

# **Active BIM with Artificial Intelligence for Energy Optimisation in Buildings**

by

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## **Certificate of Original Authorship**

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

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## Table of Contents

<b>List of Figures .....</b>	<b>x</b>
<b>List of Tables.....</b>	<b>xiii</b>
<b>List of Abbreviations.....</b>	<b>xv</b>
<b>PhD Publications.....</b>	<b>xvi</b>
<b>Abstract.....</b>	<b>xvii</b>
<b>Chapter 1: Research Background .....</b>	<b>1</b>
1.1. Introduction.....	1
1.2. Research Overview.....	1
1.3. Problem Statement .....	2
1.4. Research Questions .....	7
1.5. Aim and Objectives of the Study .....	7
1.6. Research Method.....	8
1.7. Significance of the Study.....	11
1.8. Thesis Outline .....	12
<b>Chapter 2: Theoretical Framework.....</b>	<b>15</b>
2.1. Introduction.....	15
2.2. Theoretical Framework Development .....	15
2.2.1. Sustainability.....	15
2.2.2. Information Theory Paradigms.....	17
2.2.3. Optimisation Theory Paradigms .....	19
2.2.4. Interaction of the Three Theories .....	21
2.3. Sustainable Construction Drivers.....	24
2.4. BIM and Sustainable Construction.....	28
2.5. Artificial Intelligence (AI) .....	33
2.5.1. AI Application in Sustainable Construction.....	34

2.5.2. AI Application in BIM.....	34
2.6. Energy Estimation and Optimisation Methods in Buildings.....	36
2.6.1. Calculative Methods.....	37
2.6.2. Simulative Methods.....	38
2.6.3. Predictive Methods.....	39
2.6.4. Optimisation Methods.....	42
2.7. Summary.....	44
<b>Chapter 3: BIM and Energy Efficient Design.....</b>	<b>46</b>
3.1. Introduction.....	46
3.2. Background.....	46
3.3. Previous Reviews.....	48
3.4. The Current State of the Art of BIM-EED.....	50
3.4.1. BIM-Compatible EED.....	52
3.4.2. BIM-Integrated EED.....	52
3.4.3. BIM-Inherited EED.....	53
3.5. Review Methodology.....	53
3.5.1. Systematic Review.....	54
3.5.2. Thematic and Gap Analysis.....	56
3.6. Descriptive Analysis.....	57
3.7. Content Analysis.....	60
3.7.1. BIM-EED Adoption.....	60
3.7.2. Simulation Software.....	61
3.7.3. Interoperability.....	64
3.7.4. Level of Development.....	66
3.8. Thematic and Gap Analysis.....	69

3.8.1. Research Theme .....	69
3.8.2. Research Outcome .....	70
3.9. Gap Spotting .....	71
3.9.1. Confusion .....	71
3.9.2. Neglect .....	72
3.9.3. Application.....	73
3.10. Future Research Agenda.....	73
3.11. Implications for This PhD Study.....	76
3.12. Summary .....	76
<b>Chapter 4: Research Methodology .....</b>	<b>78</b>
4.1. Introduction.....	78
4.2. Qualitative Research.....	78
4.3. Qualitative Research Instruments .....	80
4.3.1. Interview .....	80
4.3.2. Focus Group .....	81
4.3.3. Delphi .....	82
4.4. Quantitative Research.....	84
4.5. Quantitative Research Instruments .....	86
4.5.1. Questionnaire Survey.....	86
4.5.2. Simulation .....	87
4.5.3. Case Study.....	88
4.6. Mixed Method.....	89
4.7. Research Design.....	92
4.8. Research Implementation.....	94
4.9. Sampling .....	99

4.10. Data Analysis .....	100
4.11. Summary .....	100
<b>Chapter 5: Data Collection and Analysis .....</b>	<b>101</b>
5.1. Introduction.....	101
5.2. Building Energy Parameters .....	101
5.2.1. Physical Properties and Building Envelop.....	102
5.2.2. Building Layout.....	103
5.2.3. Occupant Behaviour .....	103
5.2.4. HVAC and Appliances .....	104
5.3. Data Collection.....	106
5.3.1. Participants.....	107
5.3.2. Three Round Delphi .....	109
5.3.2.1. Round 1.....	110
5.3.2.2. Round 2.....	117
5.3.2.3. Round 3.....	120
5.4. Summary .....	122
<b>Chapter 6: AI Algorithms Development .....</b>	<b>125</b>
6.1. Introduction.....	125
6.2. Dataset Generation .....	125
6.3. Data Size Reduction .....	131
6.3.1. An Overview .....	132
6.3.2. Metaheuristic-Parametric Approach in Data Size Reduction.....	133
6.4. Data Interpretation Approach.....	137
6.5. AI Development .....	139

