged on the fact that project success or failure is measured based on how well it meets the expectations of the stakeholder and their perceived value of the project. However, over the decades the construction industry has been singled out to have a poor record of satisfying stakeholders’ owing to its fragmented nature (Egan, 1998; Loosemore, 2006). Many of these problems stem from inadequate engagement of stakeholders, lack of clarity on measures of stakeholder management, poor communication among stakeholders and the challenges of identifying “invisible” stakeholder (Yang et al., 2009). This study therefore, argues that identifying common metrics for measuring satisfaction will provide knowledge that would aid the delivery of projects that gratifies all stakeholders and advance the need to soften the boundary relationship that may exist between stakeholders so as to achieve successful delivery of construction projects.

Research Proposition and Objective

The main proposition for this study was that project stakeholders’ will have different perception of project satisfaction metrics which can be influenced by identifying and prioritising the metrics. In order to test this proposition, the objective of this paper is to identify major metrics that will consist of both subjective and objective success metrics which can help in drawing more discerning conclusions about a project’s success. The study therefore has the potential to offer a means of identifying metrics relevant to success at the beginning of projects so that stakeholders can plan ahead.

Overview of Stakeholder Satisfaction

Identifying Stakeholders

In order to satisfy stakeholders, it is essential to identify who the stakeholders are on a project, what are their interests and develop means of meeting their expectations (Nguyen et al., 2009). A stakeholder can be defined as an individual or group of individuals that can heavily influence the success or failure of a project. These categories of people, in turn, have certain expectations from the project, and examining the extent to which these expectations are currently being satisfied in a balanced fashion provides a valuable metric of project success (Curtice, 2006). Different approaches of identifying stakeholders have
been used in literature, for example, French and Granrose (1995) applied *mutuality* approach which is a way of understanding the requirement of each stakeholder on a project plus the importance of the stakeholder to the project. This will assist in establishing the nature of the association between the stakeholders and project and as well guarantee that project managers comprehend the expectation of the categories. According to Pinto (1998) the project stakeholders can be categorised into different types based on various criteria such as those that have direct impact on the project, those indirectly affected and the group with most influence from either category. This study categorises stakeholders into project team, project sponsor/client and consultants. According to Chan and Chan (2004), stakeholders must be satisfied with the overall performance of the project.

**Stakeholder Perceived Success Metrics**

A metric is any type of measurement used to assess some quantifiable element of project success or performance. The saying that you cannot manage what you cannot measure is a truism in construction project. Absence of satisfaction metrics can make it extremely difficult for project managers to assess the satisfaction of stakeholders. Stakeholders’ interests vary as a result of the complex nature of construction projects and it is a common believe that identifying stakeholder interests and expectations is an important task to evaluate stakeholders’ satisfaction (Cleland and Ireland, 2007; Freeman et al., 2007).

Previously research has shown the significance of subjective metrics as determinants of construction project success, despite the complexity involved in their measurements (Hughes et al., 2004). For instance, Baker et al. (1974 cited in Hughes et al., 2004: 32) argued that if the project meets the technical expectation specifications and/or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among key stakeholders in the parent organisation, in the client organisation, on the project team, and key end users of the project effort, the project is considered an overall success. They contended further that since stakeholders’ perceptions play such a significant role in considering project a success, then it is more appropriate to view it in terms of “perceived success of a project.”

Although, success of project has been measured objectively in the past, but objective project metrics cannot offer a comprehensive story concerning project success without an explanation of the context in which the project success attributes were perceived (Hughes et al., 2004). Also, subjective metrics of project success are considered to be only important when viewed from the angle of a specific observer, this is because project success are perceived differently by different project stakeholders and thus, it essential to make clear the point of view at which the subjective success metric is been measured (Hughes et al., 2004). Researchers contend that a wrong conclusion regarding project success could be drawn by project analysts if they only considered the traditional project success metrics (cost, time, quality, and more recently, safety) while disregarding subjective success metrics (Nguyen et al., 2009; Hughes et al., 2004; Abdullah and Ramly, 2006).

Therefore, through an in-depth review of literature, four metrics were identified to measure stakeholders’ perceived success on a construction project. This includes meeting requirements, execution efficiency, on-schedule completion of projects and compliance to regulations.
**Methods**

The focus of this study is on State Owned Company’s (SOC) which was established by the government of the Cape in 1928 with the purpose of creating an enabling environment for the development and sustainability of the economy through energy supply. Over the past decades, SOC has undertaken some capital expansion projects through the construction of large new infrastructure so as to meet its objectives in rising to the challenges of the growing South African economy. The authors consider SOC to be a suitable setting for this research for the following reasons: (a) it is engaged in construction projects, which are intended to benefit the public; (b) its performance can be used to benchmark other SOC construction projects; and (c) the construction projects undertaken is unequalled in terms of values for the past five decades in South Africa.

In order to obtain relevant data and better results for the research, this study adopts sequential mixed methods approach, which involves the collection and analysis of qualitative and then quantitative data within one study. According to Tashakkori and Teddlie, (1998) and Creswell (2005), mixed methods research design is a method for collecting, analysing, and “mixing” or integrating both quantitative and qualitative data at some stage of the research process within a single study for the purpose of gaining a better understanding of the research problem. However, in this study mixed methods was used whereby qualitative data were first collected to refine the questionnaire before administering same.

The sample for the focus group interview were drawn from four major construction sites considered in this research using a purposive sampling technique (Noor, 2008) from a population of construction project practitioners (SOC Management, Funding Organization, Project/Contracts Managers, Project Supervisors, Contractor Site Managers, Construction Managers, Project Sponsors and Project Support Managers). The purposive sampling technique was used because knowledge of the project operations was not normally distributed within the target population. These construction project practitioners were perceived by the authors to be able to contribute valuable information to the research. The list of construction project practitioners to be surveyed was obtained from the SOC database, using a random sampling technique. Questionnaires were self-administered to 92 selected construction project practitioners including contractor’s on the sites from July 2012 to January 2013 (a six month period). Figure 1 shows the flow of the research framework used in this study.

![Figure 1. Research framework (adapted from Yang et al., 2009)](image-url)
Data Analysis
In order to elicit relevant information on the perception of the stakeholders on project satisfaction metrics, the respondents were requested to rank the metrics on a five-point Likert scale, where 1 = strongly disagree and 5 = strongly agree. Mean statistics were used in analysing and rating the data obtained from the questionnaires so as to establish common trends and differences amongst the respondents on each project success metric.

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MIS = \frac{5M_5 + 4M_4 + 3M_3 + 2M_2 + 1M_1}{5 \times (M_5 + M_4 + M_3 + M_2 + M_1)}
\]

(Where: \(M_1\) = strongly disagree; \(M_2\) = disagree; \(M_3\) = somehow agree; \(M_4\) = agree; and \(M_5\) = strongly agree)

To examine whether there is significant difference in the perception of stakeholders on the metrics of project success, non-parametric statistical technique was employed. This is because parametric assumptions requiring data to be normally distributed and homogenous in terms of variance are not fulfilled (Pallant, 2011), and since these assumptions were not fulfilled by survey data, the non-parametric methods was used. The research used Pearson Chi square statistics (Using R software) in examining whether there are significant differences in the perception of the project stakeholders regarding success metrics. The results of this test were interpreted in terms of goodness-of-fit test. The probability associated with the chi square statistic indicates whether or not there is a significant difference in the perception of the stakeholders on the metrics of project success. If the probability is significant at 5% level, this means there is significant differences in their perceptions. The research findings may be constrained by the fact that the available archival documents for the projects were not sufficiently explicit and comprehensive in providing details of the existing project success metric.

Results and Discussion
Profiles of Respondents
Table 1 shows the profile of the respondents in this research.

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<tr>
<td>Project Sponsor/Financier</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

The highest number of respondents by group is the project supervision team, which comprises of engineers and project managers who oversee the construction of the large...
engineering projects on behalf of the client. Designated project managers who are in charge of the individual project sites and who are employees of the SOC constitute the second highest respondents in the study. Table 1 also indicates that the highest numbers of respondents were from Site 4 followed by Sites 3, 2 and 1 respectively.

**Rating of Project Satisfaction Metrics**

The analysis of the questionnaire survey response was used to generate the means for the 4 main project satisfaction metrics identified in literature. The ranking and the mean values for the success metrics are shown in Table 2.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Execution Efficiency</td>
<td>4.60</td>
<td>1</td>
</tr>
<tr>
<td>Meeting Requirement</td>
<td>4.55</td>
<td>2</td>
</tr>
<tr>
<td>Compliance to Regulations</td>
<td>4.55</td>
<td>2</td>
</tr>
<tr>
<td>On-schedule completion</td>
<td>4.50</td>
<td>4</td>
</tr>
</tbody>
</table>

It was found out that the means of the metrics ranged from 4.50 to 4.60, which shows that all respondents consider these 4 attributes relevant in satisfying stakeholder expectations and meeting their requirements in construction projects. The highest ranking by all respondents was “execution efficiency” (mean = 4.60), which therefore was considered as an extremely significant metric in measuring the success of projects and satisfaction of stakeholder. “Meeting clients’/project sponsor’s requirements/needs and compliance to regulations” (mean = 4.55) were both ranked as the second most important metrics. The 4th ranked metric was “on-schedule completion of project” (mean = 4.50).

**Perceptions of stakeholders on project success metrics**

In order to examine whether there were significant differences in the perception of stakeholders on the metrics used in measuring project satisfaction, the Chi square statistics was used. Table 3 shows the Chi square statistics of the four metrics used in the study.

<table>
<thead>
<tr>
<th>Metric</th>
<th>(X^2)</th>
<th>df</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting Requirement</td>
<td>4.8913</td>
<td>10</td>
<td>0.8983</td>
</tr>
<tr>
<td>Execution Efficiency</td>
<td>31.4403</td>
<td>20</td>
<td>0.0496</td>
</tr>
<tr>
<td>On-schedule completion</td>
<td>2.6748</td>
<td>10</td>
<td>0.9881</td>
</tr>
<tr>
<td>Compliance to Regulations</td>
<td>3.2516</td>
<td>5</td>
<td>0.6613</td>
</tr>
</tbody>
</table>

The chi-square goodness-of-fit test presented in Table 3 indicates that there was significant difference in the perception of stakeholders on execution efficiency as measures of project satisfaction when compared with the other metrics \(\chi^2 (1, n = 92) = 31.4403, p < .05.\) These statistical results indicate a general consensus on the perception of the different stakeholders’ on the use of “meeting client’s requirement, on-schedule completion of projects and compliance with regulations as project satisfaction metrics.

**Discussion of Findings**

Findings from the survey data through ranking suggest that execution efficiency and effectiveness (i.e. meeting specification requirement, quality and health and safety) is the
The results of the non-parametric analysis indicated that there is no significant difference in the perception of stakeholders on project satisfaction metric except on execution efficiency. Therefore, it can be said that the finding do not lend credence to the proposition that there will be significant differences in the perception of stakeholders on the measure of project satisfaction metrics. This implies that data collected in this study does not support the view that there may be significant differences in perceptions within the stakeholders groups working on the four SOC projects studied on measures and use of project satisfaction metrics. The findings do not also resonate the view of previous researchers who found significant differences in the opinion of stakeholders on project success criteria (e.g. Hillman and Klein 2001; Wang and Huang, 2006; Toor and Ogunlana, 2010). This results may be due to the fact that the SOC is experienced in implementing large construction projects and it has in place documented procedures, standards and processes which it uses on its projects and hands these out to its employees and service providers to use as reference in project implementation.

Conclusions and Recommendations
This paper examines stakeholder perspectives on the use of satisfaction metrics in large engineering projects and whether there are significant differences in their perceptions on the use of satisfaction metrics. The study found that the stakeholders rated the identified satisfaction metrics very high, and meeting project requirements was rated the highest. The study also established that there was a significant difference in the perception of stakeholders on the use of meeting project requirements as a project satisfaction metrics while there perceptions did not differ on the use of the other identified satisfaction metrics. Based on these findings, the study concludes that the difficulty experienced on projects especially large engineering projects and the high degree of failure may be traced to the differing views of stakeholders on the use of meeting project requirements as a project satisfaction metric. Evidence from literature indicates that it is essential that stakeholders at the commencement of the project ensure they have a common insight into how project success will be determined and that stakeholders must be satisfied with the overall project performance. However, the research is limited in scope to one SOC in South Africa and its four project sites and this affects the generalizability of the results even though it provides significant results. Non-disclosure by the SOC of the performance of the projects under construction also brought about limitations. The study could not compare the subjective data obtained to the objective data gathered by the SOC. Therefore further research which would explore the validity of these findings with another comparable SOC project is recommended.
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Influence of Client Understanding on Quality of Design
A. Olatunji Aiyetan¹, J. John Smallwood², and Winston Shakantu³

Abstract
Clients understanding are crucial to the success of a project. This is because their understanding influences the cost and time aspects of the project and relative to maintaining these within stipulated schedule. The aim of the study is to assess clients level of understanding and quality of design relative to project delivery. The study was conducted in Lagos, Nigeria. Respondents for the study are architects, builders, quantity surveyors, and engineers. Random sampling technique was employed in the selection of samples. A total of one hundred and twenty questionnaires were analysed for the study, Descriptive statistics was employed for the analysis.

Findings include that ability to effectively brief the design team, ability to contribute ideas to the design process, stability of decisions, conflicting design information, and missing information top as factors that determines the quality of design. Recommendations include attention should be given to Adequate briefing, the evaluation of contractors’ technical and financial performance, will result in a better understanding of the contractors’ overall capabilities, and Design quality assurance / constructability reviews.

Keywords: Client, construction, design, quality, understanding.

Introduction
The understanding of clients regarding the processes of construction is very important to prompt delivery of projects. The decisions of client at different stages of the project may exert positive or negative influence on the project. Positive influence are such that afford the project to be completed as stated within the initial estimated time, cost and quality, while negative influences are such, that will pull these parameters beyond what are their initial plan. Clients are expected to make contribution to the design team at the design stage and the construction team at the construction stage. The quality of his designs affects the parameters as stated above. These could result in cost and time overruns, rework, dissatisfaction among the design, construction team and the client, and result in ultimate abandonment of the project. Therefore, this study aim to identify the factors that affects project delivery with regards to client understanding of the design and construction processes.

Literature Review
The literature review to this paper will be discussed in two pats. The first part will discuss the contributing factors relative to clients’ understanding of the design,

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procurement and construction processes, while the second part will discuss contributing factors of client to the design team.

**Clients’ Understanding of the Design, Procurement and Construction Processes**

This section discusses the various factors relating to clients which contribute either positively or negatively to project delivery time.

*Understanding of the Project Constraints*

Pheng and Chuan (2005) rate the type of client as the third factor of the fourteen found to negatively affect project performance. Clients’ understanding of the project constraints afford appreciation of the challenges encountered by the main contractor to a project. Koushki et al. (2005) identify the client’s lack of experience as a major contributor to time delay. Leung et al. (2004) report that clients’ construction experience has a high loading (0.810) regarding testing relationship between management mechanisms and the satisfaction variables for construction projects. Constraints are circumstances / situations outside the immediate control of parties to a contract that affect the smooth flow of activities. These could be in the form of finance which may marginalise H & S, transportation, material, labour and machines. In terms of design it may be the client’s ability to adequately brief the design team on what he / she intends to build. Contrary to this view, Chinyo & Akintoye (2008) cite Lerbinger (2006) who contends that organisations that engage with their stakeholders actively are more likely to succeed.

*Ability to Effectively Brief the Design Team*

Belout and Gauvreau (2003) point out that it is important to define and communicate the project mission clearly during the planning stage. Further, it is also essential at this stage to fully grasp clients’ needs and establish with them the project’s limits and priorities - expected quality standards; schedules risk acceptance; method of project management to be adopted; monitoring actors, and so on. The ability of the client to effectively brief the design team could avoid revision of drawing and reworks. The Construction Industry Review Committee (2001) recommends that clients set out requirements of their projects clearly, systematically and comprehensively. Further, Chan et al. (2004) identify clients’ ability to brief as one of the human-related factors that affect the success of a construction project. The accuracy of the briefing of the design team regarding the intention / purpose of buildings is directly proportional to the level of representation of the intention / purpose in the design. If intentions are not appropriately conveyed, it will affect the design and it implies that whatever is represented in the drawing is that which the contractor will build. Yu et al. (2006) highlight the problems associated with briefing as a lack of a comprehensive framework; lack of identification of client requirements; inadequate involvement of all the relevant parties of a project; inadequate communication between those involved in briefing and insufficient time allocated for the briefing. These are potential factors that could cause significant delays on project delivery. Mbachu and Nkado (2004) note that there is a need to grasp the needs of a client and provide satisfactory service in order to avoid undesirable consequences such as negative word-of-mouth, complaints, redress seeking, reduction of market share and profitability levels, and possible divestment from the industry. Cheug et al. (2000) declare that the extent to which a project is dispute-free from the client determines the measure of success of the project. Therefore the needs and expectation of clients should be known and met.

*Ability to Contribute Ideas to the Design Process*
Phua (2005) concludes that good communication by clients with project team members is viewed as important to project performance. The ability of the client to contribute ideas to the design process may result in a design with no or limited errors. In the instance that the client does not have an understanding of the design process, the designer is left alone to work on the brief given to him by the client, which may not be comprehensive for a faultless design. Chan et al. (2004) assert that clients’ ability to contribute to design affects the construction of projects.

**Ability to Quickly Make Authoritative Decisions**

Faridi and El-Sayegh (2006) and Dulaimi et al. (2005) identify slowness of the owner’s decision-making process as the third most influential factor out of forty-four factors causing delays in construction projects. Blisman et al. (2004) highlight the fact that client indecisiveness and non-uniformity negatively affect project delivery, which rank among the ten most influential factors within construction clients’ multi-project environment. Chan et al. (2004) say that clients’ ability to make decisions affects construction projects. The extent to which the client can make authoritative decisions helps in avoiding delays in the delivery of projects. Clients that need to consult other associates with respect to making decisions may affect prompt delivery of projects. When this type of situation is encountered decisions that may affect the project negatively could be taken.

**Stability of Decisions**

Stability of decisions is very crucial in the construction process. The changing of decisions may lead to changing of designs, plans, rework, and material loss, among others. Baldwin et al. (2004) contend that clients’ indecisiveness is the second significant factor that influences project delivery in their findings. Furthermore, Abdel-Wahab et al. (2008) declare that changes made by clients contribute to the delay of projects. Citing Olomolaiye (1996), Koushki et al. (2005) add that change-orders as a result of changing selections contribute to delays.

**Ability to Contribute Ideas to the Construction Process**

Phua (2004) concludes that the factor that has the most influence on multi-firm project success is communication between project firms and clients. Through the implementation stage, the communication needs change from provision of data by the owner, to review, and acceptance of plans and deliverables, together with early warnings if the owner cannot fulfil his/her obligations stated in the project plan. Communication can occur in order to transfer an idea or contribute to decision-making. Phua (2005) asserts further that good communication with project team members is viewed as important to project performance at all levels. Chan et al. (2004) say that, clients’ ability to contribute to the construction process affects the success of the project. The ability to contribute ideas in terms of changes required during construction as a result of changing taste to suit desire can impact either positively or negatively on the construction speed. Clients that embark on construction activities once in fifteen or twenty years may not have valuable ideas to contribute to the construction process and may affect delivery time negatively. Clients that embark on construction activities every other year may have valuable ideas to contribute to the construction process thereby affecting construction speed positively. Mathur et al. (2008) argue that the engagement of stakeholders within a project could link with the project decision-making process in order to explicitly affect key decisions.

**Quality of Management during Design**
Hsieh et al. (2004) determined that problems with design and planning are the major cause of change orders which lead to delays in the delivery of projects. Poor drawings were considered to be another cause for low productivity. Design management is a tool which managers use to increase project performance. It is a process that includes open forum presentations, a style that allows discussion of issues by all project team members and has the capacity to ensure a faultless design. Santoso et al. (2003) assessed risks in high-rise building construction in Jakarta and found that risks related to design and management are the most significant factors which affect construction performance.

Conflicting Design Information

Acharya et al. (2006) determined that ambiguous specifications are one of the six critical construction conflicting factors in the Korean context that affect project delivery time negatively. This refers to an item having double representation either in numerical value or in statement. For clarity and smooth flow of work, designs should be checked more than once before they reach the contractor. It is also advised that designs should be checked by the contractor for clarity and to avoid ambiguity upon receiving the award. If these exercises are not conducted, it may lead to delays. Oyedele and Tham (2006) conclude that architects should improve on design quality so as to satisfy their clients’ requirements and ensure successful project delivery as a whole.

Timeliness of Issuing of Revised Drawings

According to Yakubu and Sun (2009), design change(s) is the most influential factor inhibiting the delivery of projects on time in the United Kingdom construction industry from the perspective of the contractor and the consultants. Walker and Shen (2002) declare that a delay in design documentation was ranked the second most influencing factor that negatively affects project delivery. Time should not be wasted in the process of issuing revised drawings. The joint contract tribunal (JCT) specifies that revision of drawings should not take more than three days after which the contractor can claim for extension of time. This could increase the final project cost to the disadvantage of the client, which the client might not want to incur. Revisions of designs should be done promptly.

Missing Information

Andi and Minato (2003) say that poor design and documentation quality negatively affect the construction process. Alaghbari et al. (2007) identify incomplete documents as one of the top ten factors causing delay in the delivery of projects in the Malaysian construction industry. Missing information interrupts the smooth flow of work. Contractors are employed to build in such a way that they adhere to design and specification. Assumptions should not be made while constructing, therefore missing information should be brought to the notice of the designer and a quick response should be given to address this.

Dimensional Inaccuracies

Walker and Shen (200) say that mistakes in design form part of the contractor-related factors which were ranked second in contributing to delays in the delivery of projects. Acharya et al. (2006) determined that design errors are one of the six critical construction conflicting factors in the Korean context. Dimensional inaccuracies are to be brought to the notice of designers and these should be resolved promptly, to avoid delays in the delivery of project. JBCC clause 17.1.2 bestows the responsibility on the principal agent to issue the contractor instructions with regards to the rectification of
discrepancies, errors in description or omission in contract documents other than this document.

*Expediting Shop Drawings*

Out of forty-four causes of delays identified by Faridi and El-sayegh (2006) in the United Arab Emirates, preparation and approval of drawings is the most influential. Delay in the release of shop drawings could affect speedy completion of work sections. Shop drawings should be delivered to the contractor whenever the need arises with no delays. Clause 32.5.1 of the JBCC states that the failure to issue or the late issue of a contract instruction following a request from the contractor entitles the contractor to claim for the expense in loss incurred, having notified the principal agent within forty working days from becoming aware or from when he/she ought reasonably to have become aware of such expense and loss.

**Methodology**

The focus of the study was to identify and assess influencing factors of client understanding of the construction and procurement processes on the design team. The study was conducted in Port Elizabeth in South Africa. The sampling frame consisted of architects (9), master builders (18), quantity surveyors (23), and structural engineers (23), clients (12) and others (3). The formula used for the calculation of sample size is given as:

\[ S = \frac{X^2NP(1-P)}{d^2(N-1)} + \frac{X^2P(1-P)}{}; \]

- \( S \) = The required sample size;
- \( X^2 \) = The table value of chi-square for 1 degree of freedom at the confidence level of 3.841;
- \( N \) = The population size;
- \( P \) = Population proportion assumed to be .50 which provides the maximum sample size, and
- \( D \) = The degree of accuracy expressed. In this case, 0.05 was used Krejcie and Morgan (1970).

Probability sampling technique was employed for sample selection. For the Architects Master Builders, and the Clients random sampling was used. Systematic sampling techniques was used for the quantity surveyors, and for the structural engineers and other the entire sample were surveyed based on the recommendation of Leedy *et al.* (2005) that researchers should endeavour to maximise the sample size and provide the following guidelines for selecting a sample size:

- For small populations with fewer than 100 people or other units, there is little point in sampling, survey the entire population;
- If the population size is around 500, 50% of the population should be sampled;
- If the population size is around 1500, 20% should be sampled, and
- Beyond a certain point (at about 5000 units or more), the population size is almost irrelevant and a sample size of 400 should be adequate.

The research instrument for this study was a questionnaire survey, which was administered to respondents through post (Architects, MB, Structural engineers, and others) and e-mail (Quantity Surveyors). These were received through the same means.
A total of eighty-eight (88) questionnaires representing 6.1% response rate achievement recorded on questionnaire administration. Differential statistics statistical tool was used for data analysis.

The majority of respondents belong to the private sector and constitute (74%) of the total sample. The mean for the number of years an organisation has been in existence is twenty-five of the organisations surveyed. Respondents that are over the age of thirty predominate in the sample investigated. Regarding the qualification of respondents, 25% have bachelors’ degrees, and they predominate in the sample. Following closely are respondents with honours’ degrees, totalling 23%. Respondents with the B. Tech qualification rank next to those who have an honours degree in the form of 17%. A fraction constituting 5% does not have relevant qualifications in the industry they are employed in. With respect to the category of respondents’ qualification, quantity surveyors (31%) predominate among the respondents. They are followed by engineers (27%), architects (11%), and builders (11%). The lowest response is relative to construction managers (5%). On the status of respondents in organisation, managing directors / managing members / principals (35%) predominate among respondents. Following closely is senior staff (20%), and next is managers (17%). The lowest response is relative to trainer / internship staff (1%). The mean number of respondents’ years of experience is 17 and the following indicates the type of facilities respondents are involved in, the predominating type of facility that respondents have been involved in is institutional facilities (19%). Following closely is the development of residential facilities (18%); commercial offices and industrial facilities (14% each), and institutional health facilities (10%). Based on the above information the data obtained can be deemed reliable.

Data Presentation and Analysis
This section presents the data obtained of the study and the analysis.

Clients’ Influence

Table 1. The Influence of Client Understanding of the Design, Procurement and Construction Processes on Project Delivery Time

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unsure</th>
<th>Minor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to effectively brief the design team</td>
<td>0.0</td>
<td>2.4</td>
<td>5.9</td>
<td>18.8</td>
<td>27.1</td>
<td>23.5</td>
<td>22.1</td>
<td>3.31</td>
<td>1</td>
</tr>
<tr>
<td>Ability to contribute ideas to the design process</td>
<td>3.6</td>
<td>2.4</td>
<td>6.0</td>
<td>16.9</td>
<td>33.7</td>
<td>15.7</td>
<td>21.7</td>
<td>3.21</td>
<td>2</td>
</tr>
<tr>
<td>Understanding the project’s constraints</td>
<td>1.3</td>
<td>3.5</td>
<td>10.6</td>
<td>16.5</td>
<td>25.9</td>
<td>22.4</td>
<td>20.0</td>
<td>3.14</td>
<td>3</td>
</tr>
<tr>
<td>Stability of decisions</td>
<td>2.3</td>
<td>2.3</td>
<td>9.3</td>
<td>23.3</td>
<td>24.4</td>
<td>17.4</td>
<td>20.9</td>
<td>3.09</td>
<td>4</td>
</tr>
<tr>
<td>Ability to quickly make authoritative decisions</td>
<td>1.2</td>
<td>3.5</td>
<td>12.9</td>
<td>21.2</td>
<td>20.0</td>
<td>20.0</td>
<td>21.2</td>
<td>3.04</td>
<td>5</td>
</tr>
<tr>
<td>Ability to contribute ideas to the construction process</td>
<td>3.6</td>
<td>4.8</td>
<td>11.9</td>
<td>20.2</td>
<td>23.8</td>
<td>16.7</td>
<td>19.1</td>
<td>2.95</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 1 presents the respondents’ rating of the influence of client understanding of the design, procurement, and construction processes in terms of various factors on project delivery time. It is notable that all factors in the category have MSs $> 2.60 \leq 3.40$, which indicates that the factors have between a near minor to moderate / moderate influence on project delivery time.

The factor with the most significant influence is the ability to effectively brief the design team. When intentions are not adequately expressed, it may lead to a revision of the design. The impact of lack of adequate briefing and revision of drawings regarding construction may be the demolition of a section of a building, and reconstructing the building. In addition, it may cause work stoppages before the completion of design revisions. All of these may lead to a substantial waste of time, which may culminate in project delay.

Following this factor is the ability to contribute ideas to the design team. All requirements of the client should be communicated to the design team prior to the awarding of the contract. The inadequacies emanating from the design stage due to poor client brief definitions invariably leads to rework and other problems during construction. Therefore, experienced poor definitions of clients brief on most projects may be due to the level of client understandings relative to the construction process and design related specific intents of a facility.

The least significant factor is the ability to contribute ideas to the construction team. The business of construction, its constraints and methodology are the problem of the contractor. It is not compulsory for the client to be knowledgeable in construction or else there would be no need for contracting, particularly construction work. These may be the reasons why the factor is the least influential.

Quality of Management during Design

Table 2. The Influence of Quality of Management during Design Factors on Project Delivery Time

<table>
<thead>
<tr>
<th>Factor</th>
<th>Uns</th>
<th>DN</th>
<th>Minor</th>
<th>Major</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicting design information</td>
<td>2.3</td>
<td>1.2</td>
<td>13.8</td>
<td>9.2</td>
<td>23.0</td>
<td>26.4</td>
</tr>
<tr>
<td>Missing information</td>
<td>1.2</td>
<td>2.3</td>
<td>11.6</td>
<td>15.1</td>
<td>25.6</td>
<td>20.9</td>
</tr>
<tr>
<td>Timeliness of revised drawings</td>
<td>8.1</td>
<td>1.2</td>
<td>14.0</td>
<td>12.8</td>
<td>23.3</td>
<td>21.0</td>
</tr>
<tr>
<td>Expediting shop drawings</td>
<td>5.8</td>
<td>4.7</td>
<td>14.0</td>
<td>18.6</td>
<td>18.6</td>
<td>29.1</td>
</tr>
<tr>
<td>Dimensional inaccuracies</td>
<td>2.3</td>
<td>3.5</td>
<td>20.9</td>
<td>12.8</td>
<td>16.3</td>
<td>16.3</td>
</tr>
</tbody>
</table>

Table 2 presents the respondents rating regarding the influence of quality of management during design, on project delivery time. All factors in this category have MSs $> 2.60 \leq 3.40$, which indicates that these factors have between a near minor to moderate / moderate influence on the project delivery time.
The factor that has the most significant influence in the category of quality of management during design is conflicting design information stemming from client input. The probable reason for this is the process it will take to correct a mistake. It may require checking the design from the beginning, which may take longer than expected. The second most significant factor is missing information. This factor may lead to delays as a result of carelessness or incompetence in design. This factor could be a result of input from either the client or the design team, from the client in the form of forgetfulness and from the design team as omission. Missing design information will inhibit the smooth flow of operations on site, therefore introducing delay to the scheduled project completion date.

The least significant factor in this category is dimensional inaccuracies. This factor is mainly a contribution from the design team. Although this factor is the least influential in this category, it does not imply that its effect is negligible because of the time it takes to clarify inaccuracies may result in delay in the delivery of the project.

Conclusions and Recommendations

Conclusions

Based upon the factor analysis conducted, it can be concluded that all factors identified for each sub-problem adequately describe the sub-problems by the value of the loadings obtained for each category of sub-problems, which were greater than 0.60 in all cases;

Client’s ability to effectively brief the design team mostly influence project delivery time;

Clients’ ability to contribute ideas to the design process determines the extent of delay on the delivery of a project;

The lack of client understanding of project constraints influence project delivery time, and

Conflicting design information stemming from client input, result in project delivery time.

Recommendations

The following interventions should be given adequate attention with respect of mitigate the impact of delay on project as a result of contributions from both client and the design team.

At the brief / design stage, attention should be given to:

- Adequate briefing;
- Confirmation of client financial capability, and
- Design quality assurance / constructability reviews.
- Non knowledgeable clients relative to construction processes should endeavour to educate themselves on construction processes to enhance positive contribution to the construction process.

Clients’ and the design team should be committed to quality management designers. Designers’ quality management should focus on the following:

- Committed to providing a quality service;
- Production of correct and complete drawings and specifications;
- Coordinating and checking of design documentation;
- Conducting design verification through design analysis reviews, and
- Conducting constructability reviews.

