THE IMPACT OF BUILDING INFORMATION MODELLING ON ESTIMATING PRACTICE

Analysis of perspectives from four organizational Business Models

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STATEMENT OF ORIGINALITY

The thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

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Candidate’s Signature
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ABSTRACT
This study aims to explore the impact of 3D CAD and BIM on estimating practices based on the notion that both paradigms, in varying degrees, improve the cost performance of projects compared to the use of conventional design tools such as 2D-CAD. The objectives are: (1) to explore the activities required to develop workable estimates in different estimating practice domains and represent them in the form of process models; (2) to establish the degree of association and reliability of the identified activities; (3) to compare 3D CAD and BIM estimating processes across different practice domains (using discriminant analysis); and (4) to suggest how the process models can be implemented and further strengthened for application development.

The theoretical framework of the study was based on Kagioglou et al.’s (1999) process re-engineering model - to define the forms and goals of estimates in the different phases of the development of construction projects. Further review of literature shows that there are several estimating methods that are applicable to the various project development stages, which are ontologically stratified across the various construction business domains. Consequently, different perspectives of estimating practice in construction businesses are developed from four business structure models viz. the MModel (representing client organizations), the DModel (representing contracting organizations), the FModel (representing consulting practices) and the NModel (representing specialist project delivery systems such as IPD).

Mixed and plural research methodologies were used to explore the stages and activities that are involved in 3D CAD and BIM estimating. Firstly, products of four software development organizations were investigated to ascertain how the applications were used for 3D CAD and BIM estimating. Data was also explored from 5 presentations on 3D CAD and BIM estimating by the software development companies to 77 subject-experts who offered their views on estimators’ expectations of BIM applications. Secondly, participants, 17 in total, were sourced from the 4 business models indicated above to discuss their 3D CAD and BIM estimating processes. Data were captured through focus group sessions and individual interviews.

The estimating themes for 3D CAD and BIM were garnered from the aforementioned qualitative data using a combination of direct observation, focus group discussions and interview sessions. Through these methods, the stages and activities involved in the preparation of estimates based on 3D CAD and BIM across the four business structure
models were identified and rated. These ratings were statistically analysed to test whether the variables were sufficiently robust to be used to create process models, which the different practice domains can deploy to generate workable estimates with 3D CAD and BIM. The data were normally distributed and were analysed parametrically. First scoring factor analyses showed that the views of participants from DModel and FModel practices were highly correlated in both 3D CAD and BIM regimes. In addition, multiple comparisons using Fisher-Hayter and ANOVA procedures showed the key characteristics of the variations between how participants from the different practice domains viewed the importance of activities leading to estimating outcomes.

Additionally, reliability tests (Cronbach’s Alpha) were used to measure the internal correlation of the estimating activities that were identified in both 3DCAD and BIM. In 3D CAD, 16 out of the 31 themes were discounted for lack of internal consistencies. The resultant process model has an Alpha value of 0.96. In BIM regime, analyses show the Alpha value to be 0.95, while only four themes (estimating activities) were discounted for lack of statistical consistencies. The themes retained after the reliability tests formed the centroid (group representative) process models for the 3D CAD and BIM estimating. However, the derived variables in the centroid models apply differently to the practice domains. Consequently, both ad-hoc and post-hoc data were analysed to determine the discrimination of the centroid models across the four practice domains.

Implementation of the process models was also discussed. First, illustrations were made on system architectures for the process models. Second, indicative EXPRESS-G structures were provided to show how the process models can be advanced for implementation in the form of applications, training and for future research. Third, indicative integrated definition formats (IDEF0) were developed to illustrate how the outcomes of the process models can be strengthened with case-based control measures.

