Building Information Modelling: conceptual constructs and performance improvement tools

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Declaration

This *thesis by published works* is submitted for the award of Doctor of Philosophy from the University of Newcastle.

Some of the papers included as part of this submission are jointly authored and I hereby certify that I have included a written statement from each co-author or project leader - endorsed by the Faculty Assistant Dean (Research Training) - attesting to my contribution to the joint publications. Where work embodied in this thesis has been conducted in collaboration with other researchers, or in other institutions, I have included a statement clearly outlining the extent of collaboration, with whom and under what auspices.

This 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 the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968.

Bilal Succar

December 16, 2013

Acknowledgements
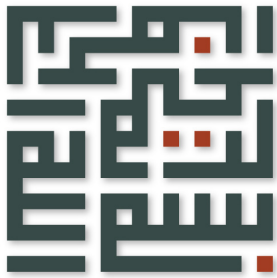
This study journey spanned eight years along which I enjoyed the support of many colleagues, friends and family. I'm in debt to *all* for their intellectual input, encouragement or active support.

I owe most gratitude to the formative words of my mentor Hadret El-Sheikh Abdul-Rahman El-Helou, the loving support of my wife Siham, the tender patience of my daughters Noor and Mariam, and the sympathetic guidance of my primary supervisor AProf Willy Sher.

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Finally, I extend my appreciation to the thesis' international reviewers from the universities of São Paulo and Salford. Their generous input - and that of all anonymous paper reviewers - has assisted in improving the deliverables of this study/journey which I hereby present to domain researchers and fellow practitioners.

Thesis Overview

Building Information Modelling (BIM) is a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility.

There are numerous challenges attributed to BIM adoption by industry and academia. These represent a number of knowledge gaps each warranting a focused investigation by domain researchers. This study does not isolate a single gap to address but espouses a holistic view of the knowledge problem at hand. It contributes to the discussion a set of conceptual constructs that clarify the knowledge structures underlying the BIM domain. It also introduces a number of practicable knowledge tools to facilitate BIM learning, assessment and performance improvement.

This study is delivered through complementary papers and appendices to answer two primary research questions. The first explores the knowledge structures underlying the BIM domain whilst the second probes how these knowledge structures can be used to facilitate the measurement and improvement of BIM performance across the construction industry.

To address the first question, the study identifies conceptual clusters underlying the BIM domain, develops descriptive taxonomies of these clusters, exposes some of their conceptual relationships, and then delivers a representative BIM framework. The BIM framework is composed of three-axes which represent the main knowledge structures underlying the BIM domain and support the development of functional conceptual models.

To address the second question, BIM framework structures are extended through additional concepts and tools to facilitate BIM performance assessment and development of individuals, organizations and teams. These additional concepts include competency sets, assessment workflows and measurement tools which can be used to assess and improve the BIM performance of industry stakeholders.

In addressing these research questions, a pragmatic approach to research design based on available literature and applicable theories has been adopted. By combining several research strategies, paradigms and methods, this study (1) generates several new conceptual structures (e.g. frameworks, models and taxonomies) which collectively clarify the knowledge structures underlying the BIM domain; and (2) develops a set of workflows and tools that facilitate BIM assessment, learning and performance improvement.

This study delivers an extendable knowledge structure upon which to build a host of BIM performance improvement initiatives and tools. As a set of complementary papers and appendices, the study presents a rich, unified yet multi-layered environment of conceptual constructs and practicable tools; supported by a common framework, a domain ontology and simplified visual representations. Individually, each paper introduces a new framework part or solidifies a previous one. Collectively, the papers form a cohesive knowledge engine that generates assessment systems, learning modules and performance improvement tools.

Thesis structure

The thesis is delivered in three parts - introduction document, published papers and supporting appendices:

Part I: introduction document

The introduction document identifies the research questions, research design and study deliverables. Part I includes eleven sections:

Sections 1-3   introduce the research context, research background and discuss the importance of BIM;

Sections 4-6   identify the research questions underpinning this study, discuss the conceptual background and overall research design;

Sections 7-8   introduce a hierarchy of conceptual structures and clarify how the BIM framework has been constructed;

Section 9   introduces the study's research deliverables, the common themes underlying the submitted papers, and how different research deliverables aggregate into a conceptual and practical continuum;

Section 10   provides a conclusion, identifies a study limitation and introduces its future extensions; and

Section 11   includes the introduction document's bibliographic references.

Part II: published papers

Part 2 includes nine papers – in three types - submitted as part of this thesis. Paper types are explained in section 9 of Part I:

Paper A1:   A Proposed Framework to Investigate Building Information Modelling through Knowledge Elicitation and Visual Models

Paper A2:   The BIM Framework: a Research and Delivery Foundation

Paper A3:   Building Information Modelling Maturity Matrix

Paper A4:   The Five Components of BIM Performance Measurement

Paper A5:   Measuring BIM Performance: Five Metrics

Paper A6:   An integrated approach to BIM competency assessment, acquisition and application

Paper B1:   Building Information Modeling: analyzing noteworthy publications of eight countries using a knowledge content taxonomy

Paper B2:   A proposed approach to comparing the BIM maturity of countries

Paper C: BIM in Practice - BIM Education, a Position Paper by the Australian Institute of Architects and Consult Australia

Part III: appendices

Part III includes six appendices to clarify and support submitted papers:

Appendix A: the BIM ontology

Appendix B: BIM knowledge content taxonomy

Appendix C: citations of published papers

Appendix D: focus groups info sheet and feedback form

Appendix E: statements of contribution

Appendix F: aggregation of all bibliographic references cited in this study

PART I
INTRODUCTION DOCUMENT

This document introduces the research topics, questions, design and deliverables. It summarizes the contribution each submitted paper made towards this study, explores common research themes across papers, and provides an insight into future study extensions.

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