References


The Influence of Satisfaction with Attributes of Off-Campus Student Accommodation on the Loyalty Behaviour of Student-Residents

OC Bella-Omunagbe¹ and WM Shakantu²

Abstract

Building satisfaction with housing and its attributes is unquestionably one of the important objectives of most investors and designers, and this objective is achieved by incorporating attributes that are considered to be satisfactory by residents. Satisfaction with housing and its attributes has consequences on the behaviour of resident such as the decision to stay, adjust housing conditions or switch residence which is crucial to the success of housing investment. The purpose of this study is to investigate how the satisfaction with attributes of student housing facilities (SHFs) affects the loyalty behaviour of student-occupants. The data used in this report were obtained through the administration of a questionnaire on students residing in off-campus SHFs in three tertiary institutions located in Edo State, Nigeria. The data were analysed using the descriptive and inferential statistics. The study revealed that the attributes of off-campus SHFs have varying degree of influence on the loyalty behaviour of students who reside in these residences. It is suggested that attributes that are incorporated in housing should be prioritised based on their ability to secure the loyalty and retention of students.

Keywords: Loyalty, satisfaction, student housing.

Introduction

Private interest in housing provision for students in tertiary institutions has grown over the years and this increase in demand is attributed to the inability of universities to build and maintain enough on-campus accommodation for the increasing student population. As a result of shortages of on-campus residences, private off-campus students housing facilities (SHFs) have become the main source of accommodation for students in tertiary institutions (Fields, 2011: 2; Rawlinson, 2007: 68; Thomsen & Eikemo, 2010:210; Akingbohungbe & Akinluyi, 2011: 69).

Off-campus private housing is generally viewed as an investment and the success depends on the level of patronage by students (Zaransky, 2006: 2) and this in turn is influenced by the degree of satisfaction experienced by residents. Satisfaction is one of the key factors that determines the prospect of SHFs. In spite of the understanding that satisfaction with residential environment has a positive impact on resident behaviour, the nature of the relationship between satisfaction and the behaviour of residents is not properly understood (Levy, 2006: 1).

SHFs are location specific and are diverse in types and attributes (Akingbohungbe & Akinluyi, 2012:69; Fields, 2011:1). Thomsen (2007:578) suggested that in the planning for the construction of student housing, it is important that attributes that promote user needs,
desires and preferences are incorporated. One notable advantage of this is that it elicits positive behaviour such as loyalty from occupants (Llinares & Page, 2011:233).

The focus of this study is to identify the attributes of the physical/dwelling that drive residents’ satisfaction and their individual impact on the loyalty behaviour of residents of SHFs. Understanding the nature of the relationship between satisfaction with product attributes and loyalty can improve the effectiveness and efficiency of resource allocation. In addition, this knowledge can be used by investors to incorporate the attributes that contribute most to loyalty.

**Literature**

Private interest in housing provision for students has attracted the attention of developers worldwide due to the inability of tertiary institutions to provide accommodation for students on campus. The main motives of these investors are to make profit and grow property. However, attainment of this goal depends on the demand for SHFs and the degree of satisfaction derived by users from the utilisation of these attributes. Generally, the success of any housing project is influenced by user satisfaction with the attributes of the accommodation and amenities and this has been the key challenge faced by investors in this sector (Ukoha & Beamish, 1997).

**Satisfaction**

Satisfaction with housing attributes is adjudged as the ultimate test of the success of a housing development project (Al-Noori 1987:1). Residential satisfaction evaluation is used to predict user response to the various dimensions of residential environment (Amole, 2009: 76). Satisfaction measures are applied as criteria to evaluate residential quality and predict behaviour of residents (Amerigo & Aragones, 1997:47). Satisfaction measure is also used in building performance evaluation as the dominant factor in the evaluation of the performance of attributes. Generally, satisfaction is explained about how consumer expectations and perception of performance of products/services are interrelated in the fulfillment of needs and desires. The two main perspectives or approaches that guide the development of these theories includes the view that consumer satisfaction is either a process or an outcome (Yang & Zhu, 2006: 668; Parker & Mathews, 2001: 38). The process approach focuses on identifying the gap that exists between expectations and the perceived performance of service or product as an explanation of consumer satisfaction (Grigoroudis & Siskos, 2010: 4). Furthermore, the feeling of satisfaction with residential environment is found to produce a positive response to the environment, effectively describe the quality of life of inhabitants in a defined residential environment and also acts as a driving factor affecting residential mobility (Amerigo & Aragones, 1997: 107).

However, housing as a heterogeneous product is generally expected to meet the expectations of providing occupants with a safe, comfortable, healthy and secure environment (Ibem, Opoko, & Adeboye, 2013: 178). Components of buildings are distinct, and each serves to achieve a function(s) individually or in combination with other attributes (Coulombel, 2011:8). The extent to which these goals are achieved is directly related to the levels of performance of the constituting elements. Thus, housing developers and designers rely on this knowledge to incorporate attributes of residential environment that are considered attractive to users. These attributes of the residential environment are categorised in existing literature as:

i. physical/structural aspects;
ii. location/neighbourhood aspects;
iii. environment aspects;
iv. management aspects; and

This study will then look at the impact of the attributes of the physical/dwelling aspects on users’ satisfaction and loyalty behaviour which is the main focus of this research.

**Physical/Dwelling Aspects of the Residential Environment**

The physical/dwelling aspects of housing refers to the attributes (equipment, amenities and facilities) of the residential environment (Amerigo & Aragones, 1997: 53). A lot of studies were carried out on the relationship between the attributes of the physical/dwelling attributes and the quality of life but little has been done to explain how residential attributes impact of loyalty behaviour of residents( Najib, et al, 2011). For example, Christie, et al (2002: 221), study shows that the conditions and types of attributes of the physical and dwellings aspect are strong indicators of the students’ quality of life and also serve as reference for future decisions on residential choice. Thomsen and Eikemo (2010) study in Norway investigated the influence of the architectural aspects of residences on satisfaction with on-campus and off-campus accommodation. The study revealed that off-campus housing with shared toilets; kitchens and bathrooms are difficult to rent out to students. Other examples of studies on satisfaction with student housing include those that dwell on the predictors of satisfaction and those that dwell on the satisfaction as a criterion variable. Najib et al (2011) in a study in Malaysia shifted the focus from measuring the levels of satisfaction alone, but applied the residential satisfaction scale (Weidemann and Anderson, 1985; Song and Yang, 2006; Amole, 2009; and Hui and Zheng, 2010) to study the relationship between satisfaction with attributes and impact on loyalty behaviour by students in SHFs.

**Loyalty as A Consequence of Satisfaction**

Loyalty refers to having or showing complete and constant support for a product or service. In essence, when residents are satisfied with the attributes of the residential environment, their behavior is affected in the subsequent transaction through repeat patronage. Otherwise, when residents are dissatisfied, they either remain as disgruntled tenants or relocate to accommodation with amenities that offer higher levels of satisfaction. The crucial success factor therefore in business performance is the “ownership” of customers (Hasan, 1996:1). Hence, loyalty by residents in SHFs is regarded as paramount in the quest for survival and prosperity of private off-campus residences.

**Method**

**Participants**

The participant in this study are students of tertiary institutions who resides in private off-campus residences. They were selected by means of convenience sampling.

**Survey Instrument**

The survey instrument used for this research was designed to gather data for a broader study bordering on the drivers and consequences of residents satisfaction with housing in
South-South, Nigeria which include Edo State as one of the seven states in the region. This study is therefore, a presentation of the results of a pilot study.

The questions in the survey instrument allow students to provide feedback on their perceived satisfaction with selected items of the physical dwelling and the impact on their loyalty behaviour. The 14 items investigated in this study were selected based on the outcome of literature search, expert panel and focus group discussions with students-residents. A 7-point semantic Likert-scale format (from 7 = high satisfaction, high impact to 1 = no satisfaction, no impact on loyalty) was used to elicit users’ perceptions on the level of satisfaction with attributes and the resulting impact on loyalty behaviour.

**Statistical Analysis**

The descriptive statistic was used to present the demographic characteristics of student-residents while the levels of satisfaction with residential attributes and loyalty behaviour are estimated using the mean scores for these items. A further correlation was carried out to determine the relationship between the perception of satisfaction with these attributes and perceived impact on loyalty.

**Presentation of Results**

The results of the study are presented and discussed as below.

**Demographic Characteristics of Respondents**

Table 1 shows the demographic characteristics of respondents that were involved in the survey. The age profile reveals that 34% and 29% of the students involved in the survey are between the age of 19-22 years and 23-27 years, respectively while a few are below or above 18 years and 28 years respectively. In addition, 53.4% of the respondents are male, while the remaining 45.6% are female. The distribution of the respondents in terms years of study shows that 40.9% are first year students, 27% in the second year, while the remainder are in their third (19.7%) and fourth year (12.1%) of study.

<table>
<thead>
<tr>
<th>Demography</th>
<th>Categories</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Below 18 years</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>19-22 years</td>
<td>34.8</td>
</tr>
<tr>
<td></td>
<td>23-25 years</td>
<td>28.7</td>
</tr>
<tr>
<td></td>
<td>26-28 years</td>
<td>25.5</td>
</tr>
<tr>
<td></td>
<td>Above 28 years</td>
<td>8.0</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>53.4</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>45.6</td>
</tr>
<tr>
<td>Year of study</td>
<td>First year</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>Second year</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td>Third year</td>
<td>19.7</td>
</tr>
<tr>
<td></td>
<td>Fourth year</td>
<td>12.1</td>
</tr>
</tbody>
</table>
Satisfaction with Attributes of the Physical/Dwelling Environment

The result of the analysis of residents’ perception of satisfaction with selected attributes of the physical/dwelling environment is presented in Table 2.

Table 2. Mean score of satisfaction with attributes

<table>
<thead>
<tr>
<th>Attributes of Physical/Dwelling Environment</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation</td>
<td>5.57</td>
</tr>
<tr>
<td>Toilet and bath</td>
<td>4.39</td>
</tr>
<tr>
<td>Daylight</td>
<td>4.39</td>
</tr>
<tr>
<td>Condition of ceiling</td>
<td>4.38</td>
</tr>
<tr>
<td>Adequacy of size of bedroom</td>
<td>4.33</td>
</tr>
<tr>
<td>Door</td>
<td>4.30</td>
</tr>
<tr>
<td>Condition of house floor</td>
<td>4.29</td>
</tr>
<tr>
<td>Size of kitchen</td>
<td>4.20</td>
</tr>
<tr>
<td>Size of window</td>
<td>4.20</td>
</tr>
<tr>
<td>Internal painting</td>
<td>4.16</td>
</tr>
<tr>
<td>Plumbing installation</td>
<td>3.94</td>
</tr>
<tr>
<td>Overall house design</td>
<td>3.88</td>
</tr>
<tr>
<td>Drainage</td>
<td>3.75</td>
</tr>
<tr>
<td>Electricity/Electrical fittings</td>
<td>3.70</td>
</tr>
<tr>
<td>Overall mean</td>
<td>4.23</td>
</tr>
</tbody>
</table>

The results show that student-residents are more satisfied with buildings with adequate provision for ventilation, toilet and bath and natural daylight in that order. It is interesting from the result that these attributes take precedence over factors like the sizes of room, kitchen and window among others which are the main focus of SHFs development. This could be interpreted to mean that factors that enhance comfort and living and learning are rated more highly than those that do not. For example, the size of the window which is influencing the amount of ventilation and daylight that is admitted into a space is rated differently but lower. Other factors that likely influence the admission of ventilation and daylight into an enclosed space include the positioning of the window in relation to the direction of the wind and solar movement. From the foregoing, poor power delivery as revealed from the rating for electricity and electrical fitting may be responsible for the high rating for ventilation and daylighting.

Impact of Attributes on Loyalty Behaviour

Table 3 depicts the impact of the quality of the physical/dwelling attributes on the loyalty behaviour of student-residents.
Table 3. Mean Score of impact of attributes on loyalty behaviour

<table>
<thead>
<tr>
<th>Attributes of Physical/Dwelling Environment</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequacy of size of bedroom</td>
<td>5.79</td>
</tr>
<tr>
<td>Size of window</td>
<td>5.64</td>
</tr>
<tr>
<td>Size of kitchen</td>
<td>5.19</td>
</tr>
<tr>
<td>Size of toilet and bath</td>
<td>5.00</td>
</tr>
<tr>
<td>Condition of house floor</td>
<td>4.87</td>
</tr>
<tr>
<td>Drainage</td>
<td>4.86</td>
</tr>
<tr>
<td>Door</td>
<td>4.82</td>
</tr>
<tr>
<td>Condition of ceiling</td>
<td>4.79</td>
</tr>
<tr>
<td>Electrical fittings</td>
<td>4.79</td>
</tr>
<tr>
<td>Daylight</td>
<td>4.72</td>
</tr>
<tr>
<td>Plumbing installation</td>
<td>4.70</td>
</tr>
<tr>
<td>Internal painting</td>
<td>4.61</td>
</tr>
<tr>
<td>Ventilation</td>
<td>4.53</td>
</tr>
<tr>
<td>Overall house design</td>
<td>4.53</td>
</tr>
<tr>
<td>Overall mean</td>
<td>4.97</td>
</tr>
</tbody>
</table>

The result indicates that the sizes of the bedroom, window, kitchen and toilet and bath contribute highly to the loyalty behaviour of student-residents to SHFs. Whereas, factors like daylight and ventilation among others are shown to be least expected to commit a resident to remain or retain an accommodation. The implication of this contradiction could be explained to mean that though residents may derive higher level of satisfaction from certain attributes, it may however not be sufficient to elicit commensurate level of loyalty.

Correlation of Relationship between Satisfaction with Attributes and Loyalty Response of Residents to Attributes

The overall means of each of the attributes of the physical dwelling selected for investigation were correlated to determine the degree of relationship between satisfaction and loyalty behaviour of student-residents. A Pearson $\chi^2$ test shows that a significant relationship (0.862 at $p < 0.001$) exists between satisfaction with physical/dwelling attributes and loyalty behavior of student-residents. This result agrees with the study of Najib et al (2011) that a relationship exists between the contribution of the attributes of the physical/dwelling to satisfaction and impact on loyalty behavior of residents.

This result reveals that investors in private off-campus SHFs who provide attributes that are satisfactory to users are more likely to secure the loyalty of their tenants with a positive implication on resident retention. Furthermore, money is saved as it is observed that it cost more to get a profitable tenant than to retain an existing one.

Conclusions

The study focused on understanding the relationship between satisfaction with the attributes of the physical/dwelling residential environment and the impact on loyalty behavior of student-residents. The study examined how the selected 14 attributes of physical/dwelling building can be maximized in SHFs investment. Findings from this study could be used to promote investment in SHFs development. For example, ventilation and natural daylight are found to be strong predictors of satisfaction in SHFs, whereas, their contribution are not as significant in retaining the patronage and loyalty of residents. Generally, it could be inferred that the performance of attributes in terms of contribution to the satisfaction and impact on loyalty is not similar. It is suggested that in the development
of SHFs, a balance should be reached on the desired level of satisfaction and loyalty that is required as the attainment of one may not necessarily mean the fulfilment of the other. Further research is suggested to expand the scope of the study to cover the entire South-South, Nigeria so as to provide a basis for generalization.

References
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Emissions Management of Urban Earthmoving Fleets
David G. Carmichael¹, Lars O. Lea¹, and Maria C. A. Balatbat²

Abstract
Earthmoving has historically been managed based on minimum unit cost. However, consistent with the debate on climate change and new carbon legislation, there has been an emerging interest in also reducing carbon emissions. Studies exist for earthmoving fleets operating off-road, but little attention has been given to on-road and urban conditions involving general traffic. This paper analyses hauling emissions and costs in such conditions, and explores possible means of reducing these emissions through changing fleet size, truck size, haul schedule and haul route. It is shown, using field data, that for regular working hours and operations, reducing unit costs via fleet and truck size selection also results in reducing unit emissions, and that larger but fewer trucks result in less or the same emissions compared to bigger fleets with smaller trucks. That is, historical management practices of pursuing least cost will also impact the environment the least. Hauling during night hours, although resulting in lower unit emissions because of decreased traffic, is shown to be not presently cost effective because of labour rates and the current low price of carbon. The paper demonstrates choices and trade-offs that need to be considered when managing an earthmoving fleet in urban conditions.

Keywords: Earthmoving, costs, emissions, traffic, urban.

Introduction
The transport sector represents approximately 13% of global emissions (IPCC, 2007), 29% of which comes from diesel fuel whose predominant users are trucks, including those associated with urban construction servicing growing populations and the need for more and changed infrastructure. Truck movement consumes large amounts of fuel, and in doing so produces large amounts of emissions. To reduce these emissions, more efficient trucks and new technology are being embraced along with more efficient management. This paper addresses the last matter, and looks at the management of transporting construction materials and waste between loading and unloading urban destinations in repeated cycles.

Diesel exhaust emissions are a mixture of gases, vapours, liquid aerosols and particles, and include carbon dioxide, nitrogen, water, hydrocarbons, carbon monoxide, aldehydes, nitrogen oxides, sulphur oxides, and particulate matter (HSE, 1999). Emissions are given in this paper in terms of CO2 equivalents (CO2-e), which take into consideration most emissions produced by the combustion of diesel fuel through a conversion based on their global warming potential (GWP). Based on DIICCSRTE (2013), the combustion of 1 litre of diesel produces approximately 2.7 kg of CO2-e.

Truck fuel consumption and emissions are influenced by many variables such as starts and stops, time spent idling, acceleration, speed, haul distance, presence of traffic, and road surface and condition (Ding, 2000; Clark et al., 2002; NSCCAF, 2009; Carmichael et al., 2012, 2014; Kaboli and Carmichael, 2014a, b; Carmichael et al., 2014). Some of these are

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determined by the truck operator, some by the urban environment, and some by management decisions. Although the effects of these parameters individually on emissions have been studied, there are no data linking urban traffic density with hauling costs and emissions. This paper also explores the influence of truck size in an urban earthmoving fleet and traffic conditions on emissions and costs.

The paper first explores the transport, technology, usage and management backgrounds. Two case studies – road construction and cable installation – are then outlined and analysed. These lead to conclusions on emissions and cost relating to construction in an urban setting. The paper will be of interest to those who design and manage construction in urban areas. The paper is original in that no other equivalent studies appear to have been done.

Background

Transport. The relationship between burning fossil fuels, such as used in urban earthmoving fleets, and greenhouse gas emissions is well documented (IPCC, 2007, 2013). 13% of global emissions come from the transport sector (IPCC, 2007), and 95% of global transportation energy comes from the combustion of petroleum-based fuels (EPA, 2014). Diesel provides approximately 29% of the global transport energy and its usage is predominantly by trucks (Fulton and Eads, 2004). Heavy and medium freight trucks are responsible for 19% of energy use in the global transport sector (WBCSD, 2004). Since 1970, the direct emissions from transport have grown by over 120% (IPCC, 2007), and transport emissions are expected to continue to grow.

Within Australia, transport is the third largest emitting sector, responsible for 15% of total emissions. Approximately 85% of these emissions come from road transport (DCCEE, 2012). In 2011, transport emissions were 85 Mt CO2-e, 38% above 1990 levels and they are predicted to grow to 92 Mt CO2-e by 2030 (DCCEE, 2012).

The most direct way to reduce emissions is through reduced fuel use, since the burning of diesel fuel is directly responsible for the emissions. New technologies also exist to process the emissions produced. The variables that are said to most affect emissions from trucks include truck class and weight, driving cycle, truck usage, fuel type, engine exhaust after-treatment, truck age and the terrain travelled (Clark et al., 2002).

Considering a fleet of trucks cycling between defined origins and destinations, the total emissions are affected by: truck type and characteristics (including size, fuel consumption, load and material type, and maintenance); technologies; operator (speed, acceleration and gear-shifts selected); road condition (grade and roughness); traffic conditions (speed, acceleration, stoppages, and idle time); and management (efficient truck usage, haul route, fleet size, equipment matching, and idle time).

Larger trucks have a higher fuel consumption but need to make fewer trips to move a given load, resulting in lower total fuel consumption. Coonan and Woodward (2010) show that, with increasing truck payload, fuel usage per unit load decreases, emphasising the benefit of using larger trucks if possible.

Technologies. Technologies available to reduce fuel usage include:

- The use of aerodynamics via fairings and trailer streamlining, reducing drag (NSCCAF, 2009).
- Low rolling resistance tyres.
- Real-time on-board vehicle monitoring systems giving the current state of the vehicle, including temperature and fuel usage.

Technologies available to reduce emissions include:
- Exhaust after-treatment, for example combining an oxidation catalyst and a particulate trap (Clark et al., 2002).
- Engine modification so that the vehicle can use alternative fuels with higher efficiencies or lower emissions.
- Using a reformulated diesel or a diesel equivalent fuel, such as biodiesel, that does not require engine modifications (Clark et al., 2002; AR Fuels, 2014).
- Catalytic converters and modified fuels to reduce nitrogen oxides.

**Truck use.** Efficient truck use depends on many factors including:
- Engine operating parameters such as temperature and fuel quality.
- Load size – the optimum load size is not necessarily the most material that can fit in a truck's tray (RET, 2011).
- Tyre wear – this can create higher rolling resistance.
- Age and maintenance.

**Haul conditions.** Haul conditions that can affect fuel use include:
- Road condition – unsealed roads have a higher rolling resistance and hence lead to higher fuel consumption. Wet roads may also have a detrimental effect.
- Haul route – The fuel use is related to the length of the haul, although the speed along the route and the traffic present need to also be taken into account. A short haul route, which takes longer to traverse, may result in higher fuel use. Hauling up an incline increases fuel consumption (RET, 2011).
- Road occupancy licence (or similar name) – a permit issued by the local road authority that outlines the conditions under which the contractor may occupy the road. This includes the time, dates and type of work, traffic control plans and the duration that traffic may be stopped.
- Average speed, which may be governed by site restrictions, local speed limits or traffic conditions. Ding (2000) shows the influence of cruise speed on fuel consumption and emissions.
- Number of stops. With frequent stopping, as required by the layout of the road or by traffic conditions, fuel consumption and products of incomplete combustion increase. Ding (2000) shows the influence of number of stops on fuel consumption and emissions.

**Equipment matching.** For a fleet of trucks, cycling between defined origins and destinations, and working with an excavator, a balance is needed between the idle time of the excavator at the load point and the idle times of the trucks. Matching excavator and truck capacity, while also taking into account excavator cycle time, truck cycle time and truck fleet size, is desirable. If a fleet is under-trucked or over-trucked, either the excavator or trucks will spend too much time idling or non-productive, yet still creating emissions. Stockpiling might also be a possibility in some cases in order to reduce loading times.

**Operator.** The way in which a truck is operated impacts fuel consumption. Operation includes the selection of gears, driving speed, acceleration, switching a truck off instead of idling, and truck load. Aggressive acceleration consumes fuel as well as producing extra products of incomplete combustion. Ding (2000) shows the influence of acceleration on fuel consumption and emissions.
Management

When configuring a truck fleet, the aim traditionally has been to minimise the cost or cost per production (unit cost). Configuration and operation choices include:

- Excavator bucket size.
- Number of excavators
- Truck size.
- Number of trucks
- Dumping location
- Haul route
- Hours of operation

Main input assisting management choice decisions includes:

- Equipment (total owning and operating) hourly costs
- Equipment fuel consumption
- Local traffic conditions
- Local road conditions and restrictions
- Loading and unloading space requirements

This enables choices to be based on unit emissions (emissions/production), and unit cost (cost/production). Or these can be normalised through dividing by distance travelled by the trucks. A normalised cost is a cost per cubic metre per km; that is, the cost of hauling 1 m³ over 1 km. Normalised emissions are CO₂-e emissions per cubic metre per km. This is demonstrated on two case studies.

Case Studies

Two case studies are examined.

Case A. Road construction. Excavated soil was moved to other areas on- and off-site. Based on data collected, costs and emissions are calculated for a different sized trucks and different numbers of trucks. Different sized trucks require different loading times. Over longer hauls, the relative impact of extra loading time decreases. Different sized fleets lead to different truck idle times at the load point.

Case B. Cable installation. In the installation of an underground cable, excavated soil was hauled to another site. Based on data collected, costs and emissions are calculated for hauling during day and night traffic conditions. Daytime travel takes longer than night time travel, and this leads to lower production and higher costs. Because fuel is being consumed while a truck is stationary in traffic, and because truck fuel efficiency is greater at higher speed (Ding, 2000), fuel consumption will also be higher in daytime conditions.

Two types of hauling vehicles are involved in the case studies – a dump truck and a truck-and-dog. A dump truck has three axles, and empties via the elevation of the front of its tray. A truck-and-dog has a three-axle prime mover with a tray, towing a three-axle trailer with a tray; both trays are emptied by the elevation of their fronts, with the trailer requiring manoeuvring in order that it is not in the way when emptying the prime mover tray.

In the following, cycle time refers to the time taken for a truck to load, haul, unload, and return, together with any waiting and manoeuvring time at the load and unload points. Idle time refers to the time involved in manoeuvring, loading, unloading and waiting, as well as any time spent stopped otherwise. Travel time refers to time on the loaded haul and unloaded haul.

Case A. Road Construction

The urban project involved the construction of a 1.9 km road in order to connect two existing roads. There were one cut area and four fill areas (denoted Fill 1 to Fill 4). Some
of the soil from the cut was suitable to be reused in the fill areas; the remaining material required hauling to a dump site.

Dump truck characteristics: 5.7 m³; $85/h; 28 litres/100 km (specification).

Truck-and-dog characteristics: 14 m³; $130/h; 49 litres/100 km (specification).

**Cut to Fill 3.** One excavator and a fleet of 6 dump trucks were employed. Trip data were collected over a period of two weeks, involving 918 loads and 506 hours. Table 1 gives the summarised site data together with calculated values.

Table 1. Case A: Cut to Fill 3, dump truck, data and calculated values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>7.8 km</td>
</tr>
<tr>
<td>Average cycle time</td>
<td>33 min 4 sec</td>
</tr>
<tr>
<td>Average total idle time per cycle</td>
<td>3 min 25 sec</td>
</tr>
<tr>
<td>Average travel speed</td>
<td>15.8 km/h</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>4745 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$8.22/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$1.05/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>2.45 kg CO₂-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.314 kg CO₂-e/m³/km</td>
</tr>
</tbody>
</table>

The equivalent number of truck-and-dogs and their corresponding trips per day are estimated based on hauling the same amount of material as the dump trucks; the resulting cost and emissions are then calculated. Table 2 gives the corresponding values.

Table 2. Case A: Cut to Fill 3, truck-and-dog, calculated values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>7.8 km</td>
</tr>
<tr>
<td>Average cycle time</td>
<td>38 min 49 sec</td>
</tr>
<tr>
<td>Average total idle time per cycle</td>
<td>9 min 12 sec</td>
</tr>
<tr>
<td>Average travel speed</td>
<td>15.8 km/h</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>3458 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$6.01/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$0.77/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>1.78 kg CO₂-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.228 kg CO₂-e/m³/km</td>
</tr>
</tbody>
</table>

For the dump truck to haul the same amount as the truck-and-dog it must do more trips, the ratio of payloads being 14/5.7 = 2.45. That is, the dump truck must make 2.45 times the number of trips needed by the truck-and-dog. The travel time is assumed to be the same for both truck types, but there is additional idle time (extra loading and unloading time) for the truck-and-dog, assumed to be the same as in the following (Cut to Dump) data set.

The hourly cost of the dump truck is lower and the fuel consumption is lower, but the payload difference outweighs these and results in a higher normalised cost and higher normalised emissions. Both the normalised cost and normalised emissions are lower by approximately 25% for the truck-and-dog compared to the dump truck.

**Cut to Dump.** One excavator and a fleet of 5 to 7 truck-and-dogs were employed. One week (241 hours) of haul data were collected. During this time, 231 trips were made. Table 3 gives the summarised site data together with calculated values.
Table 3. Case A: Cut to Dump, truck-and-dog, data and calculated values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>37.8 km</td>
</tr>
<tr>
<td>Average cycle time</td>
<td>1 h 2 min 35 sec</td>
</tr>
<tr>
<td>Average total idle time per cycle</td>
<td>9 min 12 sec</td>
</tr>
<tr>
<td>Average travel speed</td>
<td>42.5 km/h</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>5258 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$9.69/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$0.26/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>4.39 kg CO2-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.116 kg CO2-e/m³/km</td>
</tr>
</tbody>
</table>

Equivalent dump truck calculations are given in Table 4.

Table 4. Case A: Cut to Dump, dump truck, calculated values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>37.8 km</td>
</tr>
<tr>
<td>Average cycle time</td>
<td>56 min 49 sec</td>
</tr>
<tr>
<td>Average total idle time per cycle</td>
<td>3 min 25 sec</td>
</tr>
<tr>
<td>Average travel speed</td>
<td>42.5 km/h</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>7323 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$14.12/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$0.37/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>6.10 kg CO2-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.161 kg CO2-e/m³/km</td>
</tr>
</tbody>
</table>

The comparison again shows that the truck-and-dog performs better in terms of unit cost and unit emissions (by approximately 28%) than the smaller dump truck.

Comparing Cut to Fill 3 with Cut to Dump, the longer haul with higher speeds and less stoppages performs better in terms of both unit costs and unit emissions.

Case B. Cable Installation

The project involved opening an existing road in order to lay an underground cable. The dump site was located approximately 10 km away, via urban streets and dense traffic. During different stages of the project, there were restrictions on when the work was allowed to take place, as outlined in the government-issued road occupancy licence.

Day operation. Excavation at one location occurred between the hours of 10 am and 3 pm, as specified in the road occupancy licence, in order to avoid the morning and afternoon peaks in traffic, and not inconvenience residents. An excavator and a fleet of 5 dump trucks were used. The dump trucks were the same, and had similar load and unload times as the dump trucks in Case A. Data over a 1-week period (125 hours) were collected, involving 162 trips. Table 5 gives the summarised site data together with calculated values.

Night operation. Excavation at another location occurred between the hours of 9 pm and 5 am, as specified in the road occupancy licence, in order to not block the heavily trafficked road during the day. An excavator and a fleet of 4 dump trucks, of the same type as the Day operation, were used. Data over a 1-week period (160 hours) involving 249 trips were collected. For Night operation, the contractor allowed a 50% increase in costs.
because of the higher night labour rates required. Table 6 gives the summarised site data together with calculated values.

Table 5. Case B: Day operation, data and calculated values.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>9.9 km</td>
</tr>
<tr>
<td>Total volume</td>
<td>923 m³</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>1520 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$11.51/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$1.16/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>4.44 kg CO₂-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.449 kg CO₂-e/m³/km</td>
</tr>
</tbody>
</table>

Table 6. Case B: Night operation, data and calculated values.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck cycle distance</td>
<td>9.5 km</td>
</tr>
<tr>
<td>Total volume</td>
<td>1419 m³</td>
</tr>
<tr>
<td>Total fuel use</td>
<td>2290 litres</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$14.37/m³</td>
</tr>
<tr>
<td>Normalised cost</td>
<td>$1.37/m³/km</td>
</tr>
<tr>
<td>Unit emissions</td>
<td>4.35 kg CO₂-e/m³</td>
</tr>
<tr>
<td>Normalised emissions</td>
<td>0.415 kg CO₂-e/m³/km</td>
</tr>
</tbody>
</table>

A comparison of Tables 5 and 6 shows that the normalised cost of hauling during the day is lower (approximately 15%) than hauling at night, primarily because of the increased labour rates at night. However, for emissions the reverse applies – night work gives lower (approximately 8%) normalised emissions than day work, primarily because of the absence of traffic, and the ability of the trucks to travel faster with less stops.

Traffic counts on the roads travelled by the dump trucks show morning and afternoon peaks with a plateau in between, and small vehicle counts at night. The Day operation coincides with the plateau between morning and afternoon peaks. The Night operation corresponds with low traffic volumes. See Figure 1.

![Figure 1. Hourly traffic distribution – average vehicle numbers per hour (RMS, 2014).](image)
Discussion

Case A. Road Construction. Case A results show that normalised cost and normalised emissions decrease in line with:

- Larger trucks.
- Larger cycle times (where idle time is a smaller proportion of the total cycle time).

Simulations, varying the truck cycle time, give the results in Figures 2 and 3.

Figure 2. Unit cost; simulation; upper – dump truck, lower – truck-and-dog.

Figure 3. Unit emissions; simulation; upper – dump truck, lower – truck-and-dog.

For normalised cost, at very small haul durations, the smaller dump truck is the better alternative, but for more usual haul times, the larger truck-and-dog becomes more economical. For normalised emissions, the larger truck-and-dog is always better.