This study has established that estimators still use conventional methods to estimate 3D CAD projects, and more than 50% of activities leading to estimate outcomes in this domain do not add value to estimating outcomes. This study also presented the key characteristics and enablers of opportunities for estimators in BIM. Recommendations were also drawn on how to develop change management models for dealing with operational issues when transiting from conventional practices to digital systems.
SUPPORTING PUBLICATIONS (SELECTED)

The research work reported in this thesis is supported with nine articles published by the author of this dissertation. These include four journal articles, three conference papers and two book chapters. The contents of the publications are summarized below:

Journal articles

- In (Olatunji, 2010c), the author explores the relationships between macro-variability and construction costs. Analysis in the study shows that construction costs are impacted by varying economic indicators such as variability in the relationship between construction GDP and other activities in the main economy (e.g. balance of trade, government policies and cost of finance). It is also found that, more usually than represented in project drawings, and largely unpredictable so, these indicators pressure construction cashflow through hard-to-control changes in resource costs and stochastic conditions in cost of finance.

- In (Olatunji, 2011c), the author reviews the legal implications of model ownership in project implementation with BIM. The overriding argument in this study is that the process integration triggered by BIM involves substantial trust in the integrity of data that have come from different disciplines. The study concludes that the repercussion of this perception is significant to project economics. This is because the methodology for valuing intellectual property in BIM is yet undefined, and existing legal frameworks in the industry promotes fragmentation.

- In (Olatunji, 2011b), the author explores the cost implications of corporate implementation of BIM in construction SMEs. It emphasizes that BIM implementation in construction business requires strategic actions which involves changes to resource utilization and corporate philosophies on business behaviours. It presents a validated regression model for predicting the cost of BIM implementation in construction SMEs in Australia.

- In (Olatunji et al., 2010b), the authors review the relationship between quantity measurement, estimating and (mis)conception about the integrity of BIM data. The study reports that workable estimates are not promoted by putting superficial costs into model objects or by simply applying costs to quantity data that are auto-generated from BIM models; rather by conscious engineering of model data and resource data in ways that best meet project goal.
Book Chapters

- In (Olatunji and Sher, 2010b), BIM is presented as a novel platform for storing data on project lifecycle processes. The study relies on past studies in facilities management (FM) processes to explain a framework for utilizing BIM for FM. Conclusion were drawn in the study on how BIM supports data and process integration and automation of FM processes.

- In (Olatunji et al., 2010a), the authors argue that BIM requires effective collaboration to drive satisfactory project outcomes. The three primary components of gaming theory – Pareto optimal, hawk dove and prisoners’ dilemma – were used to explain the practical implications collaboration in null, partial and full forms. Different collaboration scenarios were used to outline potential outcomes when BIM project teams do not collaborate, when they collaborate partially and when they collaborate fully.

Conference Papers

- In (Olatunji, 2010a), the author developed a conceptual model to explain the implication of BIM-triggered changes to the business structure of estimating practices. The model covers the varying requirements that estimating businesses and their different levels of staff need to implement in order to fulfil their goal with BIM.

- In (Olatunji and Sher, 2009), the authors make predictions about the potentials of BIM in 2020. The paper covers the chronicles of advancements in CADD and CAD since the 19th century with conclusion on the potential of BIM in conjunction with mobile computing, remote site access technologies and laser scanning.

- In (Olatunji et al., 2010c), the authors explore BIM and its impact on construction estimating. The paper argues that estimators’ views about model objects are not the same as designers’, and for model data to meet estimators’ requirements, they must be structured in ways that promote probity and accountability.