Case B. Cable Installation. Figure 4 shows the change in normalised emissions with change in traffic density. Average speed, number of stoppages and idle time all contribute to fuel consumption. With higher traffic levels, the average speed decreases while the number of stoppages and idle time increase.
Hauling at night results in a higher production, and this can be almost entirely attributed to the faster haul times because the loading and unloading times remain unchanged whether day or night. However, this increased production is not enough to outweigh the extra labour cost of night work. Without this extra labour cost, night operation would lead to a lower normalised cost.

**Conclusion**

Under ordinary operating conditions, the least unit emissions solution coincides with the least unit cost solution. This only changes with increased labour rates resulting from night work, and may change if non-ordinary constraints existed on the earthmoving operation. Accordingly, in order to impact the environment the least, contractors should continue historical management practices of minimising unit costs.

The case studies demonstrated the following:
- A smaller fleet of larger trucks results in lower emissions and costs than a larger fleet of smaller trucks.
- Normalised emissions and normalised cost decrease with longer truck cycles, with the reduction more worthwhile for very long cycles.
- A direct link, as anticipated, exists between traffic conditions and emissions.
- Additional labour rates for night work (low traffic conditions) are not matched by the reduction in emissions at current carbon prices, or an increase in production.

**Future work.** The effect of individual operators on production and fuel use was not examined. The manner in which a truck is driven can influence both fuel use and production. The study looked at average operator behaviour only.

The emission of products resulting from incomplete combustion of diesel fuel increases at lower speeds and with higher acceleration. A detailed emission breakdown of products, rather than only looking at CO2-e based on the fuel consumption, would be helpful in showing the effects of traffic in more detail.
References


Lean Leadership Paradoxes: A Systematic Literature Review

Hend Amer¹ and Corrinne Shaw²

Abstract

Paradox is used in organizational studies to describe the tensions between two seemingly opposite entities that are in fact complementing each other. Leadership has been shown to deal with such dualities on a daily basis. The transformation process required for implementing Lean principles in manufacturing organisations, involves leadership paradoxes in their pursuit for successful Lean transformation that adds value for their organizations. This article documents a systematic literature review with the objective of investigating the extant literature on the subject that falls under the umbrella of “Lean Leadership Paradoxes”. The review is limited to peer reviewed using search terms such as lean, leadership, lean leadership, leadership paradoxes, and lean leadership paradoxes. The research has found that limited research was conducted on Lean Leadership and leadership Paradoxes while research on Lean leadership paradoxes is almost non-existing in academic journals. The value of this study lies in 1) highlighting the gaps in this body of knowledge and 2) identifying areas for possible future academic and practitioner research.

Keywords: Duality, leadership, lean, literature review, paradox.

Introduction

Reviewing the Literature

Systematic literature reviews are significant tools for researchers who aspire to make meaningful contributions to the body of knowledge. According to Webster and Watson (2002) the review of previous, pertinent literature is a fundamental part of any academic development. They claimed that an effective review generates the groundwork for emerging knowledge, enables theory building and reveals areas where study is needed. Tranfield, Denyer and Smart (2003) had accused the traditional narrative literature reviews of lacking the means for making sense of what the collections of studies are saying and that they can be biased by the researcher and often lack rigour. They claimed that systematic literature reviews, on the other hand, are transparent and reproducible. Hence, in order to embark on a new research project, one has first to acknowledge the existing literature in a manner that is systematic and analytical enough to highlight what has been researched, how it was researched and what areas are still in need of exploration.

Lean Leadership Paradoxes

Since the release of the book The Machine that Changed The World by Womack, Jones and Roos (1990), great interest has been shown in implementing Toyota Production Systems or “Lean Production” and in using it to replace the conventional Mass Production Systems (Stone, 2012). Although Toyota has been open about its method and has cooperated with all the researchers, the implementation of Lean concepts has been very

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² Senior Lecturer, Department of Mechanical Engineering, University of Cape Town, Private Bag X3 Rondebosch 7701 South Africa, Tel: +27, Fax: +27 216503240, corrinne.shaw@uct.ac.za
illusive (Spear & Bowen, 1999). After almost 25 years, very few companies managed to implement Lean. While some companies have managed to partially implement Lean concepts, the majority has faced difficulties and sometimes failed to achieve the full benefit of Lean as concluded by Jadhav, Mantha, and Rane (2014), Mclean and Antony (2014), and Sim and Rogers (2009).

According to Bhasin and Burcher (2006), the successful implementation of Lean can only materialise when Lean is not treated as a strategy but as a philosophy that involves major changes in the organization, not only on the shop floor but it extends to the whole organization. According to L. S. Lüscher, Lewis, and Scher (2008) these changes are often commissioned by higher management in order to achieve process improvements but in order to complete the implementation successfully, managers and leaders are faced with paradoxical decisions on a daily basis.

Those paradoxical decisions include the promotion of stability in order to realize changes in the culture; insisting on efficiency in order to promote creativity; or holding onto the old in order to embrace the new. These paradoxical decisions have been identified and discussed by several researchers such as Farjoun (2010), Johnston (2005), Lavine (2014), Lewis (2000), Lüscher and Lewis (2008).

Background

Lean Definition

Stone (2012) described the term Lean Production as referring to the manufacturing techniques developed over the past 100 years by Toyota Motor Company. Although many researchers refrain from giving a definition for Lean, it is defined by Scherrer-Rathje, Boyle, and Deflorin (2009, p. 79) as “a management philosophy focused on identifying and eliminating waste throughout a product entire value stream, extending not only within the organization but also along the company’s supply chain network”. Differently, Lander and Liker (2007, p. 3681) define Lean as a “philosophy comprised of set of general principles of organizing and managing an enterprise which can help any organization get on a path of positive learning and improvement”.

Lean Leadership

Flinchbaugh, Carlino, and Curtis-hendiey (2008), Katz (2012) and Pamfilie et al. (2012) agreed that Lean leadership refers to a manager or a leader that is fully aware of Lean tools, the vision of the organization and knows how to communicate those to his subordinates. Supportive of this concept, Mann (2009) strongly claimed that implementing the Lean tools comprises only 20% of the effort in Lean transformation. The remaining 80% of the effort is expended on changing the leaders’ practice and behaviour and ultimately their mind-set. Similarly, Dombrowski, Mielke, and Engel (2012) claimed that the implementation of Lean is more than the redesigning of some production systems, and that actually the most essential change has to be made in people’s knowledge. Dombrowski and Mielke (2013, p. 570) defines Lean leadership as a “methodical system for sustainable implementation and continuous improvement of Lean production system”.

Organizational Paradoxes

In contrast to the learnings of Aristotle, Descartes and Newton, that seek a single solution, paradox is when two seemingly opposites but independent solutions exist and they are inseparable (Johnson, 1998 and Lewis, 2000). The concept of opposite forces coexisting together and reinforcing each other is very evident in the Yin Yang symbol of the Taoist
culture. Yin is femininity, intuition, and dark which when it escalates to its maximum, it still retains part of its opposite, Yang, which represents masculinity, rationality and light. According to Taoism, the tension between those opposites is what is keeping the balance of this world.

In ‘1990s, organization studies showed interest in paradox as a theory. Lewis (2000) divided paradoxes in organizations into 3 types: 1) learning paradox, which addresses the paradox of holding to the old knowledge vs. building the new; 2) belonging paradox, that addresses the conflict between self vs. others; and 3) organizing paradox which is related to creativity vs. efficiency. On a different note, the management of paradox was defined as “managerial practices that realize the simultaneous accomplishment of multiple strategic objectives that are seemingly or actually incompatible” (Yoon & Chae, 2012, p. 3501).

**Lean Leadership Paradoxes**

Lean implementations are times of change, stress and high uncertainties. Lüscher and Lewis (2008) argued that managing change has become the ultimate managerial responsibility. They also claimed that even though firms continuously engage in some form of change, yet major change projects rarely claim significant success. Lean concepts are paradoxical in nature. In his article Womack and Jones (1994) discussed the conflict between specialization and cross functionality which according to Johnson (1998) and Lewis (2000) is a paradox that needs to be managed. In another article by Scherrer-Rathje et al. (2009), the authors showed a case of management hesitation to being transparent about the company long term objectives as opposed to revealing information which is a paradox of control versus autonomy. In their paper Spear and Bowen (1999) discussed how from within efficiency Lean practitioner find creativity and paradoxically achieve continuous improvement. Manderscheid and Freeman (2012) asserted that the need for polarity management is essential for successful transitions. Francis, Bessant, and Hobday (2003) also stressed the need for paradox management during organizational transformation and continuous improvement efforts.

While the literature available on Lean in general is expansive, the literature on leadership roles in successful Lean, and particularly polarity and paradox management practiced by the Lean leaders is quite limited.

**Research Purpose/Question**

Seuring and Gold (2012) claimed that the relentlessly increasing research which delivers large numbers of similar yet divergent and conflicting findings makes critical literature reviews a fundamental tool for exhuming the knowledge that lie concealed underneath. Lean has been researched in manufacturing, healthcare, services and the public sector fields. It has also been researched in several countries of the world, consequently creating a diversified research base. Similarly, organizational studies and management research has studied paradox extensively. Despite this wealth of research output available about the two areas separately, we are faced with dearth in literature addressing both areas combined.

The aim of this systematic review is to collect, organize, analyse and categorize the literature available to the researchers about “Lean leadership” and “leadership paradoxes” in order to build a knowledge base for “Lean leadership paradoxes”. As explained by Webster and Watson (2002), a valuable literature review is the one that can demonstrate how the review extends past research to draw implications for practice and future theorizing. As a result the following questions guided this literature review:

- What are the available literatures in “Lean leadership”, “leadership paradoxes” and “Lean leadership paradoxes”?
Where are the gaps in the knowledge and areas for future research?

Methodology
The methodology used in this paper is a systematic literature review as derived by Tranfield, Denyer and Smart (2003). This methodology is later refined by Easterby-Smith, Thorpe and Jackson (2012) into two processes:

- Defining your research interest, retrieving and judging the relevance of the material to your study.
- Analysing and reporting the finding to identify the gaps in the literature.

Planning the Review
This section records the preparation and administrative work needed to be completed before conducting the systematic literature review. This plan explores in details how the subject will be researched.

Define the Key Search Terms
The first step in this review was to define the search terms to be used. We have started with researching Lean, Lean production, Toyota Production Systems and Toyota Way. The second term was leadership and management which combined together helped us in searching Lean leadership in literature. The third group of terms was paradox, polarity or duality and it was searched combined with leadership, management and Lean in order to investigate leadership paradoxes, polarity management and lean paradoxes. The search target of “Lean leadership paradoxes” was also used.

Develop the Review Protocols
This search was conducted electronically using several highly recognized search databases available to the researchers. The databases searched were Academic Search Premier and Business Source Premier through EBSCO Host, Emerald, Engineering Village, ProQuest, Science Direct, Scopus and Web of Knowledge. This search scanned all available documents without limiting the time period but it was limited to journal articles published in peer reviewed academic periodicals.

Conducting the Review
This section discusses how the data retrieved, the eliminations and the final list of research to be reviewed.

Research Retrieved
The search was conducted on three steps to ensure that the literature reviewed is limited to lean leadership paradoxes in manufacturing. First step was simply running the search terms on the selected database and retrieve the results. The second step, was disregarding duplication and the third step was eliminating articles related to services, health care, construction and public services. After those three steps, the research retrieved in total 54 articles.

Research Eliminations
The articles collected was then revisited based on the title and abstract to ensure the relevance of the literature to the topic researched. The key determinant for inclusion was the research that brought insight into the role of leadership in successful Lean transformation, and polarity management. This revision resulted in narrowing the study list.
to 46. Those 46 articles were then read thoroughly to compare and analyse the main ideas in every research and then categorize them based on common ideas.

**Findings**

From the 46 articles retrieved, 21 discussed the successful Lean leadership, another 16 discussed the leadership and management paradoxes in general, and only 9 discussed the paradoxes encountered by management or leadership during Lean transformation. Due to the scarcity of literature available on Lean leadership paradoxes, the researchers decided to review literature on Lean leadership, leadership paradoxes, and Lean paradoxes separately as a mean of creating a full review that covers the existing research in order to understand what has been written under the umbrella of Lean leadership paradoxes.

**Lean Leadership in Literature**

The first results of lean leadership search resulted in 21 peer reviewed articles. Those 21 articles are categorized and summarized in table 1.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Major References Reviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barriers to Lean implementations</td>
<td>Jadhav, Mantha, and Rane (2014), Mclean and Antony (2014), and Sim and Rogers (2009)</td>
</tr>
<tr>
<td>Importance and role of leadership in Lean</td>
<td>Emiliani (2008), Francis, Bessant, and Hobday (2003), Katz (2012), Mann (2009), Pamfilie, (Draghici), and Draghici (2012), Poksinska, Swartling, and Drotz (2013), and Scherrer-Rathje et al. (2009)</td>
</tr>
</tbody>
</table>

The first category refers to the critical success factors for Lean implementations. Achanga et al. (2006), Habidin and Yusof (2013) and Hilton and Sohal (2012) claimed that Lean success factors are leadership, communication, organizational culture, organizational support, strategy, training, competency of Lean experts, project management, performance evaluations, information systems, and finance. Correspondingly, Laureani and Antony (2012) argued that the most important factors are: management commitment, cultural change, linking Lean to business strategy and leadership styles. An article by Martínez-Jurado and Moyano-Fuentes (2014) states that Lean success is due to deep-rooted culture of total quality, the Lean leader role and institutional support. Psychogios and Tsironis (2012) stated that leadership and strategic orientation, quality-driven organizational culture, continuous training, teamwork, customer satisfaction, and technical systems are the main success factors for Lean transformation. Similarly Timans et al. (2011) confirmed that the highest ranking critical success factors are linking to customer, vision, communication, management involvement and participation and it revealed three new critical success
factors: personal Lean Six Sigma experience of top management, development of the project leader’s soft skills and supply chain focus.

The second category is the literature investigating the barriers to Lean implementation. The first paper by Jadhav et al. (2014) is a literature review which claim that appropriate application of Lean tools and techniques will not ensure successful Lean transformation without top management involvement and leadership, worker’s attitude, resources and the appropriate organizational culture. The second paper is also a literature review by Mclean and Antony (2014) which claims that 8 core themes contributed to the failure of continuous improvement initiatives: motives & expectations, organisational culture & environment, the management leadership, implementation approach, training, project management, employees involvement levels, and feedback and results. Lastly Sim and Rogers (2009) in a case study added new barriers to lean transformation which are the aging and high seniority workforce and lack of committed leadership.

The next category discusses the details of the role of leadership in successful Lean implementations. Emiliani (2008) suggested that introduction of the concept and practice “standardized work” to the executive-level leadership duties improves Lean leadership capabilities and effectiveness. Likewise Katz (2012) debated that Lean leader should serve as a Lean coach or mentor to key staff members. Mann (2009) argued that sustaining Lean success requires a change in mind-set and behaviour among leadership, and then gradually throughout the organization. Pamfilie et al. (2012) suggested that Lean leaders’ knowledge of the tools otherwise their team members will not exert the required efforts for lean success. Interestingly, Poksinska et al. (2013) monitored a radical change in the manager’s role during Lean implementation from managing processes to developing and coaching people. The last paper in this category by Scherrer-Rathje et al. (2009) concluded that Lean success lessons are: 1- Visible top management commitment, 2- Encourage autonomy, 3- Openly disclose mid- to long- term Lean goals, 4- Mechanisms for long-term sustainability 5- Communicate Lean wins, 6- Continual evaluation of Lean efforts

The last category develops the concept of Lean leadership and debates in details the components of Lean leadership and their role. The first paper addressing Lean leadership is by Emiliani and Stec (2004) and it was later used by Flinchbaugh et al. (2008) in another article. But it is Dombrowski et al. (2012), and Dombrowski and Mielke (2013) that argued that Lean leadership have to develop others and that building the qualification of employees is a fundamental task in Lean leadership. In another paper Dombrowski and Mielke (2014) constructs 15 practice oriented requirements and frames them as rules for Lean leadership to support their daily efforts toward a true continuous improvement.

Leadership Paradoxes in Literature

The database search on leadership paradoxes resulted in 16 peer reviewed articles. The highlights of these literatures are summarized in table 2.

The first category refers to the evolution of paradox theory in organization’ studies and the framework for its application. The first paper by Lewis (2000) defines paradox as contradicting yet interrelated elements or elements that seem logical in isolation but absurd and irrational when appearing simultaneously. The second paper by Manderscheid and Freeman (2012) surveyed the literature relevant to leader transition and related polarities, paradoxes, and dilemmas which exist in organizations. The researchers found literature about leaders in transition and about polarity management but nothing on the combined subject. Lastly, Lavine (2014) addressed the relationship between leadership and paradox and explored the utility of the competing values framework to develop leadership skills from a paradox perspective. The research also identifies that the capacities of awareness,
exploration, and interpretation as possible resources for paradoxical conceptualizations of leadership.

Table 2. Leadership and management paradoxes in literature

<table>
<thead>
<tr>
<th>Categories</th>
<th>Major References Reviewed</th>
</tr>
</thead>
</table>

The second category discusses the different paradoxes in management. Cunha and Cunha (2010) and Farjoun (2010) both addressed the paradox of stability and change, while Coetsee (1999) and Dent and Goldberg (1999) discussed the managers’ dilemma between resistance to change and commitment. An article by Judge and Blocker (2008) investigates the paradox of exploitation and exploring of market opportunities. On the other hand, Francis et al. (2003) discussed organizations during radical change which is the paradox of change vs. stability and of old versus new. Biloslavo et al. (2013) argued that organizations which are able to transcend the duality paradox enhance their effectiveness or/and efficiency. In this article, the authors identified and examined 21 dualities at the normative and strategic level of organizational policy. Similarly, Hunter et al. (2011) identified 14 tensions or paradoxes, associated with leading innovative endeavours.

The last category is paradox or polarity management and how it can facilitate the leader’s job. The literature by Johnson (1998) explains the difference between problem solving and polarity management. He suggested an approach to analyse the paradox and then manage the tensions to maximize gain. Bloodgood and Chae (2010) used the polarity management in organizational learning. Glunk and Follini (2011) showed in their paper how polarity coaching can foster meaningful change among executives through understanding and acceptance of interdependent opposites. On the other hand Griffin and Gustafson (2007) shared the learnings from a case study of a company embracing paradoxes and training its leaders on polarity management. Lastly, Yoon and Chae (2012) in their paper attempted to address paradox management in two organizational mechanism: decision-making structure and human resource practices.

**Lean Leadership Paradoxes**

Searching for peer reviewed academic literature about the paradoxes encountered by leaders during Lean implementation and how they are managed proved to be a very challenging task. The search only yielded 9 articles. The limited research results do not allow categorization but could be studied on a timeline to show how the research evolved. This chronological evolution is shown in table 3.
Table 3. Lean leadership paradoxes in literature

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>References reviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>Thompson and Render</td>
<td>A balanced analysis of the emergence of Lean system in UK and the paradoxes it raises</td>
</tr>
<tr>
<td>1998</td>
<td>Obloj and Thomas</td>
<td>The paradoxes of transforming former state-owned companies into Lean</td>
</tr>
<tr>
<td>1999</td>
<td>Adler, Goldoftas, and Levine</td>
<td>A case study of model changeovers in Toyota: flexibility vs. efficiency</td>
</tr>
<tr>
<td>2001</td>
<td>Repenning and Sterman</td>
<td>The paradox of creating and sustaining improvements in Lean</td>
</tr>
<tr>
<td>2005</td>
<td>Videla</td>
<td>Structural constraints to implementing Lean in third world countries.</td>
</tr>
<tr>
<td>2006</td>
<td>L. Lüscher, Lewis, and Ingram</td>
<td>The social construction of organizational change paradoxes</td>
</tr>
<tr>
<td>2008</td>
<td>L. S. Lüscher et al.</td>
<td>Using paradox and polarity management for sense making during Lean implementation</td>
</tr>
<tr>
<td>2011</td>
<td>Heston and Phifer</td>
<td>The multiple quality models paradox: how much ‘best practice’ is enough?</td>
</tr>
<tr>
<td>2014</td>
<td>M. Lewis, Andriopoulos, and Smith</td>
<td>Using paradoxical leadership to enable agility</td>
</tr>
</tbody>
</table>

The first article retrieved that discusses paradoxes in Lean implementation is by Thompson and Render (1995) which discusses the case of implementing Lean in Nissan UK and the different paradoxes pertained to it. The second was a research conducted by Obloj and Thomas (1998) that discussed the paradoxes encountered during the transformation from state-owned-company into a privatized market competitor. The next articles is another case study by Adler, et al. (1999) who discussed the paradox of flexibility vs. efficiency during model changeovers in Toyota Production systems. Repenning and Sterman (2001) then discussed the improvement paradox of creating and sustaining improvements in organizations. Four years later Videla (2005) presented a paradox in garment industry in Mexico that by implementing Lean instead of becoming a flexible producer, a successful export manufacturer devolved into a sub-contractor, and eventually closed its doors. In the next paper L. Lüscher, et al. (2006) discussed the theoretical framework of paradox in Lean implementations and the most important finding in this paper is that understanding paradox does not solve problems, but rather opens new possibilities and sparks circles of even greater complexity. Lüscher et al., (2008) then published an action research conducted to implement paradox management for sense making during Lean implementation. The next paper by Heston and Phifer (2011) discusses the fact that organizations are struggling with several process improvement efforts at the same time. The paper seeks to find a suitable balance between process maturity and excessive complexity. The last paper is a very recent one by Lewis et al. (2014) which claims that strategic agility evokes contradictions, such as stability vs.
flexibility, commitment vs. change, and established routines vs. novel approaches. The paper suggests that such competing demands pose challenges that require paradoxical leadership and practices that seek creative, both/and solutions that can enable fast paced adaptable decision making.

Conclusion

This systematic literature review was conducted to better understand what research has been done in the area of “Lean leadership paradoxes”. As pinpointed by Webster and Watson (2002) emphasizing the discrepancy between “what we know and what we need to know” alerts other researchers to prospects for key contributions. This study provides a starting point for investigating a relatively new area of research that evolved from adding the paradoxical lens to the successful lean leadership practices.

The review found that although research in Lean, leadership and paradox separately has been extensive, however, combining the three areas together is fairly new. There have been some research in Lean leadership and also research into leadership paradoxes but far from being complete or thoroughly investigated. The review also found that very few research has been conducted on leadership paradoxes and polarity management practice in Lean or continuous improvement efforts.

This paper value is in pointing a new research area that could be of interest for scholars specialized in production engineering, management theories, or organization studies as a comprehensive field and researchers interested in Lean, polarity/paradox/duality management, leadership as particular areas. The research area is almost uncharted and could be explored from different perspectives.

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Applying the Lens of Complexity Theory to Project Management

Ian Jay, Nien-Tsu Tuan, and Mark Massyn

Abstract
The authors argue that the traditional way of regarding project management is too mechanistic and is rooted in an inappropriate paradigm of command and control thinking. The alternative paradigm is to view projects as complex systems and the outcomes of the project as emergent properties of the system. This alternative paradigm presents a challenge to the organization learning process. Learning happens through the ‘double loop’ process and the knowledge is held as procedural norms in the organization. This creates a paradox, the procedures are mechanistic structures embodied in the project methodology and because of their inherent nature they cannot accommodate complexity. The authors suggest the use of Interpretive Structural Modelling (ISM) as a means of overcoming the difficulty. Our argument is that through the frequent use of concept modelling tools through the duration of the project as well as the front end, a manager can navigate project to more successful outcomes.

Keywords: Complexity, emergence, project management.

Introduction
Complexity theory is a response to the mechanistic and reductionist approach or paradigm that we use to explain our world (Dann and Barclay, 2006). Management literature has traditionally focused on prediction and control based on an underlying belief that “interactions can be described in linear terms” (Lissack, 1999). This paper first argues that the mechanistic paradigm is reflected in the modern approach to project planning and management, particularly at the front end where many critical decisions are made. This position is supported elsewhere in the literature (Cicmil et al., 2006; Smyth and Morris, 2007). The paper then argues that in reality different environmental conditions create different kinds of issues that need to be addressed, and this implies that the project design should be contingent on the conditions it encounters (Shenhar and Dvir, 2004). In addition the design needs to take account of the fact that emergent behavior will arise from the particulars of any specific project (Lissack, 1999).

The typical modern project uses a standardized set of planning and execution processes (Shenhar and Dvir, 2007). The standardized approach takes the view that the project objectives are pre-set, usually being provided as part of a document issued by the project sponsors (PMI, 2013). This approach does however lead to a variety of problems (Thomson, 2011). The approach arises from a belief that claims there is a general pattern to the appropriate way to manage a project (Smyth and Morris, 2007). A problem with this kind of project design is that insufficient time is spent on defining the question the project sets out to address and developing a robust definition of the projects requirements (Morris, 2009). This problem can be attributed to the main focus of the various guides or bodies on knowledge,
these documents focus on the planning and execution stages of the project with little attention paid to gathering and monitoring requirements (Smyth and Morris, 2007).

**Front-End Ambiguity**
When the project begins a set of ‘success criteria’ may be articulated, these usually include budget and schedule constraints and some statement of the expected outcomes (Atkinson, 1999; Ivory and Alderman, 2005). Such statements of requirements inevitably result in conflicting demands leading to compromises being made by project teams (Ivory and Alderman, 2005). The approach at this point of the project is already weakened due to this failure to actually articulate the desired outcomes in a coherent way. Poor quality specifications and misunderstanding by the project team are examples of the kind of problems that may arise (Deane et al., 1997). In some cases the project evaluation criteria omit the production of a successful product, service, or benefits, and simply focus on measures of the execution of the project itself as if this was the sole objective of the undertaking (Cooke-Davies, 2004). The outcomes are effectively left as “*an emergent property of peoples different attitudes and beliefs*” (Atkinson, 1999: 337). The stated outcomes may be inappropriate solutions to the problem being addressed. For example an organization may state a requirement for major systems changes when the appropriate solution involves implementation of a new replacement technology (Deane et al., 1997). Customer uncertainty regarding the appropriate solution gives rise to inappropriate project and contractual requirements that fail to address the long term problems faced by the client organization.

Further deviations from the client’s vision of the outcomes arise when the project team fail to translate the requirements into an effective solution and project plan because they have not suitable skills or experience (Deane et al., 1997). Even in situations where planning is of a high standard and shown to be a significant contributor to project success, the planner may make “*significant changes as well as to improve the baseline for future control purposes*” (Zwikael and Globerson, 2004: 1545).

Some suggestions have been made to address these problems. One advocates the application of Value Management techniques to elicit and capture requirements. It then proposes a Programme Management framework to manage the requirements across the life-cycle of the project and between related projects (Thiry, 2002). The requirements problem has been recognized elsewhere and approaches such as Scenario Planning (van der Heijden, 2009) and Soft Systems Methodology (Winter, 2009) have been proposed as potential solutions. Another author proposes the application of a variety of tools at different points during the project front-end (Andersen, 2009).

**Project Execution and Emergence**
Once the project is under way, a variety of effects come into play which give rise to emergent phenomena, these are not usually reflected in the project plan nor anticipated by the project planners. Emergent phenomena are events or properties of a system that arise because of interactions between system components. Emergent properties range from simple and predictable outcomes of physical systems, through to quite complex and un-predictable outcomes arising from social systems (Halley and Winkler, 2008). To illustrate this point, an aircraft is a complicated system with predictable characteristics, whereas human organizations or groups are complex and their behavior is not easily anticipated (Snowden, 2003). Social systems are regarded in the lexicon of complexity theory as complex adaptive systems (Schneider and Somers, 2006). The effects observed from interaction and reaction between components of these systems, and the system and its environment are not easily predicted.
Internally these effects arise due to the nature of projects which can typically be seen as a rapidly evolving socio-technical network spread over a number of nodes or activity centers (Ivory and Alderman, 2005). In such an environment it is unrealistic to expect planners to have designed procedures and controls for all eventualities. And the conflicts and contradictions that inevitably arise are not prevented by such planning. This reality has resulted in the suggestion that “project execution may be thought of as a process of constantly adjusting the project system to fit a confounding and emerging reality” (Ivory and Alderman, 2005: 8). In such circumstances the manager is not able to use command and control methods and is restricted to influencing the situations arising in the project (Lissack, 1999). This can happen due to inadequate project controls, lack of expertise in the team, uncontrolled external interventions, and uncontrolled scope creep (Deane et al., 1997). The project goals may be fixed but the metaphorical terrain being navigated to reach them is always changing.

The practical question is how can we understand this changing landscape, what are the underlying drivers that shape it and change it? One response is to look to the intermediate processes that link the mechanistic plan to the actions of various project actors. These include processes known to us through systems thinking and game theory which explain phenomena that include feedback loops, non-linear responses, and stocks and flows (Boschetti et al., 2011).

Before continuing with the discussion it is worth noting that projects may deal with issues that are purely internal to the organization. However, there is a class of projects that are linked to organization strategy and through that link to the broader environment. Where environments change for the organization, the goals of projects involved in strategy implementation may change or lose relevance. Such changes add a dimension to the complexity faced by project managers. To a certain extent such changes can be addressed through the rigorous application of risk management and also by containing the scope and time frames of projects to manageable levels. This latter approach has been positively linked to project success rates (Cooke-Davies, 2002). Interestingly, empirical research indicates that risk management along with communications is the point of greatest weakness in project plans (Zwikael and Globerson, 2004).

An example of the processes described above is the case of a low-cost housing project in South Africa (Lizarralde and Massyn, 2008). Due to social isolation a community experienced barriers to accessing health and education facilities. The response of the community was to initiate a housing development through the government supported people housing process. This procurement model “explicitly promotes active participation of the beneficiaries in the development of mutual self-help projects supported by local or international NGOs” (Lizarralde and Massyn, 2008: 3). An NGO did become involved and it took over the project management as well as the design role for the development. The original functional designs for the housing units were subsequently changed which resulted in poor land use. As a result of the NGO taking over the project the community involvement was substantially reduced. The end result was a housing design with limited ability to expand to meet the growth needs of the family and no provision for home industry use. Due to the pre-existing infrastructure around the site, several high-speed highways, the community remains isolated from its immediate neighbors.

**System Effects on Project Execution**

The housing development example described above clearly illustrates the problem of inappropriate selection of a solution to the problem. The isolated community remained isolated in their new homes. The process of creating the project diverted attention away from the social issue to the problem of finding suitable space for development (Lizarralde and Massyn, 2008).
Once the location problem was addressed the issue of housing design came up. The original design conceived by the beneficiaries was for ‘row-houses’ with substantial space for expansion behind the housing unit. The NGO had stated reservations about local practices of shack building and had positioned the eventual designs, detached and semi-detached, to minimize the potential for expansion (Lizarralde and Massyn, 2008).

What this tale relates is a history; the narrative begins with an isolated group in need of basic housing. The required housing units need to be designed to accommodate physical extension at a later date. The tale ends with a community in formal housing located and designed in such a way that future extension is impractical, located in a geographically isolated area.

The ‘story’ above is about a community that moved into formal housing. However, the term community implies some form of homogenous entity. It has been pointed out that in fact the term has many meanings, and a community is “seldom, if ever, homogenous” (Emmett, 2000: 503), this is also true in the case of many construction projects (Thomson, 2011). In addition, when community engagement occurs, the active engaged members are likely to be doing so for personal reasons rather than the overall good of the community (Emmett, 2000). This suggests that when this ‘community’ is engaged one can expect processes such as feedback loops, games such as prisoner’s dilemma, and so on to become active in regard to the project. These are the processes that support emergent phenomena, and it is the emergent phenomena that we observe when looking into a project.

A commonly observed phenomenon with developmental projects is a loss of engagement or interest among the community participants as the project unfolds (Emmett, 2000). In fact the lack of predictability about the emergent nature of participation on these projects is what one would expect when observing a complex non-deterministic system (Johnson, 2006).

**Emergence and Emergent Phenomena**

Emergence can be described in simple terms as a property of a substance that is not present in the individual components that make up that substance (Corning, 2002). From a project management perspective, emergent phenomena are behaviors exhibited by groups or teams, teamwork, something that is not and cannot be displayed by a single individual. There are a number of sources that attempt explanations of ‘emergence’, but in order to understand organizational dynamics, all are needed (Goldstein, 1999). There are four key concepts that together explain emergent phenomena in social systems, they are; Non-linearity, Self-organization, Beyond equilibrium, and Attractors.

Non-linear effects arise when a small change in one aspect of a system results in a disproportionate response from the system. In other words the small effort put into the system is magnified in its impact giving rise to a larger or more energetic response than the effort initially put in to trigger the response. Non-linear effects can be seen in various aspects of project social practices. Examples include the increased competitive and antagonistic behavior exhibited by groups towards other groups, this often exceeds the level of antagonism that each individual in the group may exhibit towards the target prior to joining the group (see Forsyth, 2006: 451). Stress, a common phenomenon in project environments can affect different people in different ways. In some cases change and increased levels of stress give rise to over-reaction or outbursts of anger that are out of proportion to the nature of the change (Verma, 1996; Parumasur and Barkhuizen, 2009).

Self-organization is a process where people spontaneously form a grouping or shared identity. This is distinct from planned groups that are deliberately formed by their members or an outside agency. The unplanned group is known as an emergent group; in a work setting it usually manifests itself as some form of social network usually developing a set of unwritten norms that define their behavior (see Forsyth, 2006: 6). Self-organization often
arise in emergency response situations where the composition of the team, the roles of its members, and how it operates arises from the context of the situation and the participants knowledge and experience (Drabek and McEntire, 2003).

The study of systems originally looked at organizations as stable entities. However, this viewpoint did not provide insight into unpredictable phenomena in the organizational context. Once it was understood that organizations actually exist in a far-from-equilibrium state emergent phenomena could be better understood (Goldstein, 1999). Organizations typically develop mechanisms that resist change and thus preserve their established identity. To overcome this self-correcting mechanism additional information about the environment and about its own varieties of response are needed. These can be shared by members of the organization to enable the synthesis of a new understanding of itself (Goldstein, 1988). Such changes are typically brought about through some form of change project. The resulting solution to the perceived problem then emerges from the response engendered by the new information and understanding. The temporary status of projects is well understood from the very definition of the term. Projects are typically created to deal with environmental or internal situations that the parent or sponsoring organization is not capable of dealing with in its current form (Thomas, 2006). Their goal is often to change the current organization in some respect to enable it to retain its discrete identity.

Attractors are conceptual models of states that a system may tend to move towards. They may represent a stable state under certain conditions, and a system can change from one apparently stable state to another, each state being regarded as the manifestation of an attractor. Because of the different kinds of behavior systems exhibit in relation to attractors, there is a classification of types of attractors (Goldstein, 1999). The consistent application of a particular decision making process in a project when faced with a problem is an example of an attractor in human behavior (De Greene, 1990).

The Dilemma Posed by Complexity

Complexity, once acknowledged, poses a problem for the project manager. On the one hand the manager is obliged to forecast a future state that by convention will include an estimate of the project completion time and costs. This forecast is generated from a planning process that involves a large number of different professions who have engaged in an ‘evolutionary’ planning process to arrive at a suitable design (Tunstall, 2006). The construction process that follows will also involve numerous people whose precise actions and eventual relations with one another are not knowable in advance.

Organization knowledge is typically held in the form taken for processes and procedures. In the case of a project driven or mature user of project management that knowledge is held collectively by a methodology and the supporting procedures and experience of its users. This model sits within the deterministic paradigm that started this particular argument. The dilemma posed is how to capture and learn as an organization whilst retaining a fluid ability to respond to the challenges posed by complexity in the project environment.

The dilemma rests between the need to adopt a deterministic or mechanistic view to prepare the project plan and the understanding of the complex reality the future represents. This dilemma is often missed in practice when deterministic approaches are often coded in the methodology used.

A Tool to Manage Complexity

The traditional approach to problem solving has been reliant on mechanistic and predictive approaches (Rosenhead and Mingers, 2001). Such approaches aim to provide an optimal solution. An alternative view has placed the focus on the identification of the real problem, ‘what the problem is!’ The approaches developed from the latter viewpoint use models to
interpretive structural modeling (ism) is a means of constructing a model of relationships between issues. the process of building the model creates a dialog between participants which facilitates learning and sharing of viewpoints in a congenial atmosphere. the use of software ensures that the logic of the model is consistent and the use of the tool supports a process that makes efficient use of time. the output from the tool is a map or diagram of the relationships between the various issues identified.

three applications of ism are mentioned here which should resonate with project managers. the first involved the development of a balanced scorecard for a food company (thakkar et al., 2006); the second was the development of a risk model for a logistics supply chain (pfohl et al., 2011). finally the application has been applied to vendor selection in a procurement setting (mandal and deshmukh, 1994).

in the case of the balanced scorecard model (thakkar et al., 2006) ism was used to obtain a balance between strategic objectives and operational measures. the tool enabled decision makers to visualize and evaluate the overall objectives of the business unit. it also gave them faith in modifications and changes arising due to realities arising in the context of the planning exercise.

the application of ism to risk analysis facilitated pairwise analysis of risks by a group of experts from different functional areas (pfohl et al., 2011). ism thus enabled a more complete understanding of the total risk exposure faced by the organization in addition to the specific risks perceived by individual experts.

in the third example, ism was applied to a vendor selection problem (mandal and deshmukh, 1994). the approach was used to create a hierarchy of selection criteria to be applied to a ranking process, one of the steps in a procurement exercise. the surveys show that ism is a versatile approach which can be employed in various projects. figure 1 portrays the ism process and how it can be used to absorb and iron out complexity in different project phases.

**figure 1. ism in project management**

**conclusion**

this paper has argued that the modern project environment is characterized by numerous processes that do not readily conform to command and control management approaches. because of the variety and unpredictability of these processes it is suggested that a dynamic steering mechanism is needed to establish project goals and to keep it on track once it is under-way.
In this paper we have proposed that the frequent use of Interactive Management software tools enables project teams to better understand the fundamental issues they are facing and thus arrive at superior project solutions for delivery to the project client.

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Building Information Modelling (BIM) Education in South Australia: Industry Needs

John C.H Gardner¹, M. Reza Hosseini², Raufdeen Rameezdeen³, and Nicholas Chileshe⁴

Abstract
Building Information Modeling (BIM) is at the early stages of adoption in the South Australian construction industry. At present some South Australian firms have embraced BIM and consider that to boost their competitive advantage. In order for a wider adoption of BIM, the industry should have enough human capital with BIM knowhow. Nonetheless, literature review shows a very grim picture with regard to the availability of human resources with BIM knowhow in many countries. As a remedy, universities are expected to produce graduates who are capable of dealing with this new technology. In order to address such a need, this study focuses on identifying the perceptions of BIM experts on skill gaps prevalent in the South Australian construction industry that prevents large-scale adoption of BIM. The findings substantiated previous studies conducted within the Australian context highlighting that the main issue is to design and execute a systematic collaborative working procedure alongside maintaining high quality communication among the team members. Interviews highlighted the need for skills such as collaboration, communication, leadership and facilitating change management alongside technical skills related to BIM. The clear message is that the enhancement of technical skills alone would not be sufficient for an effective BIM adoption in South Australia.

Keywords: Building information modelling, collaboration, competency, skills, South Australia, training.

Introduction
There is consensus on the potential benefits of BIM for the Australian construction industry for added economic value and enhanced efficiency in project delivery (Shih & Sher, 2014). This has been supported in a recent report by Allen Consulting Group (2010) denoting that BIM adoption should be regarded as a unique practical measure to achieve higher levels of productivity in the Australian construction industry.

Against this backdrop, adoption of BIM in the construction industry of Australia has been slow and below full potential (Tsai et al., 2014). Evidence has shown that BIM implementation is around 20% lower in Australia compared to North America (Stanley & Thurnell, 2014). This situation is worse in South Australia according to Newton and Chileshe (2012) who claim 83% of South Australian construction companies implied that they have not adopted any form of BIM in their businesses.

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Such low level of uptake could be attributed to the fact that BIM adoption is fraught with challenges. One such challenge is the lack of skills and understanding of BIM within the Australian workforce (Gu & London, 2010). Given that BIM is increasingly becoming a common practice for the construction industry, training and education of BIM should be pursued through a systematic approach. As opined by Sacks and Pikas (2013) “without structured careers, professional education, and ongoing training, neither continuous improvement nor the knowledge management necessary for holistic BIM can be achieved”. Though the current level of BIM adoption relies on professionals with a reasonable level of skills and knowledge in BIM, long term sustenance need a massive investment in training and education (Pikas et al., 2013). Designing such training and education programs should be in response to the requirements of the industry. Thus, a systematic investigation of the current skills and competency gaps would immensely benefit education providers in devising effective programs for producing industry-ready professionals.

As BIM is still a very young field, such investigations are very limited. This knowledge gap is particularly apparent in the building discipline where training is provided for careers in construction management, quantity surveying, building surveying and allied fields. To fill this knowledge gap, the present study aims to identify skills needed by future building professionals to effectively function in a fully BIM-enabled work environment.

**Literature Review**

The Construction industry is a competitive industry with profit margins generally becoming smaller and the expectations of clients and business owners becoming higher. There will be a greater demand for efficiency and productivity enhancement within the construction industry (Wu & Issa, 2013). This demand for efficiency will then lean on employees to have improved level of education and more specifically a higher level of knowledge for tertiary graduates entering into the construction industry. As BIM’s popularity increases and is used on more projects, so too will the demand for employees who have an understanding of the fundamental skills of BIM. Sacks and Barak (2010, p.30) also backed this up through their study in the US arguing that “lack of BIM skills is a significant constraint retarding use of the technology in the construction industry”. Gilligan and Kunz (2007) reinforced this through their research identifying that it was not because of technology malfunctions rather it was due to the lack of training and availability of qualified staff issues arose with some models. This suggests that the technology is well advanced, however there is a challenge to educate staff to be competent with the technology.

Clevenger et al. (2010) identified the effective addition of BIM into the construction education curriculum will be critical in the preparation of future employees for the industry and goes on to say that educational institutions currently lack strategies and capabilities to effectively introduce and leverage BIM into existing or future coursework. This statement outlines that sufficient training of BIM or lack of is an issue affecting BIM adoption in the construction industry. As BIM is still young and making its way into the industry there is a very tiny group of educators who could help expand this knowledge (Becerik-Gerber et al., 2011). Sabongi (2009) from Minnesota State University in the USA conducted a study and found that from 54 Universities in the United State, only 9% currently address BIM in their coursework and less than 1% teach BIM as a stand-alone class. Some of the implementation challenges were; no room in the current curriculum for additional classes (82%); the impossibility of adding additional required or elective classes and still graduating in eight semesters (66.7%); problems with the faculty having the time or resources to develop a new curriculum (86.7%) and the availability of BIM specific materials and text books for use by the students (53.3%). Hietanen and Drogemuller (2008)
identifies how young BIM is in the industry and how it is going to pose a challenge to educators because of the versatility and profound effects of the new technology. They then argued that at a University level there should be a standard that everyone should adhere to, thus justified and presented ideas for BIM education at a University level.

Mills et al. (2013) in their report on education on BIM maintained that to enhance the relevant abilities of graduates of architecture and construction disciplines, BIM technical skills as well as collaboration requirements should be included within courses of such disciplines. Their findings revealed that few Australian universities (e.g. Newcastle and UNSW) have embarked on teaching courses associated with BIM. Likewise, Ken et al. (2014) stressed the growing requirement for universities to prepare their graduates to have a satisfactory level of knowledge of BIM.

As there is continuing evidence of the positives stemming from BIM, it will only be a matter of time before BIM is widely used throughout Australia. This technology will continue to spread throughout the construction industry due to the benefits that comes with it, including the cost and time savings, improved sharing of information and better design. In saying that, there will also be greater demand for personnel who have been educated with specific skills as the adoption of BIM continues. Thus, as opined by Mills et al. (2013, p.10) “this move can be further advanced by the development and implementation of educational innovations” as discussed in following sections.

Methods
Taking into account the exploratory nature of this study, following du Toit and Mouton (2012) a qualitative approach was used in this investigation. Discovering the skills and competency needs of future building professionals entails a rigorous exploration of the real life context. In such situations interviews were found to be very useful (du Toit & Mouton, 2012). Additionally, this study calls for mapping the subjective opinions of BIM experts on an unexplored territory which makes interviews “the best avenue for inquiry” as opined by Seidman (2005, p.11). In order for the interviewees to respond to questions freely and discuss the various issues concerning BIM adoption, the study adopted a semi-structured interview approach as suggested by Mitra and Tan (2012). Each interview lasted approximately one hour, and all the interviewees were selected based on their willingness to participate in the study. To identify eligible respondents, a preliminary list of 42 potential experts was considered through companies’ websites and professional networks and groups such as LinkedIn and BuildingSMART (http://buildingsmart.org.au). Invitation emails were sent and eventually nine experts agreed. According to Simms and Rogers (2006), such a selective sample would enhance the quality of collected data as a result of the true intention of respondents to add value to this research study. Table 1 provides an overview of interviewees participated in this study. Though the sample could be deemed small, the methodology could be justifiable in the grounds that the saturation could occur after six interviews based on the richness of data (Bazeley, 2013). Nvivo 10 was deployed to analyze the interview transcripts in order to provide a deeper insight into expert comments in conjunction with the benefits of great speed and flexibility of using such a computer package (Lewins & Silver, 2007).

As suggested by Bazeley and Jackson (2013), visualizing the emerged ideas adds value to qualitative studies by highlighting the relationships and patterns emerging from the data. That is, creating models based on analysis of interviews will show who the source of any idea was and how such an idea is associated with other ideas and broader themes. Hence, ability of Nvivo 10 in creating models out of coding the interview transcripts was deployed for compiling Figure 1 and Figure 2. As defined by Bazeley and Jackson (2013), Nvivo models provide an overview of the main ideas and concerns raised by respondents of
qualitative research studies as well as the relationships among the ideas and interpretation of ideas as fundamental explanatory concepts. This facilitates understanding how ideas developed and emerged from the data and how researchers came to presented conclusions of a research study.

Table 1. Respondents profile and attributes

<table>
<thead>
<tr>
<th>No.</th>
<th>ID</th>
<th>Occupation</th>
<th>Experience with BIM</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>3D Designer</td>
<td>5 years</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>BIM manager</td>
<td>More than 10 years</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>Project manager</td>
<td>4 years</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>3D Drafter</td>
<td>7 years</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>BIM Researcher</td>
<td>8 years</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>3D Drafter</td>
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<td>3D Drafter</td>
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<td>9</td>
<td>I</td>
<td>3D Designer</td>
<td>6 years</td>
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Status of BIM competency in South Australia

In regards to competency and skills requirements, results of the interviews unfolded some fundamental patterns manifesting the status of BIM competency in South Australia as captured in Figure 1. This reaffirmed the findings of McGraw-Hill (2014) indicating that in spite of high awareness of BIM in Australia, the level of competency and experience with BIM are still relatively low. Furthermore, as far as investment in BIM (including training and education) is concerned, the Australian construction industry could be described as “similar to the North American market in 2009” (McGraw-Hill, 2014, p.7). The major factors associated with the current status and the main lessons drawn from analysis of interviews are as follows.

Figure 1. Factors associated with the current status of BIM competency in South Australia
Lesson one: Effective BIM adoption in South Australia relies upon facilitating establishing integrated seamless BIM procedures in existing projects and widespread dissemination of acquired experiences. Interviewees were of the general opinion that BIM procedures implemented in projects are not mature enough to provide an impetus for others to learn. As an example, Interviewee B said “I am still looking for a system for BIM in which people issue the data that could be fed into a structured process so we make sure that it comes out approved in the other end”. Likewise, Interviewee D went on to say that “we are still in early stages of getting right services together and allow that happen in an intelligent way”. Interviewee E argued that “it is not about technology any more it is about putting the right people and the technology in the right place”. Such insights substantiated the claims about lack of competency in Australia when it comes to treating BIM as an integrated process opposed to a tool as argued by Gu and London (2010) and Panuwatwanich et al. (2013). Thus, successful cases of implementing integrated BIM in South Australia should be identified and immersion of young professionals to such cases to gain experience should be supported.

Lesson Two: South Australia is in dire need of addressing the issues associated with lack of in-house BIM expertise for harnessing the benefits of BIM in construction projects. Lack of in-house BIM expertise in South Australia could explain the reason why BIM tasks in many high profile projects need to be outsourced to other states or even overseas as outlined by the interviewees. This reiterates the arguments by Alabdulqader et al. (2013) on the lack of in-house expertise for BIM as a barrier impeding BIM use in Australia. Interviewee A and B observed that BIM experts need to be hired from Melbourne and Sydney to join their teams. Interviewee B added that in case of one high profile project “The reason for using overseas BIM experts from […] was that we knew that we cannot get that number of people with skills necessary in SA”. The same issues was raised by Interviewee F regarding the necessity of recruiting overseas experts only due to lack of such competency in South Australia. On top of that, it came to light that Interviewee A, B, D, and H had moved to South Australia only after obtaining a job in BIM. One remedial solution to this could be easing up the process of employing skilled overseas BIM experts as well as providing particular incentives for interstate experts to move to South Australia.

Lesson three: More resources should be allocated to enhance the widespread level of BIM awareness in construction companies in South Australia. According to the recent report by McGraw-Hill (2014), competency of BIM in Australia in all levels has remained lower than that of the North America. Some interviewees are working in high profile projects in South Australia that are regarded among the most advanced BIM projects in the Australian context. Nonetheless, there was consensus among respondents that South Australian projects are late adopters of BIM against the national level as well as other developed countries. To underpin that, Interviewee B claimed that “I have been in SA for a while and I know that what we are doing in this project has been done in South Eastern states for a bit longer. This is not something new”. Interviewee C went on to say that “even the work we do in […] is behind what happens in USA while this is an iconic project of the country at the moment. So how do we get better?”.

Skill Requirements
Different skill requirements emerged in interviews with regard to implementing BIM in the South Australian construction industry as shown in Figure 2. There are important lessons to be learned in view of such needs as discussed in following.
Lesson four: skills essential for enhancing team working and collaboration are required in South Australia as a prerequisite to adopting BIM effectively. Interviewees identified the ability to collaborate as the most striking skill gap in South Australia. According to their description of projects, collaboration procedures for BIM are designed based on a “trial and error” basis. Highlighting this as an issue, Interviewee A said “the underlying problem is that our teams still work in complete isolation”. He added “there is no control for the entire collaboration process”. Interviewee B stated that “our collaborative systems need to be improved”. Similarly, Interviewee D claimed that “everyone in our BIM teams is a mercenary fighting for their own little rights and this is not good for team working”. Thus, effective implementation of BIM in South Australia needs collaborative practices among team members and this should start at the education and training level. Likewise, according to Stanley and Thurnell (2014), incompetency and lack of protocols to design collaborative working in BIM projects was regarded as the major barrier in implementing BIM in New Zealand.

Lesson Five: There is a dearth of technical skills associated with BIM in South Australia. There was unanimous agreement among interviewees that technical skills cannot be compromised in a BIM-enabled work environment. Industry professionals should have the same level of technical skills as highlighted by Interviewee I “a difference in the levels of technical competency is a major issue. It affects the quality of communication and collaboration that finally leads to conflicts”. Most of the interviewees highlighted that BIM is witnessing a proliferation of software packages that support 3D modeling in different disciplines, which demands integration of these outputs into a single model. This observation is supported by Ahn et al. (2013) and Quigley (2013) indicating that there are too many software packages in the market supporting BIM practice. In this context, Interviewee D mentioned that “we still have a big issue for making different programs talk to one another. Someone working in Revit and the other in Tekla so that we have to use IFC to get the Tekla into Revit. We should get that IFC file into Revit and Navisworks. So
we had to award a contract to a company to do such diversions but still it is not effective”. Interviewee F reaffirmed such an insight by saying “access to different technology is a problem because there are many different programs and they are not compatible and they do not communicate with each other, so you should use communicators such as IFC and it does not work very well”. He went on to say that currently in South Australia “companies employ people based on the software they’re capable of using”. In a similar observation by Ahn et al. (2013, p.293) in the USA stated that “the construction graduates should be able to use BIM software such as Navisworks, Revit Architecture and MEP and Google Sketchup”. Interviewees A, C, E and D stressed the importance of cloud technology for managing a seamless collaborative BIM. Cloud technology and the skills associated with maintaining its security should be enhanced within the construction industry of South Australia. According to Interviewee E, “The days of having one model is over. Now it’s all about giving access to the piece of information they need; and if all could be sorted in the cloud; issues of non-compatible technology won’t arise”. Investing in “Cloud BIM” technology and allied skills as proposed by Redmond et al. (2012) and recently acknowledged by McGraw-Hill (2014) would help South Australian practitioners in future proofing their careers.

Lessons Six: South Australia is in need of people with skills necessary for managing and leading effective integrated BIM processes. While every profession demand managerial/leadership skills, interviewees referred to certain specific leadership skill requirements based on their experiences with previous projects. Interviewee B and I observed that managers of BIM should be able to develop trust among team members. Interviewee B went on to say that “based on my experience, there is an element of distrust between members in BIM projects”. Interviewee C mentioned that managing BIM takes detailed, continuous and close supervision of work by stating “if I want to do it again I will focus in being specific as much as possible and put in management attempt as much as possible and will control every aspect of work rather than allowing them to slip from my attention for a while until someone finds a fault”. The above observation gives an impression that BIM managers should resort to micro-managing the project for it to be a success. This substantiated the claims by Quigley (2013) that BIM practitioners in managerial levels should have both technical knowledge and competency to handle software packages. There was also consensus on the leadership abilities of BIM managers to make people share information and communicate effectively. According to Quigley (2013) BIM managers usually come from technical and engineering backgrounds which turned out to be true for South Australia based on interviewees’ statements. This explains why interviewees prioritized the leadership skill over technical for managerial roles in projects. According to Shelbourn et al. (2007) the main barrier in effective implementation of BIM have roots in managing human interactions and leading people than on technical aspect of a project. According to Quigley (2013) management of BIM process takes specific managerial skills and one should only take such responsibility if he/she is confident of having necessary skills and abilities.

Lessons seven: attempting to enhance level of communication skills among South Australian construction practitioners is perceived indispensable to effective adoption of BIM. Interviewees were unanimous that effective communication is an absolute necessity for a BIM environment. Interviewee B stated that “the main issue with BIM and collaborative virtual working is communication”. He added that “electronic distribution needs a robust management of data as it should substitute the seal on the paper based system”. Interviewee C conceded saying “we tried many tricks and recently managed to
find some packages by which you could share screens and that was the best method of communication we had so far”. **Interviewee B** added “we need training for effective communication. It doesn’t come automatically”. BIM environment does not need face-to-face meetings but other means of communication is vital. As explained by **Interviewee I**, “sometimes it is difficult for people who work together in a team but seldom know each other very well and the only means of communication is emails”. This idea was highlighted by Quigley (2013) as BIM workflows have to accommodate novel systems for information and data exchange, communications and documentation. As such, quality communication should be a part of the BIM execution plan (Quigley, 2013).

**Lesson eight: skills associated with change management are required in South Australia to facilitate a seamless shift from current practices to integrated BIM.** Interviewees highlighted an important but rarely discussed skill that requires in the short to medium run to be successful in a BIM-enabled environment. The requirement will slowly fade away once the industry is fully integrated with BIM technology. The skill to facilitate change management is a soft skill that interviewees were eager to discuss, for example **Interviewee D** said “the issues with change management and resistance against BIM is resolved by builders telling people that if you want to work in this job you should use BIM. Otherwise, you will not work on the job”. **Interviewee I** explained such strong resistance by postulating “we have a pervasive culture in the construction industry that does not support trust and sharing of information in BIM”. **Interviewee D** added that “I think BIM and virtual working still face some big challenges from pre-existing work flows”. Such an insight is understandable because an important prerequisite for diffusion of any innovation (including BIM) is systematic management of change (Hosseini et al., 2014). Resistance to change due to lack of understanding of BIM was identified as one of the major barriers in BIM adoption by Australian companies (Alabdulqader et al., 2013). As such, change management practices should be accompanied by enhanced training and education on benefits of BIM for construction industry practitioners.

**Conclusions**

Findings of the interview survey substantiated the claim that South Australia is in its early stage of BIM adoption due to lack of in-house expertise and immaturity of its applications in projects. Though one might expect technical skills to be the most lacking, interviewees highlighted soft skills such as collaboration, communication, leadership and facilitating change management in the South Australian construction industry. Consequently, authors are of the view that resources for training and education on BIM should be allocated not only to improve technical skills but also to promote collaboration, communication and change management in work settings. While the study unearths major aspects of education and training requirements for BIM in South Australia, some limitations should be noted. These [limitations] relate to the restrictions of the respondents’ to only South Australian construction practitioners with competency in BIM. Hence, reported viewpoints predominantly reflect the observations of South Australian BIM experts. The small sample size (n=9) for the interviewees is another limitation of the current inquiry. As a corollary, caution should be exercised in the interpretation and generalization of the results for contexts other than the South Australian construction industry. Such restrictions open the door for future enquiries in the field. As such, future investigations should target detecting the training requirements and mapping the status quo of BIM education in other contexts and countries. For South Australia, future inquiries should focus on developing training
programs and courses to provide university students as well as practitioners in the industry with the essential skills as detected by the findings of the present study.

References


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Abstract
South Africa’s construction industry has suffered stagnation since the 2010 FIFA World Cup. As the construction industry is deemed vital in economic growth, various inquiries have been made attempting to understand this trend and reverse its direction. However, these efforts were mainly based on mechanistic paradigms, ignoring the systemic nature of the problem. In contrast to the mechanistic paradigms, this paper demonstrates how to use Interpretive Structural Modelling, a systemic approach, to unearth the root cause hampering the growth of the South African construction industry. The proposed factors resulting in stagnation are modelled on an ‘ aggravate’ relationship which is transitive in logical inference. Through an interactive session, the modelers go through the relationships of system elements. The output of modelling is a diagraph surfacing the sources of the problem. The result, which is demonstrative rather than conclusive, reveals that environmental factors have a significant impact on the sustainability of South Africa’s construction industry.

Keywords: Construction, Interpretive Structural Modelling, diagraph.

Introduction
In South Africa, the construction industry significantly contributes to economic growth. However, this industry has suffered stagnation since the FIFA World Cup. As well as stagnating construction revenues show unstable fluctuations. These undesirable states significantly affect the sustainability of the construction industry.

Various research efforts have been undertaken to improve this situation. These mainly use mechanistic paradigms. In contrast to the previous work, this paper argues for systemic approach to constructing a model portraying how the system elements mutually impact. Systemic approaches not only deal with human dimensions but also embrace the conventional concepts of systems thinking, such as non-linear, asymmetric and loops.

The mechanism used for building the model is Interpretive Structural Modelling (ISM) which is a systemic approach. The ISM session is based on academic point of views. The result reveals that ‘market demand’ is the root problem of unsustainable construction. This finding is different from the previous works which mainly emphasizes solutions rather than considering that the perquisite activities are unearthing root problems. However, this research is demonstrative rather than conclusive. A more comprehensive study including the representative from South African construction industry will augment its validity.

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Background of the South African Construction Industry

According to Hargroves and Smith (2006), sustainability means “progress that genuinely sustains and improves economic, social and environmental well-being with no major trade-offs, locally and globally, now and in the future”. Organizations can choose to focus on one of the spheres to achieve sustainable development. In terms of economic aspects, Hill and Bowen (1997) explicate that promoting employment creation is one of the principles in economic sustainability. In economics, the total of quantity produced rests on how many workers are employed and how productivity each worker is (Schiller, 2005). Hence, a sustainable industry will contribute to job creations, in turn, the total production of goods.

According to Statistics South Africa in 2013, the construction industry, despite not being a major contributor in the economy, plays a significant role in GDP. The relative size of the construction industry is around 3 percent of real value of the GDP in 2011. Over the years the construction industry has grown steadily. But, according to Lion of Africa Insurance’s report (2014), it has suffered a period of inactivity since 2010 FIFA World Cup. The construction industry plunges into a ‘mini-recession’. Furthermore, PricewaterhouseCoopers (PwC, 2013) released a report on South African construction industry. The report also reveals that the construction industry suffers stagnation after the 2010 FIFA World Cup. Despite the construction revenue was improved in 2012 and 2013, its performance fluctuated in an unsteady state over the years. As the past president of Master Builders Association of the Western Cape Mr. Allen Bodill (2012) indicated, South African construction was under severe pressure due to rising cost, fuel price, higher wages resulted by strikes and other factors. These social-economic problems, in fact, not only cloud South Africa’s construction industry but also other industrial sectors.

The survey reveals that the South African construction industry no longer enjoys the boom brought by the FIFA World Cup. The ebb and flow of its performance is entangled with various factors impeding its stability, job creation and growth. In other words, the industry is not sustainable in some ways. This problem triggers the research question: What are the factors impeding the sustainability of South African construction industry? A variety of research has been initiated to address this problem. The next section outlines the works which have been done to deal with the sustainability of construction industry.

Research on Sustainable Construction

Šaparauskas & Turskis (2006) argue that sustainable construction should not be merely assessed from the environmental perspective. They assert that it should incorporate social and economic dimensions, assessing the sustainability on a national or global scale. Therefore, they put forward six indicators used for assessing construction sustainability. The six indicators embrace social, economic and environmental dimensions. Based on these six indicators, multi criteria decision analysis is used to assess the sustainability of construction on a national scale.

Hill and Bowen (1997) review various concepts of sustainable construction. Their survey reveals that confusion is inherent in the term ‘sustainability’. Authors have different ideas about sustainable construction, depending on their interests and stances. Therefore, they put forward a more comprehensive framework that sustainable construction should be supported by four pillars – social, economic, biophysical and technical. The relevant stakeholders can use these principals as a checklist and assign weight to these principals when seeking consensus in decision making.

Ugwu and Haupt (2007) developed key performance indicators for infrastructure sustainability assessment for the developing country like South Africa. Built on the earlier
research on taxonomical analysis and the development of indicators initiated in Hong Kong, the assessment indicators are adapted to address the context of South Africa. They identify seven categories that are essential to the sustainability of infrastructure construction: economy, environment, society, health and safety, resource utilization and project management. Each category is further analyzed to develop detailed indicators. They also suggest the use of multi-criteria decision analysis to compute the sustainability index.

Most research centers around the theme of relevant factors enabling sustainable construction. In contrast to these works, Windapa and Cattell (2013) entered the sustainable construction debate through a different strategy. They focus on the challenges facing South African construction industry. Thirteen challenges are identified – public sector capacity, mismatch between available skill and required skill, globalization and so forth. In their survey, respondents regard ‘increase in the costs of building material’ as the most severe impact on South African construction industry. ‘Access to affordable mortgage’ ranks 2nd out of the thirteen factors. Windapa and Cattell’s research, to a certain extent, purports that identifying the sources of a problem should be prior to formulating the means for solving the problem.

A Systemic Intervention Strategy

The literature survey reveals that the current research mainly focuses on a quick solution or universal ingredients to deal with the sustainability of construction. They search for universal indicators to achieve sustainable construction. But, according to PMI’s (2008) ‘A Guide to the Project Management Body of Knowledge’, each project is a unique activity due to the dissimilarities of circumstances. For example, automotive are manufactured with the same or similar materials, but each lot is unique – with a different design, different cost of materials, different contractors and different circumstances. These features were noticed by some great minds before. For example, Popper (1957) already said that social events are unrepeatable. The evolution of human society is a unique historical process. By the same token, the construction industry progresses in a dynamic environment, impacted by a country’s culture, law, economy and value. In addition these factors differ from company to company, from country to country. As Checkland and Holwell (1998) emphasize ‘In social situations one observer’s success is often another’s failure’. Therefore, employing identical indicators across the industry to assess its sustainability is questionable.

Apart from the danger of believing in panaceas, a hasty solution for a specific problem is risky. Solving a wrong problem might lead to a fruitless result and incur huge loss. Many works have been put forward urging people to define or clarify the problem prior to subsequent activities. For example, the Shewhart cycle, or the Deming wheel, is a cycle of plan-do-study-act. In the plan phase, the first step is to define the problem (Stevenson, 2007). In the team process, the procedure often starts from the ‘problem selection and diagnosis’ (Evans, 2005). The reason of this prerequisite is evident: If we don’t know what the problem is, how are we going to solve the problem? Imagine that a patient feels unwell, having different symptoms. Doctors often need to investigate the causes of the symptoms before treating the patient. In business operations, this principle is noticeable. Instead of asking the question ‘How do we improve the production performance’, managers need to ask the question ‘What are the causes of the poor production performance’. Therefore, defining and diagnosing problems are prior to the rest activities.