List of Publications


GLOSSARY

3D Three-dimensional
AAQS Association of African Quantity Surveyors
ABS Australian Bureau of Statistics
AI Artificial Intelligence
AIA American Institute of Architects
AIB Australian Institute of Building
AIQS Australian Institute of Quantity Surveyor
ANN Artificial Neural Network
ARIMA Auto-Regressive Integrated Moving-Average
AS Australian Standards
ASMM Australian Standard of Measurement
BAS Building Automation System
BCA Benefit-Cost Analysis
BCIS British Cost Information Service
BESMM Building and Engineering Standard Method of Measurement
BIM Building Information Modelling
BoQ Bill of Quantities
BPIBR Business Process Initiatives and Behavioural Re-Engineering
CAD Computer-Aided Design
CADD Computer-Aided Design and Drafting
CAE Computer-Aided Estimating
CBA Cost Benefit Analysis
CCI Construction Cost Index
CCP Comparative Cost Planning
CIOB Chartered Institute of Building
CMSS Change Management Support System
CMM Change Management Model
CMR Construction Management Research
CoF Cost of Finance
CP Cost Planning
CPM Critical Path Method
CPS Cyber-Physical Systems
CSG Constructive Solid Geometry
DLP Defect Liability Period
<table>
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<th>Acronym</th>
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<td>DBPA</td>
<td>Design-Based Protocol Analysis</td>
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<tr>
<td>DModel</td>
<td>Divisional business structure model</td>
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<tr>
<td>ECP</td>
<td>Elemental Cost Planning</td>
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<tr>
<td>ERA</td>
<td>Evaluated Risk Assessment</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>ES</td>
<td>Exponential Smoothing</td>
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<td>FGs</td>
<td>Focus Groups</td>
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<tr>
<td>FIDIC</td>
<td>Federation of International Council of Engineers’ Condition of Contract</td>
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<tr>
<td>FL</td>
<td>Fuzzy Logic</td>
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<td>FU</td>
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<td>GDO CAD</td>
<td>Geometric-Data Only Computer-Aided Design</td>
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<td>GIS</td>
<td>Geographic Information Systems</td>
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<td>IAI</td>
<td>International Alliance on Interoperability</td>
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<td>ICE</td>
<td>Institution of Civil Engineering</td>
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<td>ICEC</td>
<td>International Cost Engineering Council</td>
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<td>IFC</td>
<td>Intermediate Form of building Contract</td>
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<td>Integrated project delivery</td>
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<td>IT</td>
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<td>IDEF0</td>
<td>Integration Definition Format</td>
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<td>JCT</td>
<td>Joint Contracts Tribunal</td>
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<td>LiDAR</td>
<td>Laser Altimetry Techniques</td>
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<tr>
<td>LND</td>
<td>Logarithmic Normal Density</td>
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<td>LP</td>
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<td>LSM</td>
<td>Least Square Method</td>
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<tr>
<td>MModel</td>
<td>Matrix structure model</td>
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<tr>
<td>nD</td>
<td>nth-Dimensional</td>
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<td>NEC</td>
<td>New Engineering Contracts</td>
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<tr>
<td>NIBS</td>
<td>National Institute of Building Sciences</td>
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<tr>
<td>NIQS</td>
<td>Nigerian Institute of Quantity Surveyors</td>
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<tr>
<td>NModel</td>
<td>Networked business structure model</td>
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<tr>
<td>NPWC</td>
<td>National Public Works Council</td>
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<tr>
<td>NPV</td>
<td>Net Present Value</td>
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xvii
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>NSWPWD</td>
<td>New South Wales Public Work Department</td>
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<tr>
<td>OOP-CAD</td>
<td>Object-Oriented and Parametric Computer-Aided Design</td>
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<td>PDFs</td>
<td>Probability Density Functions</td>
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<td>PERT</td>
<td>Program Evaluation and Review Technique</td>
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<tr>
<td>RIFD</td>
<td>Radio Frequency Identification</td>
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<tr>
<td>RIBA</td>
<td>Royal Institution of British Architects</td>
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<td>RICS</td>
<td>Royal Institution of Chartered Surveyors</td>
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<td>SA</td>
<td>Simple Algorithm</td>
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<td>SFCA</td>
<td>Standard Form of Cost Analysis</td>
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<td>SMA</td>
<td>Simple Moving Average</td>
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<td>Standard Method of Measurement</td>
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<tr>
<td>SMMIEC</td>
<td>Standard Method of Measurement of Industrial Engineering Construction</td>
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<tr>
<td>TEN</td>
<td>Tetrahedral Networks</td>
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<td>UK</td>
<td>United Kingdom</td>
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<td>United States of America</td>
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<td>VBPM</td>
<td>Value-Based Performance Management</td>
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<td>VR</td>
<td>Virtual Reality</td>
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<td>VDC</td>
<td>Virtual Design and Construction</td>
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<td>VM/E</td>
<td>Value Management and Engineering</td>
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