In social systems, however, problems are not noticeable or easily diagnosed. They are unlike a well-structured problem in mathematics or natural science. Using Pythagoras’ theorem to deal with a right-angled triangle question is a straightforward problem solving.
Building a nuclear power station is an endeavor of engineering design. But the question ‘Should we build a nuclear power station?’ is not a simple matter. The problem is in a very noisy environment - an environment of messes. The relevant stakeholders argue from polarized positions – green energy or nuclear energy. They support different reasoning and ‘different ways’ to defend their belief. Therefore, the problem is not obvious or agreed by the affected stakeholders. As a result, the solution is not straightforward. Dealing with high crime rate is similar to this. The question might be ‘What are the causes of high crime rate?’ People, police force, educators and the rest of the stakeholders hold different opinions. Answering this question is not simple. Their unpleasant experiences might take the theme to ‘apportionment of errors’ and elicit new issues. At the end, the theme is not dealt with and the participants leave the session without a useful result.

Apart from the challenge in unearthing causes to a problem, the structure of a problem receives great attention as well. In the mechanical age, reductionism and determinism dominated problem solving. Problems are regarded as separable parts which are mutually independent. Therefore, ‘breakdown’ is pervasive in dealing with a problem. Analysis is a prevalent approach to solving a problem. In this paradigm, system elements are treated as mutually independent parts. They can be dealt with separately. This is a widespread paradigm employed in various managerial activities. For example, Work Breakdown Structure (WBS) is an important technique for defining project deliverables. Each work package is an independent element to be sequenced in a network diagram. In the sequenced activities, the relationship between system elements is linear, i.e., the occurrence of a loop is prohibited. Subsequently, project time planning can be carried out for further control over the defined activities.

However, the rise of systems thinking recognizes that causality is not confined in linear relationship. Loops exist in natural and social systems. In contrast to mechanistic thinking, systems thinking attests that a system element could cause itself. For example, conventionally, Fault Tree Analysis portrays linear causal relationships between system elements. Decision Trees also portray linear relationships between sequenced decision nodes and events. Loops are not prominent in these approaches. By contrast, systems thinking attest that a system element could cause itself. For example, sleeplessness could cause anxiety. In turn, anxiety could cause sleeplessness. Therefore, sleeplessness could cause itself. The system elements are mutually interlaced displaying non-linear and asymmetric relationships, called ‘things complexity’ by Flood and Carson (1999).

However, things complexity is not the sole factor impeding the solution to a problem. Warfield (1994) points out that an intercepted signal might elicit disparate interpretations by different persons. The blowing wind is noisy or rhythmic resting on each person’s perception. The various perceptions could result in dissonance or conflicts between the stakeholders. Apart from different perceptions, the limitation on human mental capacity could escalate conflicts as well. According to Simon (1990), human short-term memory is not big, around half dozen chunks. He also points out that rationality is bounded because of the constraint on computational limits. Therefore, in decision making, we search for satisfactory solutions rather than an optimal solution. The satisfactory solution varies according to each observer’s mental activities. The problem of ‘how to build a nuclear power station’ might be a problem of optimization. However, the problem of ‘should we build a nuclear power station’ is not a simple question. The noise is high and the situation is messy.

The messy situation mainly stems from subjective preferences, implying that the acquired knowledge is subjective because it is established on preferences, value, norms culture and so forth. All of these factors are driven by mental activities, which do not yield to the conventional scientific approach, based on replicable experiments to verify a
The differences in the nature of knowledge, objective or subjective, demarcate the boundary between system thinking and systemic thinking (Flood, 2010). Systems’ thinking focuses on the functions, loops and non-linear relationships of system elements. In contrast, systemic thinking focuses on the observers’ subjective perceptions. Instead of seeking a verification of a hypothesis, systemic thinking is a continuous learning process refining our understanding of the area of concern, framework of ideas and intervention methodology (Checkland, 1990). The polarized proposition between the two systems theories does not imply that systemic thinking competes with systems thinking. In fact, systemic thinking complements the conventional scientific method which is driven by hypotheses. In the process of inquiry, systemic thinking addresses human dimension issues, meanwhile embracing the propositions of systems thinking.

Interpretive Structural Modelling (ISM) was devised by Warfield (1976, 1994). This approach can facilitate mental model interchanges between the participants who attend the computer interfaced session. The mechanism of the modelling is a binary matrix, allowing the participants to debate and answer consecutive questions posed by the computer. The outcome is a digraph representing the structure of the systems given the defined contextual relationship between system elements. It is a continuous learning process based on the assumption that knowledge is subjective. Meanwhile, the generated model could embrace loops displaying the non-linear and asymmetric relationships between system elements. This paper demonstrates the usage of Interpretive Structural Modelling in structuring the factors impeding sustainable construction in South Africa. The generated system elements and modelling process are based on the authors’ experiences in education related to construction industry. The result is demonstrative rather than conclusive.

**Study and Finding**

The triggering question to elicit system elements was ‘What are the factors impacting the sustainability of South Africa’s construction industry?’ Through brainstorming, eight system elements were identified. The identified elements were clarified to avoid similar concepts. The generated elements and their descriptions are outlined in Table 1.

The next step was to determine the contextual relationships of the system elements. Given that the theme of this paper is to unearth the root problems leading to unsatisfactory construction sustainability, the contextual relationship used to structure the model is ‘aggravate’. The aggravate relationship not only manifest how the system elements mutually impact but also how an element worsen other elements. The contextual question is ‘Does element X aggravate element Y?’. The ‘aggravate’ relationships is transitive. In other words, if ‘X aggravates Y’ and ‘Y aggravates Z’, then we can infer that ‘X aggravates Z’. Through consecutive answer to the posed questions, an initial binary matrix was constructed shown as Figure 1.

In Figure 1, the cell with entry ‘1’ denotes that the ‘aggravate’ relationship exists between the row and column element, i.e. the row element aggravates the column element. The cells without an entry mean that the questions about the relationship between the row element and column element are not posed by the computer because they can be inferred by the answered questions. The inferred result is shown in Figure 2, called final reachability matrix.

The development of a diagraph from the reachability matrix begins by inspecting an element’s reachability sets and antecedent sets. Through an iterative process of examining the set product, the algorithm will surface the elements included in each level. Table 2 is prepared showing the reachability set and antecedent set for every element of the matrix in Figure 2.
Table 1. The Factors Impacting South African Construction Sustainability

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Elements</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Community interference</td>
<td>Actors not formally linked to the project appropriating a role through coercion</td>
</tr>
<tr>
<td>2</td>
<td>Funding failure</td>
<td>Project not initiated because budget funds are not released by appropriate authorities</td>
</tr>
<tr>
<td>3</td>
<td>Poor education of workforce</td>
<td>Low standard of basic education in communities</td>
</tr>
<tr>
<td>4</td>
<td>BBBEE (Broad-Based Black Economic Empowerment)</td>
<td>Economic redress of previously disadvantaged individuals</td>
</tr>
<tr>
<td>5</td>
<td>Finance</td>
<td>Difficulties in acquiring finance from banks</td>
</tr>
<tr>
<td>6</td>
<td>Market demand</td>
<td>The unsatisfactory economics negatively impacting market demand</td>
</tr>
<tr>
<td>7</td>
<td>Shortage of management and technical skills</td>
<td>Insufficient skillful managers and technician owning to emigration</td>
</tr>
<tr>
<td>8</td>
<td>Payment</td>
<td>Client's payments in arrears negatively impacting contractor's cash flow</td>
</tr>
</tbody>
</table>

Figure 1. Initial Matrix

```
1 2 3 4 5 6 7 8
1 1 1 0 0 1 0 0 0
2 0 1 0 0 1 0 0 0
3 0 0 1 1 0 1 1
4 1 0 1 0 1
5 0 0 0 0 1 0 1
6 1 0 0 1
7 1 1 0 1
8 1 0 1
```

Figure 2. Final Reachability Matrix

```
1 2 3 4 5 6 7 8
1 1 1 1 1 1 1 0 1 1
2 1 1 1 1 1 1 0 1 1
3 1 1 1 1 1 1 0 1 1
4 1 1 1 1 1 1 0 1 1
5 1 1 1 1 1 1 0 1 1
6 1 1 1 1 1 1 1 1 1
7 1 1 1 1 1 0 1 1
8 1 1 1 1 1 0 1 1
```
Table 2. Iteration I

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<th>Antecedent Set A(s)</th>
<th>Set Product R(s)A(s)</th>
<th>Level</th>
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<tr>
<td>8</td>
<td>1,2,3,4,5,7,8</td>
<td>1,2,3,4,5,6,7,8</td>
<td>1,2,3,4,5,7,8</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2 show that the elements of which set product equals to reachability set are elements 1, 2, 3, 4, 5, 7 and 8. Therefore, these seven elements are the top-level elements for the matrix of Figure 2. Elements 1, 2, 3, 4, 5, 7 and 8 can then be deleted from Table 2 by removing all references to these seven elements in all columns. Table 3 shows the result of such deletion.

Table 3. Iteration 2

<table>
<thead>
<tr>
<th>Element s</th>
<th>Reachability Set R(s)</th>
<th>Antecedent Set A(s)</th>
<th>Set Product R(s)A(s)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3 shows that only element 6 remained in the matrix. Furthermore, the set product equals to its reachability set. Therefore, element 6 is the second-level set of the matrix. Thus far, the iteration has identified the elements at each level. The matrix in Figure 2 is evident that elements 1, 2, 3, 4, 5, 7 and 8 are mutually reachable. Therefore, the seven elements are linked in a circular form. It is also evident that element 6 aggravates the elements in this loop. Bases on these relationships, the drawn diagraph is shown in Figure 3.

Figure 3. Diagraph of the Matrix

Figure 3 shows that the root problem causing unsustainable construction is ‘market demand’. This factor is entangled with social economics. Therefore, an external force is
responsible for construction industry sustainability. Solving the lesser important problems like funding failure, workforce education, finance and so forth only make lesser contribution to alleviation of unsatisfactory system state. The reason is that the root problem has not been solved. Hence the unsatisfactory system state is likely to happen again. However, the result is demonstrative rather than conclusive.

Conclusions

This research demonstrates how to use Interpretive Structural Modelling (ISM) to diagnose the factors impeding South African construction sustainability. ISM is a versatile approach embracing both of the concepts in systems thinking and systemic thinking. The contextual relationship used for modelling may vary according to the purpose of intervention. This research uses ‘aggravate’, a transitive relationship, to construct how the system elements mutually impact. Through an interactive session, eight elements impeding South African construction sustainability were generated. The result of ISM session revealed that ‘market demand’ was the root problem impeding South African construction sustainability. The finding suggests that authorities need to focus on solving this root problem rather than investing resources on solving lesser important problems. However, this finding is not conclusive. A more comprehensive research incorporating representatives from the construction industry will argument the validity of this research.

References


Relationship between National Culture and Safety Behaviour: Evidence from Petrochemical Employees in Saudi Arabia

Ayedh Alshahrani¹, Kriengsak Panuwatwanich², and Sherif Mohamed³

Abstract

Saudi Arabia relies heavily on its petroleum-related industries, including petrochemicals and refining, which are undoubtedly the lifeblood for the Saudi economy. Given major petrochemical accidents can be catastrophic, with significant emotional and economic impacts on businesses, families, and societies, safety management within the industry is paramount. Petrochemical industry in Saudi Arabia is a multinational company operating in 40 countries with over 40,000 employees. In any workforce, ignoring cultural differences is a serious cause of misunderstandings and, as a result and conflict. Moreover, safety behaviour is considered as the foundation of underlying safety activities that must be established by employees permitting the occupational, safety and health requirements to circumvent accidents at workplace. Within the current body of knowledge, empirical studies on the impact of national culture on safety attitudes, behaviour and performance seem to be limited. This paper presents a research study aiming to examine the relationship between national culture and safety behaviour within the context of petrochemical industry. The study surveyed 407 petrochemical employees in Saudi Arabia and uncovered a significant difference between the perceptions of Saudi and non-Saudi employees across Hofstede’s cultural dimensions. The study also revealed how these cultural dimensions are associated with the safety behaviour of both the Saudi and non-Saudi sample groups.

Keywords: National culture, petrochemical, safety behaviour, Saudi Arabia.

Introduction

Organisations seek to reduce occupational accidents because of their emotional and economic impact on businesses, families, and societies. Results from several studies support the notion that the majority of occupational accidents are caused by people rather than unsafe working environments. In the past, industrial accidents were described mainly in terms of technological errors, while the human factors that caused the accidents tended to be ignored (Gordon 1998). Since the frequency of technological failures have been reduced, the role of human factors has become more prominent (Gordon 1998).

Accidents in a highly complex socio-technical system are dependent upon the interaction of technical, human, social, organisational, managerial, and environmental factors. These factors could all be contributors to accidents (Cullen 1980). Human factors were considered to be the root cause of accidents by psychologists, reliability engineers and human factors specialists (Wilpert 1995). For this reason, safety professionals should pay attention to employee’s behaviour as a root cause, in order to develop preventive measures that reduce undesired outcomes.

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³ Professor, Griffith School of Engineering, Griffith University, Gold Coast campus, Queensland, Australia 4222, Tel: +617-5552-8575, E-mail: k.panuwatwanich@griffith.edu.au
In any workforce, ignoring cultural differences is a serious cause of misunderstandings and, as a result, conflict (Finestone & Snyman 2005). All organisations function within a national cultural context, irrespective of whether that context is defined in terms of shared meanings, values and assumptions or observable rites and rituals (Burke, Chan-Seraphin, Salvador, Smith & Sarpy 2008). It is important to consider safety issues in the context of different cultural backgrounds. This study intends to address the following research questions, within the context of the petrochemical industry in Saudi Arabia:

- What are the national culture dimensions that influence safety behaviour?
- How to develop the strategies or guidelines for the improvement of workplace safe behaviour by considering national culture dimensions.

**Theoretical Background**

**National Culture**

The term ‘national culture’ is determined by the belief that each country has people with a shared history and experiences – a homogeneous culture which is the basis for the national culture (Bhaskaran & Gligorovska 2009). According to Hofstede (1980), national culture is defined as “the collective programming of the mind which distinguishes the members of one human group from another”. To study the cultural influence on societies, one needs typologies (Schein 1985) or dimensions (Hofstede 1980) that can be used to analyse the behaviour, actions and values of the members of a society. The most replicated and cited dimensions in cross-cultural research is Hofstede (1980) framework. This study revealed four cultural dimensions: (1) the Power Distance Index (PDI); (2) the Individualism Index (IDV); (3) the Masculinity Index (MAS); and (4) the Uncertainty Avoidance Index (UAI). In 1991, a fifth dimension was identified after Hofstede and Bond (1988) worked together on a survey known as the Chinese Values Survey. The fifth dimension was the Long Term Orientation Index (LTO) (Hofstede 2001). Hofstede, Hofstede, Minkov and Vinken (2008) found two new cultural dimensions (the sixth and seventh). These dimensions were the Indulgence vs. Restraint Index (IVR), and the Monumentalism Index (MON). All these dimensions are defined below:

- **Power Distance Index (PDI)** - The extent to which the less powerful members of institutions and organisations within a society expect and accept that power is distributed unequally.
- **Individualism Index (IDV)** - Individualism refers to a society in which the connections between individuals are loose while collectivism is the opposite of individualism, which stands for a society in which the connections between individuals are tight.
- **Masculinity Index (MAS)** - Masculinity stands for a society in which social gender roles are clearly different: men are supposed to be confident, strong, and focused on material success, while women are expected to be modest, kind, and focused on quality of life. Femininity is the opposite of masculinity. It stands for a society in which social gender roles overlap: both men and women are supposed to be modest, kind, and focused on the quality of life.
- **Uncertainty Avoidance Index (UAI)** - The extent to which the members of society feel uncomfortable or threatened by uncertain, unknown, ambiguous, or unstructured situations which lead them to support beliefs promising certainty and to maintain institutions protecting conformity.
- **Long Term Orientation Index (LTO)** - Long Term Orientation stands for a society which supports virtues oriented towards future rewards, in particular adaptation, perseverance and thrift. Short Term Orientation is the opposite; it stands for a society which supports
virtues related to the past, in particular, respect for tradition, preservation of ‘face’, and satisfying social obligations.

- **Indulgence vs. Restraint Index (IVR)** - Indulgence stands for a society which allows relatively free gratification of some desires and feelings. Restraint is the opposite of indulgence, which stands for a society which regulates such gratification, and where people feel less able to enjoy their lives.

- **Monumentalism Index (MON)** - Monumentalism stands for a society which rewards people who are like monuments: proud and unchangeable. Self-Effacement is the opposite of monumentalism, which stands for a society which rewards humility and flexibility.

People from different cultural backgrounds have different ideas of how individuals observe, react and respond to activities that carry risks. This represents the cultural norms that individuals learn in their social environment, and it plays an important role in the way they behave (Fetscherin 2009). However, empirical studies on the impact of national culture on safety attitudes, behaviour and performance seem to be few and far between (Mearns & Yule 2009). Mearns and Yule (2009) examined the extent to which Hofstede’s dimensions of national culture are relevant to the study of safety climate and safety behaviour in a multinational construction, maintenance and facilities management company. Such differences in national culture could influence the efficacy of transferring safety processes and work systems from one country to another.

In the last few decades, a number of studies on Saudi national culture has been undertaken in different fields (Idris 2007). The first study by At-Twaijri (1989) investigated the comparison between Saudi and American managerial values. Also, Al-Meer (1989) compared Westerners, Asians, and Saudis concerning organisational commitment. Al-Meer (1996) undertook another comparative study concerning the importance structure between Saudis and Westerners. Another study by Idris (2007) explored the cultural barriers to improved organisational performance in Saudi Arabia. In addition, Al-Gahtani, Hubona and Wang (2007) explored the impact of cultural differences on Information Technology (IT) acceptance.

**Safety Behaviour**

Safety behaviour is a component of safety performance (Neal, Griffin & Hart 2000). Behaviour is defined as everything a person does that is visible and assessable (Vijayakumar 2007). Safety behaviour defines the behaviour that supports safety practices and activities that need to be accepted by employees according to occupational, safety and health requirements to avoid workplace accidents (Zin & Ismail 2012). Safety behaviour in the workplace was first developed in 1930 after accident reports revealed that 95% of workplace accidents were caused by unsafe employee acts (Geller 2001). Subsequent research indicated that safety behaviour were influenced by organisational safety climate and safety culture (Clark 2006; Neal & Griffin 2006), organisational safety commitment (Zohar 2002), and personality factors (Hinsz et al. 2007).

A study from Thailand by Jitwasinkul (2012) explored the role of organisational factors on safety behaviour of construction workers. The recommendation from this study is to conduct another study on influences of organisational factors on safety work behaviour in relation to different national cultures. Another study from a large petrochemical company in China revealed that the main causes of injury were a lack of safety training (63%) and equipment failure (23%). Thus, safety-related behaviour could be a key element in the prevention of accidents and deserves close attention. Petrochemical industry accidents are...
significantly associated with inadequate knowledge and unsafe behaviour of both employers and employees (Hong et al., 2004). Moreover, Salleh (2010) performed a comprehensive study regarding safety behaviour in the Malaysian petrochemical industry. The findings are encouraging in that they have been tested in relation to national culture within the same industry covered by this study—petrochemicals.

**Method**

This study utilised quantitative method resulting from the research of well-established scholars in the field. A questionnaire survey was employed to identify the important national culture dimensions that influence safety behaviour of employees. The survey was used to collect the data for two constructs: national culture dimensions (NC); and safety behaviour (SB) measured with a five point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Most of the questionnaire items adapted from the available published questionnaire instruments. The questionnaire for safety behaviour adopted from a study in the petrochemical industry performed by Salleh (2010) and national culture questionnaire used from Values Survey Module 2008 (VSM 08) by Hofstede et al. (2008). The questionnaire was distributed online via emails to managers and employees (web-based survey). The following section provides details of the results.

**Results**

An examination of the socio-demographic characteristics was presented in Table 1. The six socio-demographic characteristics used for this examination was: (1) age; (2) gender; (3) educational background; (4) work experience; (5) current position; and (6) nationality. The study population comprised of 407 (258 Saudi, 149 other nationality) managers and employees. All participants are males, and the participant’s ages ranged from 20 to more than 59 years, with almost half of them (48%) aged from 30 to 39 years. The educational background of the participants shows that almost half of the participants (48.6%) had a Bachelor’s degree. More than a quarter of the participants (36.4%) had 6-10 years of work experience. The majority of the participants (85.5%) had non-safety related position. The descriptive data analysis was performed using the SPSS program (version 21). In regard to national culture dimensions they were measured by four questions for each index and 12 questions for safety behaviour. Table 2 and 3 show the mean scores and the standard deviation for each variable.

Given the presence of significant number of non-Saudis responded to the survey, an independent sample t-test was conducted to compare the mean scores between Saudis and other nationalities to determine whether there is a significant difference between the data obtained from these two sample groups. A t-test for independent groups is useful when comparing the difference between the means of two groups with the same variable. Table 4 and 5 show that there are significant differences between Saudi and non-Saudi participants across many variables within both NC dimensions and SB construct. This indicates that the relationship between NC dimensions and SB should be analysed separately for each of the Saudi and non-Saudi sample groups.

Due to the significant differences of the NC dimensions and SB variables between the Saudi and non-Saudi samples, the dataset was separated into two. To ascertain the reliabilities of the survey items, the study utilised Cronbach’s alpha ($\alpha$) to determine how consistent the responses is across the items used in the survey questionnaire. Table 6 shows the values of the alpha coefficient of the NC and SB scales for the Saudi and non-Saudi samples. The alpha coefficients of the NC for both samples (0.77 and 0.78) are considered
good, whereas those of the SB for both samples (0.80 and 0.92) are considered very good to excellent. These results indicate that the internal consistency of the NC and SB scales can be upheld in both Saudi and non-Saudi sample groups.

Table 2. Mean and SD of the National Culture (NC) items

<table>
<thead>
<tr>
<th>National culture dimensions</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Distance Index (PDI)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have a boss (direct superior) you can respect</td>
<td>3.84</td>
<td>1.31</td>
</tr>
<tr>
<td>Be consulted by your boss in decisions involving your work.</td>
<td>4.25</td>
<td>1.15</td>
</tr>
<tr>
<td>An organisation structure in which certain subordinates have two bosses should be avoided at all cost.</td>
<td>2.91</td>
<td>1.12</td>
</tr>
<tr>
<td>How often, in your experience, are subordinates afraid to contradict their boss?</td>
<td>3.28</td>
<td>1.17</td>
</tr>
<tr>
<td><strong>Uncertainty Avoidance Index (UAI)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All in all, how would you describe your state of health these days?</td>
<td>4.19</td>
<td>.859</td>
</tr>
<tr>
<td>A company's or organisation's rules should not be broken - not even when the employee thinks breaking the rule would be in the organisation's best interest.</td>
<td>3.03</td>
<td>1.67</td>
</tr>
<tr>
<td>One can be a good manager without having a precise answer to every question that a subordinate may raise about his or her work.</td>
<td>3.23</td>
<td>1.81</td>
</tr>
<tr>
<td>How often do you feel nervous or tense?</td>
<td>2.83</td>
<td>.845</td>
</tr>
<tr>
<td><strong>Individualism Index (IDV)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have security of employment.</td>
<td>3.85</td>
<td>1.10</td>
</tr>
<tr>
<td>Have sufficient time for your personal or home life.</td>
<td>3.77</td>
<td>1.52</td>
</tr>
<tr>
<td>Do work that is interesting.</td>
<td>4.11</td>
<td>1.30</td>
</tr>
<tr>
<td>Have a job respected by your family and friends.</td>
<td>4.30</td>
<td>1.34</td>
</tr>
<tr>
<td><strong>Masculinity Index (MAS)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get recognition for good performance.</td>
<td>3.97</td>
<td>1.38</td>
</tr>
<tr>
<td>Have chances for promotion.</td>
<td>3.68</td>
<td>1.73</td>
</tr>
<tr>
<td>Have pleasant people to work with.</td>
<td>4.14</td>
<td>1.31</td>
</tr>
<tr>
<td>Live in a desirable area.</td>
<td>4.29</td>
<td>1.32</td>
</tr>
<tr>
<td><strong>Long Term Orientation Index (LTO)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent efforts are the surest way to results.</td>
<td>3.35</td>
<td>1.50</td>
</tr>
<tr>
<td>We should honour our heroes from the past.</td>
<td>3.84</td>
<td>1.06</td>
</tr>
<tr>
<td>If there is something expensive you really want to buy but you do not have enough money, what do you do?</td>
<td>3.26</td>
<td>1.22</td>
</tr>
<tr>
<td>Are you the same person at work and at home?</td>
<td>3.40</td>
<td>1.60</td>
</tr>
<tr>
<td><strong>Indulgence vs. Restraint Index (IVR)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keeping time free for fun.</td>
<td>3.47</td>
<td>1.65</td>
</tr>
<tr>
<td>Moderation: having few desires.</td>
<td>3.74</td>
<td>1.64</td>
</tr>
<tr>
<td>Are you a happy person?</td>
<td>2.48</td>
<td>1.30</td>
</tr>
<tr>
<td>Do other people or circumstances ever prevent you from doing what you really want to?</td>
<td>3.06</td>
<td>1.01</td>
</tr>
<tr>
<td><strong>Monumentalism Index (MON)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modesty: looking small, not big.</td>
<td>3.48</td>
<td>1.71</td>
</tr>
<tr>
<td>How important is religion in your life?</td>
<td>3.68</td>
<td>1.46</td>
</tr>
<tr>
<td>Being generous to other people.</td>
<td>3.11</td>
<td>1.54</td>
</tr>
<tr>
<td>How proud are you to be a citizen of your country?</td>
<td>3.80</td>
<td>1.70</td>
</tr>
</tbody>
</table>
Table 3. Mean and SD of the Safety Behaviour (SB) items

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I voluntarily carry out tasks or activities that help to improve workplace safety.</td>
<td>3.84</td>
<td>1.13</td>
</tr>
<tr>
<td>I help my colleague when they are working under risky or hazardous conditions.</td>
<td>3.94</td>
<td>1.17</td>
</tr>
<tr>
<td>I often make suggestions to improve how safety is handled around here (e.g. plant areas).</td>
<td>3.97</td>
<td>1.00</td>
</tr>
<tr>
<td>If I see something unsafe, I go out of my way to address it.</td>
<td>4.03</td>
<td>1.15</td>
</tr>
<tr>
<td>I am directly and/or indirectly involved in improving safety policy and practices.</td>
<td>4.18</td>
<td>.98</td>
</tr>
<tr>
<td>If I think it will make work safer, I initiate steps to improve work procedures.</td>
<td>4.19</td>
<td>1.02</td>
</tr>
<tr>
<td>I ensure the highest levels of safety when I carry out my job.</td>
<td>4.21</td>
<td>.97</td>
</tr>
<tr>
<td>I put in extra effort to improve the safety of the workplace.</td>
<td>4.27</td>
<td>.75</td>
</tr>
<tr>
<td>I carry out my work in a safe manner.</td>
<td>4.27</td>
<td>1.02</td>
</tr>
<tr>
<td>I use the correct safety procedures for carrying out my job.</td>
<td>4.31</td>
<td>.95</td>
</tr>
<tr>
<td>I often try to solve problems in ways that reduce safety risks.</td>
<td>4.09</td>
<td>1.01</td>
</tr>
<tr>
<td>I use all the necessary safety equipment to do my job.</td>
<td>4.36</td>
<td>.936</td>
</tr>
</tbody>
</table>

Table 4. Comparison between Saudi Arabian and other nationalities in terms of National Culture (NC) dimensions

<table>
<thead>
<tr>
<th>National cultural dimensions</th>
<th>Mean</th>
<th>T-Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saudi Arabian</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td><strong>Power Distance Index (PDI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have a boss (direct superior) you can respect.</td>
<td>3.82</td>
<td>3.89</td>
<td>.524</td>
</tr>
<tr>
<td>Be consulted by your boss in decisions involving your work.</td>
<td>4.25</td>
<td>4.23</td>
<td>-.208</td>
</tr>
<tr>
<td>An organisation structure in which certain subordinates have two bosses should be avoided at all cost.</td>
<td>3.14</td>
<td>2.53</td>
<td>-5.45</td>
</tr>
<tr>
<td>How often, in your experience, are subordinates afraid to contradict their boss?</td>
<td>3.30</td>
<td>3.24</td>
<td>-.346</td>
</tr>
<tr>
<td><strong>Uncertainty Avoidance Index (UAI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All in all, how would you describe your state of health these days?</td>
<td>4.17</td>
<td>4.23</td>
<td>.728</td>
</tr>
<tr>
<td>A company's or organisation's rules should not be broken - not even when the employee thinks breaking the rule would be in the organisation's best interest.</td>
<td>3.38</td>
<td>2.43</td>
<td>-5.73</td>
</tr>
<tr>
<td>One can be a good manager without having a precise answer to every question that a subordinate may raise about his or her work.</td>
<td>2.94</td>
<td>3.75</td>
<td>4.42</td>
</tr>
<tr>
<td>How often do you feel nervous or tense?</td>
<td>2.84</td>
<td>2.82</td>
<td>-.179</td>
</tr>
<tr>
<td><strong>Individualism Index (IDV)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have security of employment.</td>
<td>3.62</td>
<td>4.23</td>
<td>5.50</td>
</tr>
<tr>
<td>Have sufficient time for your personal or home</td>
<td>4.10</td>
<td>3.21</td>
<td>-5.89</td>
</tr>
</tbody>
</table>
life.
Do work that is interesting. 4.06 4.18 .881 .251
Have a job respected by your family and friends. 4.32 4.27 -.363 .854

**Masculinity Index (MAS)**
Get recognition for good performance. 3.90 4.08 1.29 .253
Have chances for promotion. 3.47 4.04 3.26 .000***
Have pleasant people to work with. 4.07 4.27 1.49 .786
Live in a desirable area. 4.40 4.09 -2.31 .000***

**Long Term Orientation Index (LTO)**
Persistent efforts are the surest way to results. 3.12 3.74 4.07 .000***
We should honour our heroes from the past. 3.97 3.63 -3.14 .600
If there is something expensive you really want to buy but you do not have enough money, what do you do? 3.35 3.12 -1.84 .014*
Are you the same person at work and at home? 3.29 3.67 1.94 .060

**Indulgence vs. Restraint Index (IVR)**
Keeping time free for fun. 3.24 3.86 3.71 .002*
Moderation: having few desires. 3.42 4.29 5.31 .000***
Are you a happy person? 2.37 2.67 2.25 .000***
Do other people or circumstances ever prevent you from doing what you really want to? 3.15 2.90 -2.44 .894

**Monumentalism Index (MON)**
Modesty: looking small, not big. 3.41 3.61 1.17 .000***
How important is religion in your life? 4.31 2.59 -13.7 .000***
Being generous to other people. 3.41 2.59 -5.28 .000***
How proud are you to be a citizen of your country? 3.49 4.34 4.99 .000***

* Significant at p<0.05; ** Significant at p<0.01; *** Significant at p<0.001

Table 5. Comparison between Saudi Arabian and other nationalities in terms of Safety Behaviour (SB)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean Saudi Arabian</th>
<th>Mean Others</th>
<th>T-Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I voluntarily carry out tasks or activities that help to improve workplace safety.</td>
<td>4.06</td>
<td>3.44</td>
<td>-5.46</td>
<td>.000***</td>
</tr>
<tr>
<td>I help my colleague when they are working under risky or hazardous conditions.</td>
<td>3.99</td>
<td>3.85</td>
<td>-1.10</td>
<td>.218</td>
</tr>
<tr>
<td>I often make suggestions to improve how safety is handled around here (e.g. plant areas).</td>
<td>4.09</td>
<td>3.77</td>
<td>-3.14</td>
<td>.174</td>
</tr>
<tr>
<td>If I see something unsafe, I go out of my way to address it.</td>
<td>4.28</td>
<td>3.59</td>
<td>-6.03</td>
<td>.000***</td>
</tr>
<tr>
<td>I am directly and/or indirectly involved in improving safety policy and practices.</td>
<td>4.27</td>
<td>4.02</td>
<td>-2.54</td>
<td>.289</td>
</tr>
<tr>
<td>If I think it will make work safer, I initiate steps to improve work procedures.</td>
<td>4.03</td>
<td>3.85</td>
<td>-5.24</td>
<td>.000***</td>
</tr>
<tr>
<td>I ensure the highest levels of safety when I carry out my job.</td>
<td>4.31</td>
<td>4.02</td>
<td>-2.91</td>
<td>.023*</td>
</tr>
</tbody>
</table>
I put in extra effort to improve the safety of the workplace. 4.31 4.20 -1.40 .361
I carry out my work in a safe manner. 4.25 3.90 -5.69 .000***
I use the correct safety procedures for carrying out my job. 4.21 3.95 -5.98 .000***
I often try to solve problems in ways that reduce safety risks. 4.10 4.08 -1.17 .027*
I use all the necessary safety equipment to do my job. 4.29 4.08 -4.71 .002*

* Significant at p<0.05; ** Significant at p<0.01; *** Significant at p<0.001

Table 6. Reliability coefficients

<table>
<thead>
<tr>
<th>Number of Items</th>
<th>α (Saudis)</th>
<th>α (Non-Saudis)</th>
<th>α (combined)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>28</td>
<td>0.77</td>
<td>0.78</td>
</tr>
<tr>
<td>SB</td>
<td>12</td>
<td>0.92</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Tables 7 summarises the Pearson’s correlation (r) values between the NC dimensions and the SB construct of both the Saudi and non-Saudi samples. According to the table, SB of the Saudi sample is significantly correlated with IDV (individualism), MAS (Masculinity) and LTO (Long-term orientation). More specifically, the relationships between SB and both IDV and MAS is negative, indicating that higher levels of individualism and masculinity are linked with lower safety behaviour among Saudi workers. On the other hand, the positive relationship between LTO and SB within the Saudi sample indicates that the higher level of long-term orientation is associated with the higher level of safety behaviour.

For the non-Saudi sample, the only NC dimension that is significantly and positively correlated with SB is UAI (Uncertainty Avoidance Index). This suggests that only the higher level of uncertainty avoidance of the non-Saudi workers is associated with their increased level of safety behaviour.

Table 7. Pearson correlation between Safety behaviour (SB) and National Culture Dimensions (NC)

<table>
<thead>
<tr>
<th>SB (Saudi)</th>
<th>SB (Non-Saudi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB (Saudi)</td>
<td>1 - .126* - .030 -.143* -.072 .047 .027 .124*</td>
</tr>
<tr>
<td>SB (Non-Saudi)</td>
<td>1 - .098 .061 -.071 -.109 .132 .263** .051</td>
</tr>
</tbody>
</table>

**Correlation is significant at p<0.01 level (2-tailed)
*Correlation is significant at p<0.05 level (2-tailed)
N.B. Correlation coefficients between NC dimensions are not shown.

While the above results require further in-depth analysis into the specific nature of the relationships between national culture and safety behaviour of both sample groups, they clearly highlight the need to acknowledge the different demographics of workforce within the Saudi petrochemical industry to ensure appropriate level of safety behaviour is maintained. It is apparent from the findings that the perceptions of the Saudi sample on their national culture differ to a significant extent from those of the non-Saudis. More importantly, such difference can be seen in the way in which specific dimensions of the
national culture of these two distinct sample groups relate to the levels of safety behaviour. For management, the findings shed light on the need to appreciate and understand such cultural diversity among their employees and how it can be applied to help achieve superior safety management within the Saudi petrochemical industry.

**Conclusion**

In any workforce, ignoring cultural differences is a serious cause of misunderstandings and, as a result, conflict. All organisations function within a national cultural context, irrespective of whether that context is defined in terms of shared meanings, values and assumptions or observable rites and rituals. It is important to consider safety issues in the context of different cultural backgrounds. This study addressed this knowledge gap, within the context of the petrochemical industry in Saudi Arabia.

The results from the study presented in this paper show that there is a significant difference between the Saudi and non-Saudi employee groups in terms of the perceived national culture and safety behaviour. The difference between these two sample groups is also apparent in the relationships between specific national culture dimensions and the levels of safety behaviour. For the Saudi group, higher levels of masculinity and long-term orientation are associated with higher level of safety behaviour whereas higher level of individualism is associated with the lower level of safety behaviour. Only one national culture dimension, uncertainty avoidance, is shown to have a positive correlation with the level of safety behaviour of the non-Saudi sample. The finding highlights the need for managers to acknowledge the diversity among their employees and to understand how different attributes of national culture may have an impact on employees’ safety behaviour. Future work is however required to further examine the nature of influence national culture has on safety behaviour.

**References**


Engendering Change within a Water Infrastructure Client Organisation: A Participatory Action Research Approach

M. Potts¹, B. Awuzie², P. McDermott³, and A. Stephenson⁴

Abstract
Continuing demands by stakeholders for improved service delivery has caused Infrastructure Client Organisations (ICO) in the UK to embark upon organisational restructuring. It is expected that such restructuring would enhance cost-effectiveness and quality in asset management and service delivery. However, this change, if not properly managed and sustained, could result in the inability of the ICO to achieve these targets. This study outlines the use of systemic thinking and Participatory Action Research (PAR) in driving and managing such change within a UK-based Water and Wastewater ICO (UK WASC). Besides highlighting the context for change in response to policy, austerity and regulatory pressures, this study portrays how the PAR approach can assist in the management of change within ICOS. Furthermore, it provides an insight into the evolution of an external researcher, from a novice to an expert within the ICO, imbued with the required knowledge to encourage other stakeholders to participate in driving the change management process. Preliminary findings indicate the usefulness of this phased approach toward PAR. This study provides a platform for researchers wishing to engage with ICOS to improve service delivery; identifying the value of engagement, change and systemic thinking.

Keywords: Infrastructure delivery, participatory action research, change management.

Introduction
Issues concerning poor quality infrastructure and the delivery of infrastructure-related services have continued to elicit high levels of interest in recent times (HM Treasury 2010). Successive governments have sought to devise strategies that ensure investments in the provision of infrastructure achieve optimum benefits for both society and the economy. Regulation, deregulation and unbundling of service provisions are among a plethora of mechanisms through which governments aim to achieve value for money amongst other favourable benefits associated with the delivery of infrastructure services (Alexander & Estache 2000; Kessides 2005; Eberhard 2007). However, criticisms continue to trail these Infrastructure Client Organisations (ICOs) especially with regard to poor cost effectiveness and service delivery despite the introduction of these mechanisms (IUK 2012).

In the UK, these criticisms have led to a shift in focus towards the resilience, value, investment and efficiency of infrastructure assets; coupled with their procurement, delivery and management (IUK 2012). ICOS in the UK are being tasked to streamline their internal and external processes towards efficient and effective procurement, delivery and management of critical infrastructure assets and services to the final consumer (IUK 2013). Undoubtedly,

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streamlining the internal and external processes within these ICOs would bring about change. Achieving such change can pose a herculean task; and often, introducing enduring change into such organisations requires the collaborative resolve of all stakeholders involved. One of these such ICOs in the UK (UK WASC) keen on achieving both regulatory and organisational service delivery targets, commissioned a study into a review of its internal and external processes. It is expected that this study would identify barriers to efficiency and introduce change processes to influence and enhance optimised service delivery.

This paper seeks to highlight the significant value of the approach applied to this project. Whereas the capability of the Participatory Action Research (PAR) approach in facilitating enduring and sustainable change has been buttressed elsewhere (Whyte 1991, Rahman 1993), there appears to be a paucity of studies detailing the evolution of the researcher from an external party to the organisation and its processes, through to an involved practitioner able to drive change and encourage participation of various stakeholders. This is what this paper seeks to achieve. This evolution has been summarised as the Three Phase Change Approach (TPCA), which sees a transition from using Participant Observation (PO), to Action Research (AR) and onto PAR.

**Infrastructure Investment and Delivery: Issues Arising**

As far back as Adam Smith (1776), the topic of infrastructure spend to encourage economic growth has been a focus for policy. Notably, 'there is an obvious and important policy implication (from the 'Aschauer Hypothesis'): that governments can increase real output and productivity substantially by stepping up infrastructure investment' (Ford & Poret 1991). Although more recent reports (Egert et al 2009, Crafts 2009) point towards the positive impact of infrastructure investment on GDP growth, Gramlich (1994) draws attention to the need to understand appropriate levels of infrastructure requirement. Infrastructure investment and its resilience (Bissell 2010) and the future challenges to the economy, industry and national prosperity are also important (Ofwat 2013). This has led to a two pronged discussion around infrastructure, namely; the requirement to invest in infrastructure to facilitate growth; and the efficient delivery of that infrastructure to gain best value (HM Treasury 2010; 2013).

The divestiture of the water sector in England & Wales, resulting in private regulated regional monopolies, can be seen as an example of this drive to create efficient delivery; while issues with monopolistic infrastructure delivery pertain to vertical integration, bilateral monopolies, and lack of competition and monopoly-monopsony relationships (Hillebrandt 1985). Within this type of delivery arrangement, there is an assumption which indicates that the need to drive value and competitiveness does not exist. The water sector and its typically long term relationships and high fixed investment costs (Akintoye & Renukappa 2013) should therefore become subject to assessment of its delivery of relational contracting and the effectiveness of their delivery systems. Buoyed by the construction industry's prevalence towards a 'systematic approach' to delivery (Mazet & Portier 2010), creating an industry of specialists, there is a need to focus on the 'systemic' delivery of services to drive out inefficiencies and create value. The high costs associated with the delivery of infrastructure services have been traced to stop-start investment programmes; lack of clarity and direction; poor budget management; over-specification; in-effective use of competition; poor strategic use of supply chains; and a lack of investment in skills (HM Gov. 2011) resulting in the UK having the fifth highest civil engineering costs in Europe (HM Treasury 2010).

**The State of Infrastructure in the UK Water Sector**

Within the UK context, the sector’s focus on resilience, value, investment and efficiency is evident in Infrastructure UK (IUK 2012) and the Industrial Strategy (HM Gov. 2013) both of
which build on the principles within the National Infrastructure Plan (IUK, 2011). The focus here is on the maximization of investment below the optimum level discussed by Barro (1990) and with the financial crash and resultant downturn in GDP (OECD 2013) policy makers have focused their attention towards issues such as stability, value, client skills, efficiency, cost benchmarking and growth (Cabinet Office 2011).

Despite an increase in annual infrastructure investment in the UK from the £41billion annual average between 2005 and 2010 to its present level of £45 billion per annum (IUK 2013), EC Harris (2013) lists the UK as being ‘asset rich’ and relatively ‘cash poor’. The World Economic Forum (2012) lists the UK as 24th in terms of overall infrastructure quality while the Treasury (2013) and Infrastructure UK (2013) refer to ageing assets and inefficient delivery of projects as the main stumbling blocks in UK infrastructure. Efficiency and maximizing appropriate value from infrastructure investment is the key to sustaining a strong economy; and to this end, focus is given to critical, asset rich, but efficiency poor infrastructure providers such as the privatised water sector in England & Wales (HM Gov. 2013). Private water and waste water companies regulated by Ofwat (The Water Services Regulation Authority) can see this value focus on efficiency, as recently as January 2013 and the ‘Setting price controls for 2015-2020 framework and approach’ issued by Ofwat focusing on delivery; securing Value for Money; using water resources better; evaluating and mitigating risk; and assessing historic performance. With an ageing infrastructure and forecast population growth, the water sector is under considerable scrutiny with regard to its effectiveness in delivering value, driving innovation and their preparedness for the growth in demand (Akintoye & Renukappa 2013).

**Change within UK WASC**

Change management is an important process which assists an organisations' transition to a desired future state. It can focus on a number of levels, from the individual, to the team or the whole organisation (Kotter 2011). Balogun & Hope Hailey (2004) assert that seventy percent of change management programmes fail; Todnem (2005) traces this failure to the likely 'lack of a valid framework of how to implement and manage organisational change'. This project seeks to address the gap in knowledge around the improvement of the delivery of infrastructure within a regulated environment. The research proposition is to address the institutional gap in knowledge with regard to the delivery of infrastructure assets within the UK context through a single institutional arrangement, such as with a regional monopolistic Water and Sewerage Company (UK WASC).

This project has been formulated around a three phase participative process, utilising a PhD programme as a driver (among other initiatives), in tandem with the formulation and creation of a new Infrastructure Delivery System (IDS) to act as facilitators for change. The project focuses on a core compliment of change within the organisation to facilitate the data gathering for the system itself. Building on Lewin’s Unfreeze, Move and Re-freeze (Lewin 1951), this project is aligned to a 3+ year relationship with the ICO during which an embedding of the researcher within UK WASC; data gathering; changing and testing; and finally, adapting and finalising the changes occurs. A valuable business change and procurement process was underway within UK WASC and the value of immediate change and the creation of self-help competencies (Shani & Pashmore 1985) was seen as an invaluable process. This caused the creation of an Action Research Framework (ARF) (McNiff & Whitehead 2009) with a three phased approach aligned to Lewin (1951). However, considering the emergent approach to change; the development of the researcher within the focus ICO; the development of organisational acceptance of the approach; and the need to ensure active participation of stakeholders; the approach is better described as the Three
Phase Change Approach (TPCA). The TPCA is split into Unfreeze, concerned with PO, among other methods; Move which utilises AR; and Re-freeze which is focused on PAR.

PAR- An Appropriate Approach for Change Management?

PAR has been defined as a research approach wherein persons from within the organisation actively participate with the professional researcher throughout the research process (Whyte 1991). Similarly, whilst appraising the strength of PAR, Argyris and Schon (1974) observe that the approach offers a more practicable platform to enable researchers to achieve both rigour and relevance when carrying out a research project; a constraint which had appeared insurmountable in the past for social science researchers. The decision to adopt the PAR approach was premised on achieving sustainable change within UK WASC via collaboration with the various stakeholders identified as being responsible for the organisation’s internal change processes. As a result, it was vital that stakeholders participated in the identification of the problem, data collection, and reflection in collaboration with the researcher. This active participation in the research process has since been identified as a salient advantage of the PAR approach (Rahman 1993). It leads to the development of workable change model(s) based on group consensus, as well as the promotion of the continual improvement and if need be, (re)invention of the developed model(s) long after the culmination of the research project.

Research Methodology

In this study, a qualitative single case strategy was applied within the focus ICO. Although there continues to be concerns about the validity of single case study findings, Yin (2009) insists that the choice of whether to adopt a single or multiple case study strategy is dependent on the purpose and nature of the research. It is maintained that single case studies are especially advisable where the case is either unique, critical or an exploratory one. In this study, the case satisfies these three tenets. In similar studies, it has been shown that the collection of data has involved a great degree of spontaneity (Hartley 2004) and is usually of a qualitative nature. This made the adoption of PO, unstructured and semi-structured face-to-face interviews and workshop sessions, a natural route for data collection.

As with most cases involving participatory focused research, the process of initiation always poses a challenge to the researcher. Whether initiated by the client or researcher, the entry paradigm differs; such as with guaranteed organisational entry with client initiated research, but this can be counterbalanced by a drive to focus on client derived issues (Schein 1999). It is important then to define the social and psychological contract that will govern the relationship, and thus make clear its foundation and focus. To this end, a project evaluation model is proposed in Table 1. For this project, the initial originator of this project is the research body, in collaboration with UK WASC with a view to the development of a PhD programme within the research body. With this, the level of organisational entry is high; however, the focus is loosely prescribed and the skill level of the researcher is expected to develop in stages. The results are concerned with the parameters set in collaboration between researcher and organisation, utilising high client involvement.

Schein (2008) observes that researcher initiation of a 'project' where the researcher and client involvement is high, usually results in AR. When linked in conjunction with the development of a PhD programme, the associated change in researcher skill level requires the division of the research process into phases, and as such aligns with the Three Step Change model of Kurt Lewin (1951). This is not to say that the consideration of 'change readiness and facilitating for change' (Todnem 2005) of the emergent approach is not considered, especially with regard to the changing internal and external pressures of a contingent approach to change strategies (Fawcett et al. 2008). But that, although the three step model may be
criticised for its small scale nature, its application is being used in a macro 'structural' sense, and thus the overall structure of the change approach is in three phases, with contingent strategies within it that correspond to a changing research narrative.

Table 1: Project Initiation

<table>
<thead>
<tr>
<th>Originator</th>
<th>Entry</th>
<th>Focus</th>
<th>Skill level expectations</th>
<th>Results expectations</th>
<th>Client involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Specific</td>
<td>Predefined issues</td>
<td>Medium</td>
<td>Practical and directive</td>
<td>Medium</td>
</tr>
<tr>
<td>Research body</td>
<td>High</td>
<td>As unearthed</td>
<td>Low - High</td>
<td>Unexpected</td>
<td>Low - High</td>
</tr>
<tr>
<td>Consultant</td>
<td>Low</td>
<td>Within skill-set</td>
<td>High</td>
<td>Specific to topic</td>
<td>Low</td>
</tr>
</tbody>
</table>

The PAR Approach to Fostering Sustainable Change

Considering a multitude of factors, from understanding the focus organisational issues, researcher development, project definition to participatory learning through an iterative cycle; the TPCA is split according to three constituent research phases, each representing a differing psychological contract with the focus ICO.

Firstly, PO is in essence a data collection method, whereby immersion of the researcher into the setting allows the researcher to gain a rich understanding of the factors affecting those being studied (DeWalt & DeWalt 2010). By 'putting you where the action is' (Bernard 2011), PO acts as one of several methods within the qualitative research framework, whereby the goal is to understand the nature of the phenomena opposed to quantification of it. Multiple sources are used from informal interviews, pure observation, a review of policy and literature, document reviews and the building of social networks within the organisation. Gorman & Clayton (1997) identify four main qualitative research approaches as observation, interviewing, historical research and group discussion; all of which are utilised in this approach. It is important that a social contract is created here by which the practitioners understand the aims of the project and its foundations (Mackenzie et al. 2012); collaboratively and sensitively defining the project expectations in the process (Denscombe 2010). A moderate participation role (Spradley 1980) is taken in order to differentiate between researcher and practitioner whereby PO in this manner allows appropriate involvement and a relevant amount of detachment to remain objective (DeWalt & DeWalt 2010). A primary aim with Phase 1 of the research is to define the baseline from which the AR effectiveness can be judged (McNiff & Whitehead 2009) and future organisational engagement can be addressed (Mackenzie et al. 2012).

As the researcher becomes more skilled and further aligned with the processes and forces affecting the focus organisation, collaborative working strategies with participants begin to form and an effective 'observation into action' barrier is crossed. This leads to the use of AR and the beginning of Phase 2. AR is a self reflective process aimed at improving practice, that goes beyond the extent of external review and strategic theory building, but keeps full integration at arm's length. Again, multiple methods are used, from semi-structured interviews, surveys, workshops, discussion groups and further policy and literature reviews as action strategies are developed with co-researchers. Shani and Pashmore (1985) summarize the situation as 'it (AR) is simultaneously concerned with bringing about change in
organizations, in developing self-help competencies in organisational members and adding to scientific knowledge’. AR and the ‘Action Reflection Cycle’ (ARC) of McNiff & Whitehead (2009), follows a process of ‘Observe, Reflect, Act, Evaluate, Modify, Move in new directions’. This cycle, which is self-perpetuating in nature, suits the enacting of organisational change within a project or programme culture. With this, AR becomes 'Research in action, rather than research about action' (Coghlan & Brannick 2005), so takes a pro-active role within an organisation. It therefore takes on a human role within the organisation as the researcher becomes an active member of the process. A key point is the responsibility on the researcher to 'enact' change. This imparts a component of direction, such that the researcher dictates the extent to which the result will be defined.

Following a series of ARC’s, the researcher gathers knowledge and generates a set of skills comparable to that of their peers. As the researcher and peer group begin to focus on 'I/we' and 'our practice', the research process moves beyond the PO focus on 'they', and the directive 'we' of AR to become a collective 'I/we' of PAR. This then becomes Phase 3. Ottoson (2003) connects the holistic 'quantum' paradigm of PAR with self-reflection and managerial / organisational change, utilising participation or involvement as a key differentiator of the method from Newtonian classical approaches. PAR is focused on the improving of group / organisational practice wherein the process itself forms an appropriate basis for effective change within the given scenario (Whyte 1991). Here the focus is on enacting real world organisational learning to better understand the complexities of the organisational issues (Ottoson 2003, Mackenzie et al. 2012). This leads to an ongoing reflective process where actions have become the ownership of the individual and the ICO, and 'spin-off' groups / actions and changed processes replace the directive focus of AR. It is important during this stage to take stock of the resultant knowledge change within the organisation and the formation of new behaviours (Burnes 1996). Here, the data gathered during the AR cycles will be viewed in relation to the initial baseline defined by PO. It will be instrumental to seeing the effectiveness of diffusion (Hall & Mairesse 2006) within the ICO to provide feedback into the organisation about how to reflectively enact the process again. Here, artefacts such as Action Research Reports will become important reflective documents for the ICO. During Phase 3, it is important to act and reflect simultaneously, identifying one's own practice and reflecting on next steps (Kindon et al. 2007).

It is important to note that this structure shares some comparisons with the Soft Systems Methodology (SSM) of Checkland (1989) and lends heavily to interpretive systems thinking (Daellenbach 2001). A key difference with the TPCA structure, is the creation of what can best be described as the '8th step' (see Table 2), whereby the next step encompasses 'finding and changing', and PAR encompasses practice, off-shoots in action and the 'refreezing' of change into commonality.

Table 2. The TPCA in comparison

<table>
<thead>
<tr>
<th>Soft Systems Methodology</th>
<th>Action Reflection Cycle</th>
<th>3 Step model</th>
<th>TPCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Entering the situation.</td>
<td>Enter organisation</td>
<td>Unfreeze</td>
<td>PO</td>
</tr>
<tr>
<td>2. Expressing the situation.</td>
<td>Observe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Formulating root definitions</td>
<td>Reflect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Comparing the models</td>
<td>Evaluate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Defining changes</td>
<td>Modify</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Taking action</td>
<td>Move in new directions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>Refreeze</td>
<td>PAR</td>
</tr>
</tbody>
</table>
Contingency theory plays an important part in this change, whereby moving away from the no-one best way paradigm of polar opposites towards a more situation specific approach is considered. This places the specifics of the situation at the forefront of the decision making process (Woodward 1965). While restricted by the internal and external forces via the planned approach, managers utilising an emergent / contingent view are free to determine the extent to which factors exist or play a part on the key elements of technology, size and environment (Burnes 1996). This ability to modify parameters led to the focus of change within a planned 'structure', but with a focus on emergent principles. Such that, change, and change management is coherent, with the initial focus issues being targeted, but with the aim of facilitating 'change' skills and creating 'changing' knowledge pathways opposed to creating a desired future state. The TPCA is thus aligned to the 5 stage ICO internal re-procurement change process within the UK WASC; see Figure 1 below.

![Figure 1. The TPCA structure in comparison](image)

**Findings and Discussion**

As a method, the TPCA demands a high level of commitment, from both researcher and organisation. Change does not naturally sit well with everybody, and little credence is often given to 'outsiders' to change processes. This evolution from outsider to insider is the core tenet of the TPCA. The process cannot be thrown to one side as a consultants whimsy to suit the bias' and demands of a task master, but instead is as much the responsibility of the organisation as it is the researcher who primarily enacts it. In accordance with the 5 stage ICO internal re-procurement change process, the following outlines the value of the TPCA:

1. **Directive:** The project is initiated and the respective roles of participants are made clear. Initial focus on intervention areas remains unclear while the researcher is immersed into the focus environment. It is important to limit the focus scope to a manageable level at this point, hence making project drivers clear throughout the research is vital. The next step is to gather information on focus areas, creating a picture and definition of the wider issue.
(2) **Strategy:** There should be an amalgam between research focus areas and a reflection on theory. This is where the step into praxis begins. The focus areas remain ostensibly large at this point, but the definition of the project can take place. There is synthesis between literature and the ICO to find a valuable, effective and usable medium between wider systemic focus, internal politics and availability of resources (primarily). Coming toward the end of the stage, the understanding of the project drivers are more clearly known by ICO participants and they can push back on the final areas of focus. This creates a tiered level of ‘buy-in’ from stakeholders, those with little interest, and then those that either (1) want the result, (2) want a result and the knowledge of how, and (3) those that want to co-design the process and be a part of the result.

(3) **Formation:** The key participants are both emotionally and resourcefully brought into the process and areas of focus are clear. The next step is to design the range of interventions collaboratively, ironing out stakeholder engagement issues and tying together with other relevant ICO processes. Interventions at this stage may very well become of more interest to the disengaged. It is then important to begin the interventions, being careful and open enough to either abandon a route of enquiry, or re-assess assumptions to suit the changing ICO environment. At this stage, the co-creation of objectives may lead to unknown outputs born out of collective and collaborative learning requiring reflection on initial change parameters.

(4) **Results:** Here, the results of any intervention are communal. Researcher becomes a developed participant and the value of the process may have become more valuable to others. The value at this stage is engagement and progression and the developmental knowledge of the fellow participants. The researchers’ role is now to facilitate the embedding of these results into practice and day to day working. This requires the focus of what’s next, and how would we be better?The researcher should now be viewed as an instigator of the programme at hand. The trust and focus on ‘ours’ and ‘mine’ is where the interventions and changes now spiral out beyond the design of a research intervention as organisational participants take their respective learning and affect their day to day lives.

(5) **Mobilisation:** Here, the focus is on enactment and the value of day-to-day working. Processes and practices focused on 'moving' from one state to another have been replaced with the performing of 'new working'. The focus is now on my work, and how I interact with my fellow employees; this may require clarification of the intent of the researcher around the initial reasons for the focus.

The TPCA is an effective process for managing change in a number of ways. In Phase 1, this is by using objectivity and externalisation as reasoning behind identification of change factors of focus. Then in Phase 2, it takes the organisation 'on the journey' to redefining strategies in relation to those issues. In Phase 3, those strategies become as much the responsibility of the researcher as they do anyone else. This transition from external to internal, from identification to enactment is a core tenet of the TPCA.

**Conclusion**

The TPCA has helped to identify preliminary findings, such as the usefulness of the PO, AR & PAR phased approach. The TPCA approach has unearthed issues such as the duplication of resource, internal power structures as inhibitors and the need to change behaviours to overcome internal organisational silos as the core areas requiring change management. The study provides a platform for engaging with ICOs to improve service delivery. It identifies the value of engagement, change and systemic thinking as well as a process for use beyond the focus context. This study offers an alternative approach to the delivery of service improvements from within an infrastructure client organisation besides identifying the nature of intervention in a collaborative and innovative manner to drive and manage internal change.
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Effect of Embedding Shape Memory Alloy (Cu-Zn-Al) in an Aircraft Wing Panel

Ruan Pretorius¹, Izendu Aghachi², and Rotimi Sadiku³

Abstract

Aircrafts that are designed with fixed wing structure have to sacrifice design efficiency. Most airplanes wings are designed to perform optimally at cruising speed in order to save on fuel consumption. Flight conditions that consume the most fuel are: take-off, ascending, descending and landing. At these instances, the aileron is expected to deflect, thereby using more energy. In this work, shape memory alloy, Cu-Zn-Al was used to simulate an aileron deflection, using the effect of temperature change in the behavior of this material. The rate of austenite and Martensite start and finish were first established. With that knowledge, a suitable dimension and the number of the alloy to be embedded for the desired aileron deflection was determined by iteration method, using MATLAB codes. The effect of temperature on the embedded material at different altitudes were determined and plotted. It was observed that it is very easy to reach a down aileron with the shape memory alloy than it is to get the aileron up. It was also concluded that a shape memory, self-actuating material can be used to achieve this motion in an aircraft wings without additional energy.

Keywords: Aircraft, austenite, martensite, shape memory alloy.

Introduction

Smart materials are defined as materials that react to their surroundings, resulting either from the addition or removal of energy. Such surroundings includes changes in pH, temperature, pressure, light and also magnetism (Jahanzeb, 2012). Smart materials have inherent and induced capabilities. According to Akhras, smart materials respond to stimuli and changes in the environment. They can activate functions, such as deformation or deflection according to these changes (Akhras, 2000). Smart materials can be classified as follow: Thermo-to-mechanical, electrical-to-mechanical, and magnetic-to-mechanical and vice versa. The most common smart materials are: Piezoelectric Materials, Shape Memory Polymers (SMP) and Shape Memory Alloys (SMA). Advances in technology of smart materials provide an opportunity to make air flight more efficient(Amariei, Miclosina,Vela and Tufoi, 2010). By researching on the possibility of getting rid of the heavy actuators and changing the shape of the airfoil to suit different flight conditions, it is envisaged that there will be a reduction in fuel consumption and hence savings in energy. This will in turn increase the distance aircrafts can travel with the same amount of aviation fuel.

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Shape Memory Alloys (SMA)

Shape Memory Alloys (SMA) have the ability to return to their original shapes when heated and then cooled. Thus, the material remembers its previous shape. The deformation of SMA occurs at relatively low temperatures and when heated, the material will return to its original form (Callister, 2007). The material moves between austenite and martensite phases when cooled or heated. Figure 1. shows a fundamental characteristics of Ni-Ti as reported by Callister. Shape memory alloys can be used as actuators in the automotive industry. It is also used extensively in dentistry for certain dental corrections.

![Diagram showing material moving between austenite and martensite phases](Herkules, 2013)

Deflection in SMA can either be a one-way-memory or a two-way memory. In a one-way memory, the material deflects only when it is heated. When it is cooled at a low temperature, it does not change in shape. Conversely, a two-way memory alloy is able to deform when heated and reverse when cooled beyond certain temperature (Otsuka and Wayman, 1999.).

**Phase Transformation of Cu-Zn-Al**
The material used for the simulation is Cu-Zn-Al. The composition of the alloy used was Cu-25.63%, Zn-4.2% and Al-70.17%.
Table 1. Input Parameter

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>6mm</td>
</tr>
<tr>
<td>Α</td>
<td>18.06 x 10^-6 °C^-1</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td>σ^+</td>
<td>6 °C</td>
</tr>
<tr>
<td>σ^-</td>
<td>3 °C</td>
</tr>
<tr>
<td>μ^+</td>
<td>290</td>
</tr>
<tr>
<td>μ^-</td>
<td>270</td>
</tr>
<tr>
<td>Austenite Start</td>
<td>289 K</td>
</tr>
<tr>
<td>Austenite finish</td>
<td>290 K</td>
</tr>
<tr>
<td>Martensite start</td>
<td>287 K</td>
</tr>
<tr>
<td>Martensite finish</td>
<td>270 K</td>
</tr>
</tbody>
</table>

The input data were taken from the experimental data of (Lexcellent and Bourbon, 1996)

Modeling of the Wing

The material used for this Simulation is Cu-Zn-Al. The composition of the alloy used was Cu-25.63%, Zn-4.2% and Al-70.17%. A wing panel was drawn in Solidworks of 1000mm in length and 300mm in width. The thickness of the carbon fiber weave was 8mm. The wing design that was used is Wortmann FX60-126airfoil.
The deflection of the wing, due to its own weight, was calculated using the beam deflection equation. The wing was analyzed as a cantilever beam. Practically, the in-flight deflection of a full wing for a Boeing 787 is about 7.62 m with a full length of about 30 m long (Paur, 2010). Using a 1 m long wing and mimicking an in-flight condition gave a maximum deflection of 0.254 m using equation 1.

\[
\frac{UAV}{7.62} = \frac{1}{30}
\]

(1)

**Iteration of the Number of SMA Wire**

A script was written in order to iterate the number of Cu-Zn-Al SMA wires required to obtain a way deflection of a 1000 mm long wing, as shown in the figure above. The result is plotted in figure 4.

![Figure 4. The number of wire required for the maximum deflection of the 1 m length wing](image)

It can be seen from Figure 4 that the number of wires required to obtain a deflection of the wing to 0.254 m are 20 wires.
Temperature and Altitude on Cu-Zn-Al SMA Wire

Temperature changes from day to night in summer and in winter. Also, as the altitude increases, the temperature drops. Table 2 shows the average temperatures (during the two seasons of the year) over South Africa and the drop in temperature for every 1000 meter in to the air.

Table 2. Data used to calculate temperatures at various altitudes (Gratz, 20013).

<table>
<thead>
<tr>
<th>Season</th>
<th>Day</th>
<th>Night</th>
<th>Temperature drop for every 1000m increase in altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>28°C</td>
<td>8°C</td>
<td>-9.8°C</td>
</tr>
<tr>
<td>Winter</td>
<td>18°C</td>
<td>1°C</td>
<td>-6°C</td>
</tr>
</tbody>
</table>

After about 11 000m, the temperatures average out and the formula is no longer necessary which is in Table2.

Figure 5. Wire temperature of 6.85 °C

Figure 6. Wire temperature of 13.85 °C
By making use of the surrounding temperatures of the wing at different altitudes, the wing wild deflection due to the temperature outside the plane, can be determined. Most of the deflections will take place at Austenite finish temperature. However, it can be seen that the change in temperature due to altitude deflection will also take place at martensite start temperature.

**Conclusion**

This study shows that it is possible to actuate a UAV wing by making use of the environments temperature and altitude. The higher the altitude of the UAV and the higher the temperature of the shape memory alloy, the greater the deflection of the wing. For this system to perform at its best an on board computer should calculate the desired deflection of the wing and change the temperature of the shape memory alloy accordingly for optimal performance.
References


The Role of Socio-Cultural and Technological Factors in Adopting the Project Management Office (PMO)

Abdulaziz Alghadeer¹ and Sherif Mohamed²

Abstract
The purpose of this paper is to develop and empirically test a conceptual model comprising organisational innovation dimensions and characteristics within public and private project-oriented organisations operating in Saudi Arabia. Data for the study were collected through a large-scale survey targeting professional project managers working for organisations which had either adopted, or intended to adopt, the Project Management Office (PMO). Responses were statistically analysed to assess the relationships between four variables related to the diffusion of organisational innovations, namely; socio-culture, technology, organisational climate for innovation, and innovation characteristics. The findings suggest that participative culture and, technology availability and implementation intensifies organisational climate for innovation. They also reveal compelling evidence in support of the moderating role of technology on the relationship between the country’s socio-culture and organisational climate for innovation. Equally important, the findings confirm the notion that organisational innovation characteristics play a crucial role in the intention to adopt a particular innovation.

Keywords: Innovation, organisational climate, PMO, socio-culture.

Introduction
According to Burgess, Shaw, and Mattos (2005), the core competency of any organisation is organisational innovations. The introduction of an organisational innovation through business practices usually involves new methods to conduct work and operate. The link between innovativeness and projects undertaken is intimate; therefore, integrated advanced project management (such as the PMO) is recommended to address challenges faced by project managers in improving organisations’ performance (Geraldi et al., 2008; Thiry & Deguire, 2007). The PMO can also be seen as a business strategy supporting innovativeness in the sense that it integrates managerial and operational mandates (Aubry, Hobbs, & Thuillier, 2007), thus improving productivity (Dooley & O’Sullivan, 2007). The PMO introduces changes to the organisation, ensuring its competitiveness; hence, it is an organisational innovation (Aubry et al., 2010; Hobbs, Aubry, & Thuillier, 2008).

From the above it is clear that the PMO is an ideal candidate to represent innovation in this research. The Project Management Office (PMO) – a relatively new practice enhancing organisational project management (Aubry et al., 2010) – is used in this paper as a representative of ‘organisation innovation’ as the PMO fits well with the following definition of organisational innovation: the adoption of a useful application which comprises new rules, processes and structure (Hobbs, Aubry, and Thuillier, 2008).

The central focus of this paper is on innovation diffusion in project-oriented organisations operating in Saudi Arabia in order to identify the factors affecting the level

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of innovation adoption. Not surprisingly, a number of external and internal factors are expected to, positively or negatively; affect the level of innovation diffusion at the organisational level.

In the context of the above, this paper develops and empirically tests a conceptual model incorporating key elements of four areas of study which are related to the diffusion of organisational innovations, namely; national culture, technology, organisational climate for innovation, and innovation characteristics. The paper is organised as follows: it looks at relevant theory background, describes the proposed conceptual model, outlines the adopted research methodology, reports on study findings, and finally it draws some conclusions.

**National Culture and Technology**

The dominant culture theory of Hofstede (2001) divides the national culture into five dimensions: 1) power distance, which means power is distributed unequally; 2) uncertainty avoidance, which means the culture’s members feel threatened by uncertainty; 3) individualism means tasks prevail over relationships; 4) masculinity means gender roles are separated; and 5) long-term orientation means the degree of tradition in a specific culture and to what extent these traditions are connected to its past and future. As the tendency to explore new ideas comes with greater freedom to express opinions (Vecchi & Brennan, 2009), a country which has a high power distance and/or high uncertainty avoidance, creative behaviour is expected to be limited by strict rules and minimal interaction among social groups. In a conservative society (such that of Saudi Arabia), striving to maintain the status quo makes it difficult to implement innovation. Anecdotal evidence suggests that Arabian cultural beliefs have a strong influence on Information Technology (IT) diffusion (Straub, Loch, & Hill, 2003). This evidence is supported by earlier studies who identify the diffusion of technology in Saudi Arabia as hindered by cultural and social barriers, as well as technical problems, such as lack of expertise (AL-Turki & Tang, 1998) and lack of infrastructure and broadband services. Accordingly, this paper investigates the influence of socio-cultural and technological factors on innovation diffusion.

**Organisational Climate for Innovation**

Organisational climate is related to the work environment in the organisation, including the behaviour and feelings of the members. These feelings are subjective to those who influence the organisation through power-management (Denison, 1996). It is widely reported that organisational climate influences the diffusion of innovations within organisations (Dackert, Lööv, & Mårtensson, 2004; Dulaimi, Nepal, & Park, 2005). Moreover, the innovation success or failure is related to how a particular innovation is adopted, because organisational climate also influences the innovation’s characteristics (Peansupap & Walker, 2005).

Moreover, several studies have indicated that organisational context influences innovativeness within an organisation. Contextual factors (leaders, their attitude towards change, decision-making decentralisation) and intra-group factors (support system from management, organisational committees, employee exposure to innovation and improvement, employee diversity and satisfaction) are determinants of an innovative organisational climate. Management’s exposure, experience and background, as well as its attitude towards change, shapes the subordinates’ perception and attitude to innovation. It is important to have leaders whose skills involve risk-taking and calculation, as well as openness to new concepts (Mohamed, 2002). Creating a management culture that has higher congruency with manager perceptions and organisational readiness may be considered a more beneficial means of promoting diffusion of innovations within the
project management discipline. Accordingly, this paper argues that socio-cultural and technological factors at the country level influence the climate for innovation, and hence the innovation diffusion at the organisation level.

**Innovation (PMO) Characteristics**

Rogers (2003) posits five perceived characteristics for innovation which influence its adoption: relative advantages, compatibility, complexity, observability and trialability. However, among these five, only relative advantages, compatibility, and complexity were found the most relevant (Dillon & Morris, 1996; Hsiu-Fen & Gwo-Guang, 2006). These three identified characteristics are also more relevant to this paper for several reasons. First, since the PMO has long-term impact, management is less concerned with observability of the PMO. Second, the PMO involves significant organisational change which is difficult to reverse. Third, relative advantages, compatibility and complexity have consistently been found to be important influences of behavioural intention (Yi et al., 2006).

**Conceptual Model**

Extending the above discussion, the objective of this paper is to identify causal relationships between organisational innovation diffusion dimensions and characteristics. To achieve this, a conceptual model was first developed. As presented in figure 1, the model proposed that socio-culture (SOCL) and technology (TECH) have relationships with organisational climate for innovation (OCI), organisational climate for innovation has a relationship with innovation characteristics, and then innovation characteristics (PMO Relative Advantages, PMO Compatibility and PMO Complexity) determine the intention to implement the PMO (IIPMO). Put differently, a hypothesised causal relationship is assumed to exist between: 1) the SOCL construct and the OCI construct; 2) the TECH construct and the OCI construct; 3) OCI and the PMO characteristics (PMORA, PMOCT and PMOCX); and 4) PMO characteristics and the intention to implement the PMO (IIPMO).

![Figure 1. Conceptual Model](image-url)
Research Methodology

The causal relationships between the constructs, and their effect on the intention to implement the PMO, were studied through quantitative analysis. Data collection for the analysis was gathered through a questionnaire survey conducted in Saudi Arabia over a two-month period with the collaboration of the Project Management Institute-Arabian Gulf Chapter (PMI-AGC).

The SOCL construct was operationalised using a predefined questionnaire adopted by reported studies (e.g. Wang & Liu, 2007). Similarly, the OCI construct was operationalised using the ‘support for innovation and resource supply’ measures developed by Scott and Bruce (1994) and adopted by several studies (e.g. Dulaimi, Nepal, & Park, 2005). The IIPMO was measured using a three-item scale employed by (Hsiu-Fen & Gwo-Guang, 2006). Terms such as ‘needed’, ‘acceptable’, and ‘likely’ were used to assess the organisation’s intention to implement the PMO. These items were measured with a five-point Likert scale, ranging from 1 (very needless, very unacceptable, and very unlikely) to 5 (very needed, very acceptable, and very likely). The current paper used a ‘behavioural intention’ scale, over an ‘actual use’ scale, as the IIPMO dependent variable for two reasons. First, according to Ajzen and Fishbein (1980, as cited in Yi et al., 2006), intention has an important effect on the behaviour to mediate the influence of other determinants on behaviour. Second, even though the PMO is becoming more popular worldwide, it is still regarded as an emerging organisational innovation in Saudi Arabia.

One major task in this research was to develop an appropriate questionnaire for the TECH construct and the three PMO characteristics constructs (PMORA, PMOCT and PMOCX). No existing questionnaires were adequate to deal with the areas of project management and innovation which were specific to this study. The results are a Technology scale with 13 items and the PMO scale with 27 items. The PMO scale is divided into: 1) the PMO’s Relative Advantages scale with 10 items; 2) the PMO’s Compatibility scale with seven items; and 3) the PMO’s Complexity scale with 10 items.

All items were measured with a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), except for the fifth section which solicited the respondents’ background information. Five-point scales were considered suitable for the multivariate analysis techniques adopted in this paper (Hair, 2006; Neuman, 2006).

In this paper, the unit of analysis was at the organisational level in Saudi Arabia ((because most recent studies on innovation use organisation as the unit of analysis (Phonkaew, 2001); hence this study collected organisations’ perceptions regarding all seven constructs. The candidate sampling frame comprised 223 Saudi public and private project-based organisations. To avoid potential bias in the data, no more than five valid feedback questionnaires were chosen from each organisation (Thiagarajan & Zairi, 1998).

Data Examination

For a distribution to be considered normal, its skewness and kurtosis should fall between +2.00 and -2.00 (Garson, 2011). Skewness of all variables, ranging from 0.01 to 1.13, and for kurtosis values ranging from 0.04 to 1.38, fell within the recommended range from +2.00 to -2.00. Moreover, any cases with absolute value of z-scores (|z|) greater than 3.29 were considered potential outliers (Tabachnick & Fidell, 2007). In this study there were no indications for outlier values greater than 3.29. In addition, the standard deviation values of all variables in this study were not large, ranging from 0.85 to 1.30, while the standard error values were relatively small when compared with the statistical mean values, ranging from 0.05 to 0.08. Therefore, the mean value can be used as a representative score for each variable in the data, and the small values of the standard error suggest that the sample used
in this study was sufficiently representative of the population (Field, 2009). Furthermore, a one-way Analysis of Variance (ANOVA) was performed to determine whether the differences in the opinions of these groups of respondents were statistically significant and meaningful. The results of ANOVA revealed that the data distribution was not distorted significantly by the different opinions of specific groups. Hence, the data set could be treated as a single sample.

**Data Analysis**

For data reliability, Hair (2006) recommends that values of 0.60 to 0.70 are at the lower limit of acceptability for the alpha coefficient. The values of the alpha coefficient of all seven scales, ranging from 0.836 to 0.954, which were well above the acceptable lower limit. In addition, according to Pallant (2007), a value of the corrected item-total correlation of less than 0.30 indicates that the variable is measuring something different from the construct as a whole. The results show that most of the variables within each construct were greater than 0.30, with the exception of the eight variables within the SOCL construct and one within the OCI construct. These nine variables out of 89 variables were eliminated from both constructs.

According to Pallant (2007), the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO), and Bartlett’s test of sphericity, are generally applied to determine data factorability of such a matrix. The results show that the values of KMO ranged from 0.689 to 0.928, making them well above the minimum acceptable level of 0.60 (Tabachnick & Fidell, 2007), and thus indicating sampling adequacy. Bartlett’s test of sphericity statistic for each construct was large and significant at the 0.0005 level, indicating that there were adequate relationships between the variables included in the analysis. Finally, all anti-image correlation values ranged from 0.492 to 0.946. These results confirmed the factorability of the exploratory factor analysis (EFA) conducted for each construct (Hair, 2006; Pallant, 2007).

To identify the structure among the measurement variables, the VARIMAX method for orthogonal rotation under the component factor model was chosen to give a clear separation of the factors. Regarding sample size, the 223 cases in this study were adequate for conducting the EFA (i.e., greater than 100 (Hair et al., 2006)). EFA was performed separately for each of the seven constructs using the SPSS program. The factor loadings of all variables were significant and well above the 0.50 threshold level without being loaded equally highly on more than one factor (i.e. cross loadings). Nevertheless, six variables out of 80 variables were dropped from TECH and OCI constructs due to their low factors.

**Relationship Identification**

Structural equation modelling (SEM) was employed primarily to determine whether a theoretical model is valid by specifying, estimating and evaluating the linear relationships among a set of variables (Shah & Goldstein, 2006), version 19 of AMOS was used. Regarding sample size, the 223 cases in this study were adequate for conducting the confirmatory factor analysis (CFA) (i.e., greater than 200 (Kline, 2005)). All variables loadings, ranging from 0.48 to 0.91 were greater than or close to the threshold level of 0.50 and were all significant at \( p < 0.001 \), demonstrating convergent validity. The correlation coefficient between each pair of factors was less than 0.85, thus confirming the discriminate valid of the seven constructs (Kline, 2005). The model exhibited a good level of fit (\( \chi^2 = 663.572; df = 293; \chi^2/df = 2.26; GFI = 0.82; IFI = 0.89; TLI = 0.88; CFI = 0.89; \) and RMSEA = 0.08). (Hair et al., 2006). The results of the factor structures demonstrated adequate reliability, validity and uni-dimensionality.
Seven out of the eight path coefficients were statistically significant and were considered meaningful (ranging from -0.29 to 0.72), see Figure 2. The SOCL construct had a positive influence on the OCI construct (0.56, \( p < 0.001 \)), thus supporting H1. The TECH construct had a positive influence on the OCI construct (0.47, \( p < 0.001 \)), thus supporting H2. All PMO constructs were found to be influenced by the OCI construct. The OCI construct had an equal positive influence on both PMO relative advantages and compatibility (0.48, \( p < 0.001 \)), whereas OCI had a negative influence on PMO complexity construct (-0.29, \( p < 0.001 \)), thus supporting H3. Additionally, PMO relative advantages and PMO compatibility constructs had nearly equal positive influence on the intention to implement PMO construct (0.30, \( p < 0.001 \)) and (0.32, \( p < 0.001 \)) respectively. PMOCX construct was not related to the intention to implement PMO construct (-0.07, \( p < 0.001 \)), thus H4 was partially supported. These results suggest that all the seven paths within the developed conceptual model were all supported by the data, except one path (PMOCX to IIPMO). In addition, SOCL was found to positively influence the TECH construct (0.72, \( p < 0.001 \)) and both SOCL and TECH were found to positively influence the OCI construct. This pattern of relationships suggests that TECH may be an intervening construct, mediating the relationship between the SOCL and OCI constructs.

![Figure 2. Structural model with standardised path coefficients](image-url)

Multiple regression analysis was also performed to test the proposed relationships between the seven constructs. The regression results of the relationships between SOCL, TECH and OCI, which indicate that both SOCL and TECH are positively related to OCI, \( R^2 \) values are 0.312 and 0.244 respectively. The regression results of the relationships between OCI and PMO three constructs indicate that OCI and PMO constructs are positively related, \( R^2 \) values are 0.103, 0.141 and 0.015 respectively. The regression results of the relationships between PMO three constructs and IIPMO indicate that PMO constructs related to IIPMO, \( R^2 \) values are 0.143, 0.128 and 0.005 respectively.

The more detailed picture on these relationships was revealed by the findings of the regression analyses at the factor level. The results indicate that within Socio-Culture, participative culture is a significant predictor of both managerial support climate and operational support climate factors within OCI construct, whereas collectivist culture and hierarchical culture within SOCL construct are significant predictors of the status quo factor within OCI construct. The results also indicate that the technology availability and implementation factor is a significant predictor of all OCI factors (managerial support climate, operational support climate and status quo), whereas technology research and development factor is a significant predictor of only managerial support climate and operational support climate.
The results also indicate that within the OCI construct, managerial support climate factor is a significant predictor of PMORA and PMOCT, while the status quo factor is a significant predictor of PMOCX. The results indicate that PMORA and PMOCT had significant predictive power over IIPMO, while surprisingly PMOCX had no predicting power over IIPMO.

**Discussion**

The results of this study suggest that at the country level, both socio-cultural and technological factors in Saudi Arabia are positively related to organisational climate for innovation. The obtained results reveal that participative culture factor has greater influence on organisational climate for innovation, especially managerial support climate and operational support climate. Whereas collectivist culture and hierarchical culture factors have an active predicting power upon the variance of status quo. Prior studies on Saudi Arabia (see for example, Evangellos, 2004) identified some barriers to employees’ creativity. First, task completion is the priority of Saudi managers; therefore, there is less creativity. There is no room for flexibility, constructive criticism or public evaluation. Another barrier is the decision-making mechanism. Decisions are made independently and without consulting subordinates, and are not delegated to a lower level in the hierarchy. Prior studies have indicated that creativity is encouraged by organisations which utilise a participative management style, employee engagement in decision-making, effective communication channels, supportive risks and democratic practices (Sharadindu & Sharma, 2009).

This study also reveals that technology availability and implementation, and research and development activities have a strong influence on organisational climate for innovation factors, especially managerial support climate and operational support climate, and they have less predicting power upon the variance of maintain the status quo. From the above relationships it can be reasonably deduced that technology’s usage brings changes into organisations, which may conflict with management’s cultural values. It then becomes difficult to accept (Johnson & Clayton, 1998) because it may threaten top hierarchy status.

The study finds that organisational climate for innovation has a direct influence on organisational innovation characteristics and the PMO in particular. In line with prior studies, the obtained results revealed that organisational climate for innovation has a positive influence on perceived relative advantages and compatibility, and a negative influence on complexity of organisational innovation (Hsiu-Fen & Gwo-Guang, 2006). The study further reveals that managerial support climate has an active predicting power only upon the variance of PMO relative advantages and PMO compatibility. The status quo factor has an active, but limited, predicting power upon the variance of PMO complexity. It appears that the operational support climate factor is passive and has no predicting power upon the variances of innovation characteristics and the PMO in particular. There have been underlying assumptions about the influence of adopting the PMO on the perception of managerial power-loss, even if managers fully understand its benefits. The PMO hands over some top management control to a centralised entity and inevitably faces resistance. This can lead to lack of project effectiveness; consequently, PMO adoption is at risk (Pellegrinelli & Garagna, 2009). It seems that compatibility plays an important role in the organisation’s decision to adopt a particular innovation, since it is the most sensitive among the three characteristics (Lowry, 2002).

For the relationship between PMO characteristics and intention to implement PMO, the current study reveals that both PMO relative advantages and PMO compatibility have positive and statistically significant relationships with the intention to implement the PMO.
In contrast, PMO complexity has no influence or predicting power on the intention to implement the PMO. The results of the present study are consistent with Lowry (2002) suggestion that an innovation’s perceived advantage and compatibility are most significant and its complexity is less so.

Several explanations may be posited for these findings. First, in Saudi Arabia organisation’s decisions are made in isolation from the operational environment; in other words, making a decision is not a two-way process between management and staff members. This could be a result of the country’s hierarchical culture. Asad and Ali (2008) stressed that a key barrier against creativity in Saudi Arabian organisation is the lack of communication channels between an organisation’s levels. Second, organisational innovations would affect the management environment only, which gives top management the sole right to decide whether to accept them. Under such conditions, a gap is more likely to exist between the managerial and operational environments within Saudi Arabian organisations, reducing the likelihood of implementing innovations. Furthermore, top management do not consider the operational environment an important element of the decision-making process. It seems that maintaining the status quo is a priority in the decision-making process in Saudi Arabia. Hence, before implementing any changes to the work environment, an organisational innovation’s advantages and compatibility should work in conjunction with the current decision-makers’ status quo, and not contradict it. Changes may also be manipulated to conform to the status quo; therefore, the eventual change will be under control.

In addition, PMO complexity has a negative and statistically significant correlation with the status quo factor, and a passive predicting power upon the variance of the intention to implement the PMO. Therefore, it can be deduced that that the more complex and ambiguous the new system, the more the status quo is maintained. Top management becomes the source of problem-solving and conflict resolution. This approach may justify the lack of effective concern over the innovation’s cost. In sum, it seems that status quo has been perceived as a source of power. Aubry et al. (2010) stated that to avoid this problem, it is important to examine the organisation’s politics in the sense that it integrates the PMO characteristics. The current study suggests that the reverse should be practical in the Saudi context. The PMO characteristics should integrate with the organisation politics and power system in order to facilitate the adoption process.

Concluding Remarks

The findings suggest that participative culture and, technology availability and implementation intensifies organisational climate for innovation. They also reveal compelling evidence in support of the moderating role of technology on the relationship between the country’s socio-culture and organisational climate for innovation. Equally important, the findings confirm the notion that organisational innovation characteristics play a crucial role in the intention to adopt a particular innovation. From the above discussion, these relationships represent the status quo in its profound format. First, a hierarchical culture supports the status quo, with the assistance of collectivist culture, allowing it to hang over the entire group, team, organisation, or even the whole country. Second, the maintaining status quo factor has a positive and statistically significant correlation with managerial and operational support climate factors; all the three factors support each other. Third, PMO complexity has a negative and statistically significant correlation with status quo, in which complexity of a new system or practice is another incentive to maintain the status quo.
References


Construction Experts’ Perception on the Causes and Effects of Cost Overruns in Johannesburg, Gauteng Province, South Africa

Mukuka MJ\textsuperscript{1}, Clinton Aigbavboa\textsuperscript{2}, and Wellington Thwala\textsuperscript{3}

Abstract

The construction industry is a key sector in the development and economic growth of South Africa. However, the industry has not escaped the challenges facing other countries worldwide in terms of delivering construction projects within cost as stipulated in the contracts. This paper assesses the construction professionals’ perception on the causes of construction project cost overruns and their consequent effects in the Gauteng – South African construction industry. The data used in this paper were derived from both primary and secondary sources. The secondary data was collected via a detailed review of related literature. The primary data was collected through a well-structured questionnaire which was distributed to construction professionals, which include: Architects, quantity surveyors, civil engineers, construction managers and project managers. Out of the 80 questionnaires sent out, 52 were received back representing a 65% response rate. Data received from the questionnaires was analysed using descriptive statistics procedures. Findings from the study revealed that contractors project inexperience, poor project management, inadequate planning, contractors inefficiency, inadequate financial provision, shortage of skilled site workers and poor workmanship are the major causes of cost overruns. The study also revealed that increased project cost due to extension of time, projects abandonment, company/firms liability to insolvency, tying down clients capital, under-utilization of manpower resources, liability of companies or firms to bad debt and under-utilization of plants and equipment purchased for the projects are the effects should there be cost overruns during the construction process. The study contributes to the body of knowledge on the subject of the causes and the effects of construction project cost overruns in gauteng, South Africa.

Keywords: Cost overruns, construction industry, Gauteng, South Africa.

Introduction

The construction industry is a key sector in the development and economic growth of South Africa. However, the industry has not escaped the challenges facing other countries worldwide in terms of delivering construction projects within cost as stipulated in the contracts. Cost is among the major considerations throughout the project management life cycle and can be regarded as one of the most important parameters of a project and the

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driving force of project success. Despite its proven importance it is not uncommon to see a construction project failing to achieve its objectives within the specified cost (Memon, Rahman and Azis, 2010). Al-Najjar (2008) defines cost over runs as the change in contract amount divided by the original contract award amount. However, Zhu and Lin (2004) states that Cost overruns can be defined as excess of actual cost over budget. Cost overrun is also sometimes called “cost escalation,” “cost increase,” or "budget overrun. Cost overruns do not just occur naturally, there are a number of factors during the construction process that when not managed properly can lead to cost overruns. The Cost overrun trend on construction projects has become a global concern because not only does it increase the cost of the project, it has negative impacts on low or middle class people in achieving the basic needs for prosper life like housing (Memon and Rahman, 2013).

Like other countries, construction industry in South Africa is also facing a lot of challenges such as the delay to complete the project on time, the expenditure exceeding the budget and the building defects. To avoid construction cost overruns, the very first and most important step is to identify and understand the factors responsible for the overruns (Memon et al, 2011). Hence the aim of this paper was to identify the causes and effects of construction projects cost overruns in in Gauteng, South Africa.

**Construction Project Cost Overruns – Causes**

Causes of cost overruns are factors or events that occur before and during the construction process that will affect the cost of completing a project. Cost overruns do not just occur naturally, there are a number of factors during the construction process that when not managed properly can lead to cost overruns. Al-Najjar (2008:117) identified a total of 42 factors that cause cost overruns and ranked the top ten causes as follows: Technical incompetence, poor organizational structure, and failures of the enterprise; lack of cost reports during construction stage; inadequate project preparation, planning and implementation; delays in issuing information to the contractor during construction stage; lack of coordination at design phase; change in the scope of the project or in Government policies; Some tendering manoeuvres by contractors, such as front- loading of rates; incomplete design at the time of tender; bad allocation of labour inside the site and delays in decisions making by government were ranked the top ten causes of cost overruns.

Eshofonie (2008:32) revealed a total of 40 causes of cost overruns with the top ten causes being the following: cost of materials; incorrect planning; wrong method of estimation; contract management; fluctuation of prices of materials; previous experience of contractor; Absence of construction cost data; Additional cost and Project financing. However, the study of Ameh, Soyingbe and Odusami (2010:61) identified factors that cause of cost overruns, these factors were then categorised in 5 categories namely: environmental factors; construction factors; construction Item Factors such as frequent design changes; Cost estimating factors and financing factors. Baloyi and Bekker (2011:60) revealed that increase in material cost; inaccurate material estimates; shortage of skilled labour; client’s late contract award; project complexity; increase in labour cost; inaccurate quantity take-off; difference between selected bid and the consultants’ estimate; change orders by client during construction and shortage of manpower.

Rahman, Memon and Abd. Karim (2013:290) identified the following as the top ten causes of cost overruns in large construction projects: fluctuation of prices of material; cash flow and financial difficulties faced by the contractor; poor site management and supervision; lack of experience; schedule delay; inadequate planning and scheduling; incompetent
subcontractors; mistakes and errors in design; frequent design changes and poor financial control on site. These results were not in agreement with the results of Memon et al (2011:65) where poor design and delays in design; unrealistic contract duration and requirements imposed; lack of experience; late delivery of materials and equipment; relationship between management and labour; delay in preparation and approval of drawings; inadequate planning and scheduling; poor site management and supervision; mistakes during construction and changes in material specification and type were identified as the top causes of cost overruns. Kasimu, (2012:777) identified five categories of causes of cost overruns which include: financial related factors; factors related to construction parties; factors related to construction items; environmental related factors and politics related factors.

Construction Project cost Overruns – Effects

Effects of cost overruns are the consequences that will be encountered when cost overruns occur on a construction project. Nega (2008:63) states that cost overruns have obvious effects for the key stakeholders in particular, and on the construction industry in general. To the client, cost overrun implies added costs over and above those initially agreed upon at the onset, resulting in less returns on investment. To the end user, the added costs are passed on as higher rental or lease costs or prices. To the professionals, cost overrun implies inability to deliver value for money and could well tarnish their reputations and result in loss of confidence reposed in them by clients. To the contractor, it implies loss of profit for non-completion, and defamations that could jeopardize his or her chances of winning further jobs, if at fault. To the industry as a whole, cost overruns could bring about project abandonment and a drop in building activities, bad reputation, and inability to secure project finance or securing it at higher costs due to added risks (Nega, 2008:63).

The study of Nega (2008:103) further identified the following as the major effects of cost overruns: delays during construction; supplementary agreement; additional cost, budget short fall; adversarial relationship between participants of the project; loss of reputation to the consultant, the consultant will be viewed as incompetent by project owners; high cost of supervision and contract administration for consultants; delayed payments to contractors; the contractor will suffer from budget short fall of the client and poor quality workmanship. However, Eshofonie (2008:20) identifies four effects of cost overruns as follows: company or firm liability to insolvency and liability of the companies or firms to bad debt; under-utilization of man-power resources, plants and equipment; increased project cost due to extension of time: Longer project duration means that more resources will need to be allocated to the project, which then increases the project costs and project abandonment.

Research Methodology

The data used in this paper were derived from both primary and secondary sources. The primary data was obtained through the survey method, while the secondary data was derived from the review of literature and archival records. The primary data was obtained through the use of a structured questionnaire survey. This was distributed to a total of 80 construction professionals that included; Architects, quantity surveyors, civil engineers, construction managers and project managers who are currently involved in construction works in Gauteng, South Africa. This yardstick was considered vital for the survey in order to have a true reflection of the causes and effects of construction project cost overruns. All
professionals in Gauteng province had an equal chance to be drawn and participate in the survey. Out of the 80 questionnaires sent out, 52 were received back representing a 65% response rate. This was considered adequate for the analysis based on the assertion by Moser and Kalton (1971) that the result of a survey could be considered as biased and of little value if the return rate was lower than 30–40%. The data presentation and analysis made use of frequency distributions and percentages of all the respondents.

Mean Item Score (MIS)

A five point Likert scale was used to determine the causes of construction project cost overruns in Gauteng province with regards to the identified factors from the reviewed literature. The adopted scales was as follows:

1 = Strongly disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly agree

The other scale used was as follows;

1 = Extremely unlikely
2 = Unlikely
3 = Neutral
4 = Likely
5 = Extremely likely

The five-point scale was transformed to mean item score (MIS) for each of the factors of causes of cost overruns as assessed by the respondents. The indices were then used to determine the rank of each item. The ranking made it possible to cross compare the relative importance of the items as perceived by the respondents. This method was used to analyse the data collected from the questionnaires survey. The mean item score (MIS) was calculated for each item as follows;

\[
MIS = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{\sum N}
\]

Equation 1.0

Where;

\[
\begin{align*}
n_1 &= \text{Number of respondents for extremely unlikely or strongly disagree;} \\
n_2 &= \text{Number of respondents for unlikely or disagree;} \\
n_3 &= \text{Number of respondents for neutral;} \\
n_4 &= \text{Number of respondents for likely or agree;} \\
n_5 &= \text{Number of respondents for extremely likely or strongly agree;}
\end{align*}
\]
N = Total number of respondents

After mathematical computations, the factors were then ranked in descending order of their mean item score (from the highest to the lowest).

**Findings and Discussion**

Findings from the 52 usable questionnaires revealed that 23% of the respondents had a metric certificate, 27% had post-graduate degree and 50% had diploma degrees as their highest qualification. Further findings revealed that 8% of the respondents had 16 - 20 years’ experience in the industry, 10% had more than 20 years’ experience, 12% had experience of 11 - 15 years, 35% hand 1 - 5 years’ experience and 37% had 6 - 10 years’ experience in the construction industry.

The following section presents the causes and effects of cost overruns as revealed from the questionnaire survey.

*Causes of cost overruns in Johannesburg- Gauteng Province*

Based on the ranking (R) of the weighted average of the mean item score (MIS) for the listed causes of cost overruns, it was observed that the most dominant cause of cost overruns on construction projects were contractors project inexperience (MIS=4.40; R=1), poor project management (MIS=4.10; R=2), inadequate planning (MIS=4.02; R=3), contractors inefficiency (MIS=4.00; R=4) and inadequate financial provision (MIS=3.98; R=5). Other factors identified in the study include; site conflicts (MIS=3.75; R=10), delays from employer (MIS=3.72; R=11), material price fluctuations (MIS=3.68; R=12), lack of executive capacity by the employer (MIS=3.66; R=13) and over design (MIS=3.64; R=14). The study further revealed that unpredictable weather conditions (MIS=3.40; R=20), breach of local regulations (MIS=3.32; R=21), unstable economy (MIS=3.22; R=22), project site location (MIS=3.16; R=23) and inflation (MIS=3.14; R=24) were among the cause of cost overruns in Gauteng, South Africa.

These results were in agreement with the study done by Al-Najjar (2008:117) where technical incompetence and inadequate project planning and implementation were identified as the major causes of cost overruns. The study also agreed with the study by Memon et al (2011:65) where lack of experience was one of the major causes of cost overruns. However, the study was not in agreement with the study by Eshofonie (2008:32) where the major cause of cost overruns identified was cost of materials. The study did not also agree with the work of Baloyi and Bekker (2011:60) where the major cause of cost overruns identified was increase in material cost.
Table 1. Causes of cost overruns

<table>
<thead>
<tr>
<th>Causes of cost overruns</th>
<th>MIS</th>
<th>RANK (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractors project inexperience</td>
<td>4.40</td>
<td>1</td>
</tr>
<tr>
<td>Poor project management</td>
<td>4.10</td>
<td>2</td>
</tr>
<tr>
<td>Inadequate planning</td>
<td>4.02</td>
<td>3</td>
</tr>
<tr>
<td>Contractors inefficiency</td>
<td>4.00</td>
<td>4</td>
</tr>
<tr>
<td>Inadequate financial provision</td>
<td>3.98</td>
<td>5</td>
</tr>
<tr>
<td>Shortage of skilled site workers</td>
<td>3.92</td>
<td>6</td>
</tr>
<tr>
<td>Poor workmanship</td>
<td>3.90</td>
<td>7</td>
</tr>
<tr>
<td>Inaccurate estimate</td>
<td>3.84</td>
<td>8</td>
</tr>
<tr>
<td>Project complexity</td>
<td>3.82</td>
<td>9</td>
</tr>
<tr>
<td>Site conflicts</td>
<td>3.78</td>
<td>10</td>
</tr>
<tr>
<td>Delay from employer</td>
<td>3.72</td>
<td>11</td>
</tr>
<tr>
<td>Material price fluctuations</td>
<td>3.68</td>
<td>12</td>
</tr>
<tr>
<td>Lack of executive capacity by employer</td>
<td>3.66</td>
<td>13</td>
</tr>
<tr>
<td>Overdesign</td>
<td>3.64</td>
<td>14</td>
</tr>
<tr>
<td>Shortening of contract period</td>
<td>3.62</td>
<td>15</td>
</tr>
<tr>
<td>Unsteady material supply</td>
<td>3.56</td>
<td>16</td>
</tr>
<tr>
<td>Ceaseless variation order</td>
<td>3.55</td>
<td>17</td>
</tr>
<tr>
<td>Change in project design</td>
<td>3.54</td>
<td>18</td>
</tr>
<tr>
<td>Insufficient time for estimation</td>
<td>3.44</td>
<td>19</td>
</tr>
<tr>
<td>Unpredictable weather condition</td>
<td>3.40</td>
<td>20</td>
</tr>
<tr>
<td>Breach of local regulation</td>
<td>3.32</td>
<td>21</td>
</tr>
<tr>
<td>Unstable economy</td>
<td>3.22</td>
<td>22</td>
</tr>
<tr>
<td>Project site location</td>
<td>3.16</td>
<td>23</td>
</tr>
<tr>
<td>Inflation</td>
<td>3.14</td>
<td>24</td>
</tr>
</tbody>
</table>

*Effects of construction project cost overruns in Johannesburg*

When the respondents were further asked to rate the effects of construction project cost overruns in Gauteng, the following results were obtained: increased project cost due to extension of time (MIS=4.19; R=1), projects abandonment (MIS=4.12; R=2), company/firms liability to insolvency (MIS=3.78; R=3), tying down clients capital (MIS=3.74; R=4), under-utilization of manpower resources (MIS=3.71; R=5), liability of companies or firms to bad debt (MIS=3.60; R=6) and under-utilization of plants and equipment purchased for the projects (MIS=3.34; R=7) were the causes of cost overruns.
These findings were in general agreement with the study done by Nega (2008:103) where delay during construction was identified as the major effect of cost overruns.

Table 2. Effects of construction project cost overruns

<table>
<thead>
<tr>
<th>Effects of cost overruns</th>
<th>MIS</th>
<th>RANK (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased project cost due to extension of time</td>
<td>4.19</td>
<td>1</td>
</tr>
<tr>
<td>Projects abandonment</td>
<td>4.12</td>
<td>2</td>
</tr>
<tr>
<td>Company/firms liability to insolvency</td>
<td>3.78</td>
<td>3</td>
</tr>
<tr>
<td>Tying down clients capital</td>
<td>3.74</td>
<td>4</td>
</tr>
<tr>
<td>Under-utilization of manpower resources</td>
<td>3.71</td>
<td>5</td>
</tr>
<tr>
<td>Liability of companies or firms to bad debt.</td>
<td>3.60</td>
<td>6</td>
</tr>
<tr>
<td>Under-utilization of plants and equipment purchased for the projects</td>
<td>3.34</td>
<td>7</td>
</tr>
</tbody>
</table>

Conclusion and Recommendation

This study examined causes and effects of construction project cost overruns compiled from an extensive literature review and a well-structured questionnaire. Findings from the study supported work done by previous researchers and scholars that not a singular factor is responsible for causing cost overruns on construction projects. Further findings revealed that there are corresponding negative effects of construction project cost overruns in Gauteng, South Africa. In recommendation, it has been observed that construction project cost overruns usually occur during the construction phase and this is mostly caused by contractor’s inexperience and poor management by all parties involved. It is hence, recommended that the construction team need to be aware of the factors that cause cost overruns in order to minimise the construction project cost overruns in Gauteng, South Africa.

References


A Theoretical Perspective on Leadership Development in the Construction Industry

Murendeni Liphadzi¹, Clinton Aigbavboa², and Wellington Thwala³

Abstract

The construction industry is one of the largest industries in the world and in order to stay competitive, construction firms must find a way to train their employees to become competent leaders in their specific disciplines. It is to this end that the study presents a theoretical framework relating to leadership development in the construction industry, with the specific aim of outlining the importance of good leadership skills. The study is conducted with reference to existing theoretical literature on leadership requirements for the construction industry. Findings show that it is essential to give low-level employees new experiences and responsibilities to engender appropriate leadership attributes in them. Findings also reveal that good leadership is essential to the success of the construction industry. Hence different leadership development strategies were also discussed. The study explores leadership and leadership development in the construction industry and it further highlight’s the theoretical literature with regard to leadership. The study presents a robust background on the construction industry and the importance of construction leadership. Lastly, a great insight on how leaders can be development was outlined.

Keywords: Construction industry, leadership, project management, leadership development, development strategies.

Introduction

Leadership is one of the most important and essential factors in good project and construction management, and leadership can be seen as the art of influencing others to achieve desired results. According to Walker (1999), leadership is defined as the manner in which the project leader conducts themselves in their role, in order to obtain the best performance from the people they are leading. However, leadership development remains an important aspect in the construction industry, furthermore in the light of globalization and advances in technology, there is a pressing need for a new breed of construction industry leaders. Moreover, features of the construction process and construction projects render leadership even more essential. Thus, the need for effective leadership in construction is even more important. The leader is responsible for the performance of their team and the achievement of their goals. However the construction leader, who has good,
high skills, can alter and modify their approach to overcome backsets and guarantee success (Suresh et al., 2009). The term leadership will be defined in detail in the paper but leadership development can be defined as the act, process, and result of expanding by a process of growth (Price, 2009) The paper focuses on leadership and leadership development in the construction industry followed by the presentation of the methodology and the findings from literature before conclusion and recommendations are drawn.

Leadership in Construction

According to Odusami (2002), leadership is a key factor for success in any activity that involves collaboration among a group (or groups) of people. In construction, leadership is even more essential. Munns and Bjeirmi (2001) emphasise that the success or failure of construction project management is highly dependent on the project leader. Chinyio Ogunlana, (2008) found that effective leadership in construction projects can aid in harmonizing their goals and preventing conflict. Despite this recognition that leadership is important at all levels of the construction industry, emphasis is placed on the technical aspects, as well as management however leadership still receives inadequate attention (Skipper & Bell, 2006). Many studies in developing countries show that both business and project failures are common in construction. Moreover Ofori (2012) cited several failures in construction. He noted that the construction industry has been the subject of ongoing criticism for its fragmentation and poor record on quality, waste, financial claims, safety and efficiency. Much more to this failures one can further say that part of the cause is ineffective leadership. Thus it is important to know more about good leadership development in the construction industry.

Leadership Traits in the Construction Industry

Jarad (2012) stated that, the true task of leadership involves the ability to make change happen. Although multitudes of research have been done on what makes an effective leader, there appears to be no guaranteed consensus. Essentially outstanding construction leaders become a fine balance between traits, abilities, behaviors, sources of power, and aspects of the situation. Leadership traits should build on the basic management skills by adding motivation and advanced problem solving skills. Moreover different leadership traits would be appropriate for different types of project. Leadership traits of the construction project leader are important to push team members to pass their own self-interests, then their performance will be enhanced. Bass (1990) suggested that the elements of leadership trait are drive; desire to lead; honesty and integrity; self-confidence and knowledge of the business (Ogunlana, 2008).

Leadership for Good Project Performance

A great leadership element is essential for effective project performance in a typical project environment where a high degree of uncertainty is confronted with the cost, schedule and scope changes of a project. According to Wysocki (2007), the project leader should have five skills: experience, leadership, technical capability, interpersonal competence, and management skill. Whereas, Gray and Larson (2008) stated four important skills for good project performance by a project leader, it includes: task oriented, inspiration and good employee relationship. Lastly, Bass (1990) stated that an effective project manager exhibits both transactional and transformational leadership behaviors. Transactional leadership considers the leader and follower interacting through a reward and punishment criterion,
where the employee will seek rewards and recognition for adherence to the wishes of the project leader while he may be reprimanded for acting in manners contrary to the directions (Bass, 1990). Whereas, the transformational leader seeking to inspire their followers through emotional stimulation and personal characteristics, such as charisma and motivation (Bass, 1990).

**Leadership Development in Construction**

Allen and Roberts (2011) state that “leadership development is a continuous, systemic process designed to expand the capacities and awareness of individuals, groups, and organizations in an effort to meet shared goals and objectives.” And indeed, there is a need to develop leadership in the construction industry. Nowadays, the construction industry faces difficult environment of socio-economic, cultural, political, and business challenges. Therefore, effective leadership interventions should help to accelerate and overcome the challenges, moreover to develop new leadership (Toor & Ofori, 2008). The industry will be more successful if we can develop leaders who can have an understanding of skills, knowledge and characteristics needed of an effective project leader. Moreover, certain construction companies have now considered the importance of developing its employees for improving their competitive and dynamic abilities. Much more to the project leader in the construction industry, it is important to develop the originality, initiative, leadership and ethical standards. In addition to insuring good problem solving techniques, decision making method and technical competencies.

Development of leadership is a trip which requires fixed attention. Either leaders are born or can learn, but modern leaders must take initiative to make tomorrow’s leaders. Moreover, leadership training with the emergence of leadership opportunity is the way leadership scholars can make tomorrow’s leaders (Bogus and Rounds, 2006). However, the first step in developing a leadership development strategy is to determine why the organisation believes that this is a strategy that should be pursued, in other words, what it hopes to achieve with the strategy, moreover leadership development initiative cannot be successful unless it clearly targets a specific goal (Jarad, 2012). For this reason, the construction industry players need to be very clear about what they are trying to accomplish before implementing any single leadership development strategy (Jarad, 2012). Recent literature has noted that leadership development strategies are transitioning from the idea of teaching skills and competencies to teaching values and concepts (Bennis, 2007). This monumental shift is built on the idea that skills and competencies change from person to person, but the basic values and concepts are more common, leader to leader. This means that leadership development programs must become more personal and unique to individuals. Jarad (2012) observed that there are nine key drivers for the development of leadership skills in UK construction industry, which include long term drivers - developing future leaders, retaining staff, the growth of the company, equip staff for change, and continued professional development, and short term drivers - strengthen teams, motivate staff, increased efficiency, and increase competitiveness.

According to Moore (2006), most leadership development activities can be placed in one of four broad categories of goals. Each requires a different approach in the design of leadership development programmes. The first category is about building counter strength of leadership talent. The second broad category of leadership development goals is about using leadership development to transform the business. A third area of leadership development is just helping leaders become more effective at what they are already doing,
for example by helping leaders become better at managing people. The fourth area of leadership development is to help other low level employees through critical leadership transitions (Jarad, 2012).

Jarad (2012) suggested that the potential sources of leadership development include observing, mentoring or coaching by seniors, reading or self-study, education courses during university, education courses since college, company training, and job experience. Bogus and Rounds (2006) suggested that employees can be better leaders from self-education, attending seminars, reading, watching, experience, and from having active organizational mentors. Further on, Jarad (2012) was of the view that construction firms can develop leadership and management skills by developing a culture of teaching, mentoring, self-study, and frequent job changes. Companies can also use their own professional personnel to offer formal leadership and management training. Thus done correctly leadership development sets the stage for organizational success by empowering employees to develop their skills and competencies, improves retention, provides a foundation for succession planning and for training the next generation of leaders and to focus on how managers lead, develop and partner with their employees (Price, 2009).

**Methodology**

The study is conducted with reference to existing theoretical literature on leadership requirements for the construction industry. The study is mainly a literature review and looks at literature relating to leadership, leadership skills and leadership development in the construction industry. Moreover, the concept of leadership in the construction industry has been under researched. The current methodology falls within the qualitative research methodology.

**Results and Discussion**

It is evident from the study that leadership is important in the construction industry. This supports the work by Odusami (2002), who states that leadership is a key factor for success in any construction activity that involves collaboration among a group (or groups) of people. Moreover to the construction industry, the leadership concept continues to grow and develop, and perhaps it will never stop evolving as it is psychological, social and cultural in its functioning. It is also important to note that, when there are leaders who have good leadership skills they are prone for success in their construction firms, thus being able to overcome challenges that face the construction industry. According to Wysocki (2007), the project leader should have five skills: experience, leadership, technical capability, interpersonal competence, and management skill. However, there is still the need to develop leadership in the construction industry. In this study, certain methods were identified that can help in the development of construction leaders. This includes the real job experience, watching and observing can also contribute to leadership development. Secondly, mentoring or coaching by senior leaders can help develop the lower level construction employees to be future construction leaders. Moreover, company training is one of useful methods to develop construction project leaders in the construction industry. Thirdly, it is evident from the reviewed literature that leadership educational courses or attending seminars is also a good method for leadership development in the construction industry. However, self-education or reading needs to be an initiative by the aspiring leader.
Conclusion and Recommendation

This paper has examined literature relating to leadership and leadership development in the construction industry. It is evident that good leadership is important to the construction industry and it can increase the leader’s knowledge, competitiveness, effectiveness, and interest in the job, and encourage new ways of doing things, that will bring success into construction project. The increased need and focus on leadership in the construction industry makes it a priority for the construction industry to implement leadership development strategies and programs. It is evident from the study that good leadership development strategies and educational programs can ensure that future construction and project managers have developed leadership skills. It is therefore, recommended that the industry should also focus on developing skills and characteristics of low level employees, through proper and continuous training programs which focuses on the leadership. Future research can focus on types of programs and methods that can be used to develop leaders in the construction industry. This study may add to value to the field of leadership by contributing literature to leadership development in the construction industry with the aim of presenting the importance of good leadership skills.

References


The Management of Environmental Bridge Design

Slawomir Karas\(^1\) and Janusz Bohatkiewicz\(^2\)

Abstract
The aim of the paper is to characterize the inconsistencies appearing during the bridge design process, maintenance and ecological issues which were caused by lack of proper environmental management system. Several examples of the road and bridge investments carried out in Poland in the last decade have provided the basis to formulate several statements and questions. The difference between the approach of bridge engineers and environmental experts to the concept of animal migrations is shown against the background of technical and environmental standards that were implemented in the investment. The existing problems are of dual nature, the first group being very general issues i.e. concerning the concept of ecology, while the other one involves detailed matters, e.g. the appearance of a bridge. Several questions of great significance have been formulated and addressed to ecologists. The answers are indispensable for bridge engineers to work on technical aspects of proper design of environment-friendly bridges. Last but not least, the suggestion to use bridges as sites to monitor the environment in their surroundings is presented. This research work might be crucial for further good cooperation of bridge engineers and environmental engineers only when a simple and consistent management system embracing different standards is created and put into operation.

Keywords: Bridges, environment management, sustainable development.

Introduction
The article shows the development of environmental proceedings in bridge design in Poland during the last decade and attempts to propose a useful control option for monitoring the environment near rail and road corridors, especially now when hundreds of highways as well as express roads have been built. The starting point was the basis worked out by foreign ecological institutions, the main element i.e. animals migration corridors included (Rochelle, 1999). The turning point was the so called Rospuda River case. In 2008 the road construction works were stopped because of the protest organize by local ecological organizations. The protest had a form of blocking the road construction works.

Many young acting spontaneously people chained themselves to the trees, set up their encampment in the area and commenced regular occupation. The purpose of the planned new road was to alleviate the impact of heavy transport which caused infrastructure damage, noise pollution and even fatal traffic accidents in several small towns. On the other hand, there were some road sections that crossed the selected ecologically sensitive areas marked as Nature 2000. It was a situation, where neither party was absolutely right. The compromise was not reached. In such circumstances a new deal was indispensable.

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Since that time, instead of the semi-environmental approach the real technical-environmental design considerations have taken place.

**Rospuda River Casus – Polish Experiences**

The beginnings of the ecological movement in Poland was characterized by spontaneous, intuitional but less professional activity. The first action focused on the preservation of old poplars along the roads. This tree system created a typical sight in our landscapes. However, when the tree achieves the age of ca 40 years, its expanded branches tend to fracture, especially under the snow layer and during high winds. Many cars were damaged by falling trees' branches. It was necessary to cut out thousands of old poplars but simultaneously this decision implied an opposition of the old trees aficionados connected with the youth' ecological movement. The final effect of this action was easily predictable, but earlier it was necessary to fight a battle which led to the fundamental conclusion that cutting off a tree is acceptable provided a new tree is planted.

A more spectacular action took place when the construction of the bypass of the small town of Augustów was commenced. In 1992 the decision on the design work of the bypass road was taken. Among dozens of bridges, overpasses and culverts there were also passages designed for small and big animals. All this, i.e. roads and bridges as project elements, was performed strictly according to the Polish (Regulation, 2000) and European standards on nature conservation (Directive, 1985), (Convention, 1998), (Directive, 2001). On the course of the road was the nature reserve on the Rospuda River which was intended to be traversed by means of high road embankments and overpasses as well as bridges in the valley of the river.

It is necessary to emphasize that the life of citizens in Augustów reached the limit of uncomfortable conditions due to heavy transport traffic, high noise, difficulties of pedestrian and bicycle traffic and even dangerous accidents.

The road construction works started in 2007 but soon the works were blocked due to an ecological action which was supported by some TV channels. In 2008 the investment was stopped until 2014, when again after some modifications road works are continued. Till now the slogan Rospuda is recognizable anywhere and anytime in Poland when one thinks of designing roads.

Here a question arises why such a situation occurred. Firstly, there is an analogy to the case of the overpass highway of Pilzno, the Czech Republic. Also there, the young ecological movement blocked the road construction works, and also after ~10 years the construction was continued. Probably here and there appeared the same sociological mechanism. It is worth mentioning that those were the days when both Poland and the Czech Republic joined the European Union and when new circumstances provided a new range for independent criticism and freedom to express personal distrust to government’s decisions. But 10 years' periods seems to be enough for mature understanding of both road and bridge technical conditions and environmental requirements. This interval enabled to avoid a really dramatic cost of struggle between the two sides of the investment process and allowed time to transform the two opposite sides parties into partners. At present one may quite confidently say that partnership works. However, civil engineers have been still waiting for more detailed and uniform rules related to the environmental requirements for design than those contained in (COST, 2003) for instance.

**Basic Environmental Requirements Related to Bridges**

There are no special technical standards to design bridge structures regarding environmental needs. Instead of standards there are paragraphs in (Regulation, 2000)
where such requirements are formulated in detail and by using very formal provisions. Briefly, they go as follows.

For wild animals a non-collision path ought to be ensured to let them move from one side to the other of higher class of roads in areas of increased animal migration, in particular in larger forest complexes and areas of wetlands and other habitats of rare and endangered species, as indicated by the relevant government authorities or appropriate local government units. This ought to be done as:

- passage in tunnels across the body of the road of a width equal to min 10m,
- viaducts over the road with entrances equipped with a screening fence in the approach to the facility, off-axis crossing at an angle close to 60 deg, and connecting with the green surrounding - in order to provide guidance to animals.

\[ B \geq \frac{N \cdot L}{H} = \frac{3}{2} \left( \frac{L}{H} \right) \]  

where \( N \) is the measure of narrowness of min value \( N=1.5 \); \( H \) - the height; \( L \) - the length of the passage. Another, more comfortable, parameters are proposed in (COST, 2003).

Basically the bridges were located over the rivers, while the viaducts over existing roads, agricultural fields or meadows. The aim was to integrate the new passages with migration paths, as shown on figure 2.

3 wild boar, roe deer for example
and walking paths of a min breadth 50 cm, see figure 1-3, also in culverts along water courses.

Outside of the culvert, the surface of the passage should be designed according to the existing ground surface. In the case of water-courses additional side benches running along the passage near the culvert walls should be constructed. The surface of the benches has to be placed above the average water level. To protect animal migration along roads or railway lines an appropriate fencing system should be introduced to direct small animals to the safety zone where the culvert passage is located. The above mentioned fences could be made from different materials (like steel shields) but in practice they are made of green color plastics. 

Finally, even though it is not written down in any technical or administrative document, the local stone, ground and vegetation are recommended for use.

![Figure 3. River culverts a) built in 2006 b) constructed in 2013](image)

In figure 3 the culverts present their beauty as elements of the river's landscape. Also the photos show differences occurring within the range of environmental approaches. In the first photo, figure 4.a, there are no side paths for small animals. In figure 4.b such a side bench was made. The slope protection is made by use of openwork precast concrete heavy plates which start being overgrown by grass. Technically it is a typical and well verified solution, whereas the concrete stiff elements are extraneous in the natural river bed system.

![Figure 4. The bridge over the Lopa River in Lopiennik; transition for medium-sized animals a) just after construction b) after 2 years](image)

Now, the dominating solution is to use more environmental-friendly gabion mattresses which are filled with crushed natural stones, appropriately to the mesh size, figure 4.a. The gabion mattresses protection easily becomes overgrown by meadow grasses, figure 4.b.
Long Span Bridges - Small Ones

Large river or even a medium-sized river always has a wide floodplain. Additionally, high water levels are significant because the height of the clearance gauge is large. Designing a long span bridge means to obey hydraulic and hydrologic criterions for easy flow of high river water. This automatically fulfills the conditions for minimum clearance gauge for big animals. Also, bigger distances from the carrying-deck to the ground level result in a more quiet solution considering road traffic but also, increasingly for new rail bridges. This positive ecological impact was for a long time countered by extensive damage to surrounding area caused during construction of long bridges. Nowadays however, building technologies limit very strongly bad influence on bird habitats, especially during the breeding season (Garniel, 2010).

Existence of biotopes in the surrounding of long bridges is a challenge for both environmental and bridge engineers. Locally, during erecting a bridge the previously existing biotope is destroyed. Figure 5.a shows a change of vegetation occurring during the replacement of the existing old RC⁴ bridge with a new composite of steel-concrete one. According to the environmental rules the previous condition of vegetation should be reconstructed in the coming 18 months after finishing the construction works. As it is clearly visible, it is not possible in practice, as shown on figure 5.b. Here arises a question of options i.e. which solution is right - a meadow, bushes or a forest?

Figure 5. The bridge in Neple over the Bug River a) an old bridge b) the new one

Also here two additional views encounter. In a technical sense for instance if the empty meadow clearance is perfect for the water flow, than from the environmental point of view shall we go back to the choice between a meadow, bushes or a forest? Here, bridge engineers are still waiting for the answer.

Small span bridges, up to 20 m, were not so automatically designed as long span ones. From time to time it happened that the leading rules for small bridge design come from environment needs. Mainly the height of clearance gauge, which has to be proper for medium or big animals migration, influences road and bridge gradeline. Finally, a small bridge may be more expensive than a bridge of average size one due to environmental conditions.

Animals - People

While creating the environmental surrounding for animals it was forgotten that the human - in a sense - is an animal too. Many rainwater reservoirs near the highways were practically immediately populated by amphibians, even when vegetation was not fully grown. Reservoirs were designed for two reasons: first to collect the water and the second to

⁴ RC - reinforced concrete
shelter amphibians. On the other hand, a water mirror, a green slope of highway embankments, an easy access i.e. in the vicinity of a city, all these were elements which attracted people for camping, barbecuing, fishing, bird watching - in general - for relaxation, figure 6. This is a new role for reservoirs which was not predicted earlier.

Let us notice that the noise of highway traffic at the foot of the road embankment is relatively not high and the car movement plays a similar role to a TV series. This provides the unity of nature and home for people around. Also, while building highways many secondary service roads are provided were necessary. This service net discloses many interesting nature places. When one thinks 'environment', the human is excluded. This sounds like a very popular idea i.e. to separate nature from human activity or at least to limit the contact between them. This is the basic concept accompanying the foundation of national parks, for instance.

![Figure 6. On the S17 road a) nature refuge b) place of recreation](image)

From the authors' point of view, the contact between the human and the nature is an elementary organic relation; (Karas, 2011). It ought to be organized properly for both of them. To do this, the more commercial approach is necessary. At the design level the parking places must be taken into consideration. The administrator of such areas has to introduce clear rules of behavior, entry fee, etc.- so in short all the elements which are in use in countries like Belgium or the Netherlands.

Here appears another mental barrier which should be broken through. This should become be obvious to non-environmentalists and bring about discussion among ecologists.

**Questions that are Waiting for Discussion**

Building a bridge structure proceeds according to proven, almost typical rules which correspond to those given in the Eurocodes. The possible variation is only in terms of details. Environmental engineers have repeatedly raised questions the impact of the appearance of a bridge on the behavior of large animals but so far there is no one good answer. Actually, there are two approaches, not congruent at all, see figure 7.

For example, the cones of road embankments at bridge abutments may have at least two forms. The cone may be surface-enhanced by means of semi-rigid elements made of concrete blocks of 15cm thickness. The expression of such a solution is a strong color image corresponding to the geological rock formation occurring in the rock mountains, figure 7.a. The other option is a solution used not so long ago, in which the cones of embankments were reinforced with laying turf, figure 7.b. In this case, the image is characteristic of the lowland meadow views. Which one is better? The point is that one can get the answer in two variants.

5 Actually, in the sense of geometry, it is a quarter of truncated cone.
In terms of maintenance both discussed solutions are correct and equivalent. Therefore the question mentioned above arises, which of these solutions is more environmentally friendly? There is also a similar question: how large animals perceive color or the color intensity? So far as coloring is concerned bridges are designed only in the context of acceptance by man.

Both questions are reasonable in a much broader context, namely: what is the psychology of large animals? This question is so broad that the problems of shaping bridges constitute its small fraction.

Another issue is the cost of engineering and road bridges. Based on the Polish experience of the past 10 years, it is estimated that construction costs of passages for small, medium and large animals, noise screens, planting of trees and shrubs were from 10 to 20% of the total investment costs (Madaj, 2012). This is a significant sum. The most expensive are green bridges for large animals, which amount to the cost of normal overpasses over the highway, figure 8.

Another reasonable question arises concerning the effectiveness of these expenses. Currently monitoring of the use of these structures by animals is commonly conducted. The answers are partial, but positive. The material collected from the observation includes animal trails and single images of passing animals, which indicate that the animals use the newly built passages. However, so far no conclusions can be drawn in terms of statistics. Probably, animals need a generation or more to get used to the new situation. The answer to this question is very important, as the cited 10 to 20% of costs represent a significant compromise and may impede achievement of the objectives necessary to the people, (Karas, 2011).

Although the road and bridge standards in the field of ecology were formulated long ago and are precise and clear, the environmental criteria laid down in the relevant documents are not. In the field of environment there is an exponential growth in various regulations and instructions, which means that the goals are not clearly defined. Hence,
their implementation may cause technical troubles. This is a major difficulty, which in the opinion of the authors, results from not enough professionalism of environmentalists.

Numerous mishaps show clearly that this area requires a significant cognitive and technical discipline, (COST, 2003).

As an example, reference is made to a temporary stop in design and consequently a holdup of construction of the airport in Swidnik (eastern Poland). The area destined for the runway proved to be inhabited by the spackled ground squirrel - in Poland, briefly called gopher - (Spermophilus suslicus), which is a protected species.

The problem has become popular because of its extensive coverage in the mass media.

After a thorough examination it turned out that the existing colony of gophers was the result of release of a few individuals from a breeding home. Due to unfavorable natural conditions and degeneration within the group colony the gopher disappeared.

The above example shows that good intentions must be supported with solid research.

Here is therefore another question. Our perception of ecology is dominated by human perspective but is this a right approach? What about animal’s perspective? The above question is related to yet another issue of nature - the problem of locally favored conditions; (Gałaś, 2004).

Can We Protect the Nature?

The symbol of the last conference on environment and road construction was a stork preying at a guiding fence. Another recorded picture was of a snake hunting along the guide fence. Hence comes a question - to what extent are human activities appropriate to protect nature ? And to what extent are the protecting processes leading to the imbalance of the whole system of fauna? Since nature is governed by the primary rule of survival and human standards create a feature of predation and ruthlessness, every facility that benefits certain animals raises an increased risk for others (Bohatkiewicz, 2014). From the point of view of a road and bridge engineer this problem is of minor significance, but every road and bridge engineer is also an ordinary man for whom the idea of equality, justice, etc. is crucial.

![Figure 9. Effects of the beavers activity](image)

For several years, beavers in Poland have been under strict protection. These animals are not very timid in the neighborhood of man. Their nature is to build systems of dams using trees growing along the rivers. Following the introduction of protective provisions

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6 VI International Conference on Environment and Aesthetics in the Road Construction, which was held in Kazimierz Dolny, this year on 23-25 April; organized, among others, by the Road and Bridge Chair of Lublin University of Technology [online]. Available from: http://wbia.pollub.pl/pl/o-wydziale/struktura-wydzialu/katedra-drog-i-mostow/konferencja-kazimierz-2014. [Accessed 1 August 2014]
there was a significant growth of the population of beavers. Hence there was clearly a greater range of their activities which was manifested by fallen trees, figure 9, and significant damage (sometimes up to 100%) to population of fishes in rivers. Here and there a new flood plain river areas occurred, even coming to the surface of ca 5 hectares. There was a visible change of the image of woodlots after some poplars, ash and alder trees has disappeared. There were problems with availability of grassland, maintenance of riverbed profiles, uncontrolled damming of the water. In the case of bridges and culverts the problem strongly appeared during the high water flow when the water carried logs of trees blocking the clearance gauge of the bridges, causing additional stacking water and often blurring the bottoms of the rivers.

**Conclusions**

Poland is a young, 10 years, EU member state, where in the last 5 years ca 1,800 km of highways and expressways were constructed, creating a new transportation network. Simultaneously conflicts the with environmental organisations of different types – official and social - arose. Currently the environmental control system is in its infancy. Professional management system does not work properly. It is especially badly felt by constructional engineers. But also in old member states such as Germany and Austria some deficiencies are visible. The environmental management system which will govern in the field of different aspects of human activity, especially in the field of road and bridge design, maintenance and monitoring of nature is a nowadays a dire need. The postulated management system should be related to technical standards as for instance the Eurocodes and others.

In Poland, animal migration corridors on a local and continental scale, have been changed due to construction of a systems of highways. The road construction works have not been completed yet. The next step in modernisation of the country will be a similar process, but now connected with rail transport.

Now truly exists the awareness of the necessity to protect the environmental system, which also requires additional remedies resulting from infrastructure development. The only way to do this will be when qualitative recognition is completed through research based on quantitative considerations. Such processes have to be transparent and understandable for any group of people i.e. be in accordance to (Directive, 2003).

Bridges are cutting points for roads and railways on the one hand side and a provide continuity of animal migration paths on the other. On this basis existing bridges should be supplemented by monitoring systems which will be able to record continuous or selected ecological events in the surrounding of bridges. Also temperature, moisture, air pollution and noise level have to be added to the recorded elements.

Monitoring of bridges, although is not common, works in special cases. Lots of suspension or cable-stayed bridges are supplied with facilities to observe strain, stress or displacement processes. The archiving could be done on a disk or in cloud. As it is seen – nothing is to discover. Some general concept and some examples of monitoring were included in (COST, 2003), however those suggestions do not form a typical technical solution i.e. solution which would be easy to apply into bridge design procedures. The only action is to develop and to unify the existing systems and adopt them to environmental needs. With a good database it will be easier to find reliable solutions to challenges that occur in road and bridge design practice.
References