6.5.1. Introduction.....	139
6.5.2. Artificial Neural Network .....	140
6.5.2.1. ANN Model Configuration and Performance Analysis.....	141
6.5.2.2. Final ANN Model.....	145
6.5.3. Decision Tree .....	148
6.5.3.1. An Overview.....	148
6.5.3.2. DT Model Configuration and Performance Analysis .....	149
6.5.4. Hybrid Objective Function Development .....	158
6.6. Summary.....	166
<b>Chapter 7: BIM-inherited EED Framework Development and Verification.....</b>	<b>167</b>
7.1. Introduction.....	167
7.2. Optimisation Procedure .....	167
7.3. Integration Framework .....	169
7.3.1. Database Development .....	170
7.3.2. Database Exchange.....	171
7.3.3. Database Optimisation.....	173
7.3.4. Database Switchback.....	174
7.3.5. Database Updated .....	175
7.4. Testing and Validation.....	176
7.4.1. Case Study .....	176
7.4.2. Energy Simulation .....	178
7.4.3. Baseline Case Simulation Results .....	179
7.4.4. Case Optimisation Procedure .....	181
7.4.5. Case Optimisation Results .....	183
7.4.6. Optimisation Reliability Tests.....	189



7.5. Sensitivity Analysis.....	191
7.6. Summary .....	194
<b>Chapter 8: Conclusion .....</b>	<b>195</b>
8.1. Introduction.....	195
8.2. Review of Research Background, Problem, Aim and Method .....	195
8.3. Review of Research Processes and Findings .....	197
8.3.1. Objective 1: Examining the potential and challenges of BIM to optimise energy efficiency in residential buildings .....	198
8.3.2. Objective 2: Identifying variables that play key roles in energy consumption of residential buildings .....	200
8.3.3. Objective 3: Investigating the AI-based algorithms in energy optimisation.....	203
8.3.4. Objective 4: Developing a framework of AI application in BIM in terms of energy optimisation purposes and processes .....	205
8.3.5. Objective 5: Assessing and validating the functionality of the framework using case studies .....	206
8.4. Contribution to Knowledge.....	208
8.4.1. Originality.....	208
8.4.2. Implications for Practice.....	209
8.5. Limitations .....	210
8.6. Recommendations for Future Studies.....	211
<b>Appendices .....</b>	<b>214</b>
Appendix A. Research Themes, Outcomes and Gap Spotting of BIM-EED.....	214
Appendix B. Ethics Clearance.....	218
Appendix C. Delphi Participants Consent Form.....	219
Appendix D. Participants Information Letter.....	220
<b>Bibliography .....</b>	<b>221</b>

## List of Figures

Figure 1.1. Research Problematisation.....	4
Figure 1.2. Research Gap Diagram.....	6
Figure 1.3. The Hierarchical Diagram of the Research Aim, Objectives, Methods, Steps and Instruments.....	11
Figure 1.4. Thesis Outline.....	14
Figure 2.1. Classifications of Optimisation Paradigms.....	20
Figure 2.2. Interaction of Three Theories and Their Components.....	22
Figure 2.3. Building Energy Consumption Outlook.....	37
Figure 2.4. The Conceptual Structure of ANN.....	40
Figure 2.5. The Conceptual Procedure of GA.....	43
Figure 2.6. The General Flowchart of PSO.....	44
Figure 3.1. The Current State of the Art of BIM-EED .....	51
Figure 3.2. Review Methodology Diagram .....	55
Figure 3.3. Annual Distribution of the Publications.....	57
Figure 3.4. Regional and National Distribution of the Publications.....	59
Figure 3.5. The Percentage and Number of BIM-EED Adoption Categories in the Decade.....	60
Figure 3.6. Simulation Software Used Over the Studied Years.....	62
Figure 3.7. The Annual and Percentage Distribution of Interoperability and LoD in BIM-EED Literature.....	65
Figure 3.8. LoD and the Contained Information in BIM-EED.....	69
Figure 3.9. Research Theme Distribution of the Literature on BIM-EED.....	70
Figure 3.10. Future Research Agenda for BIM-EED.....	75
Figure 4.1. Mixed Method Research Implementation.....	97
Figure 5.1. Three Round Processes in This Delphi Study.....	109

Figure 5.2. The Schematic Illustration of the Variables Resulted from the First Round.....	116
Figure 5.3. The Graphical Diagram of the Steps Leading to the Output.....	123
Figure 6.1. 3D Model and the Layout.....	127
Figure 6.2. Parametric Setting of the Variables.....	134
Figure 6.3. Holistic Cross Reference.....	135
Figure 6.4. Conceptual Diagram of Heuristic Data Size Reduction .....	136
Figure 6.5. Annual Energy Load of the Whole Dataset vs. Number of Observations.....	139
Figure 6.6. The Conceptual Architecture of the Developed ANN.....	143
Figure 6.7. Different Training, Testing and Validating Percentage Performances.....	145
Figure 6.8. ANN Training State.....	146
Figure 6.9. Best Validation Performance.....	147
Figure 6.10. Regression Test of Final ANN Model.....	147
Figure 6.11. Simple Tree.....	152
Figure 6.12. Medium Tree.....	152
Figure 6.13. Complex Tree.....	154
Figure 6.14. Classification Errors of the Trained Bagged Tree.....	155
Figure 6.15. The Confusion Matrix for Four Developed DTs.....	157
Figure 6.16. Performance Error of the Trained Bagged Tree in Hybrid Model.....	160
Figure 6.17. Regularised vs. Unregularised Ensemble in the Hybrid Model.....	162
Figure 6.18. Validation Performance of ANN in the Hybrid Model.....	163
Figure 6.19. Regression Test of Hybrid ANN.....	164
Figure 6.20. Conceptual Structure of Hybrid Model.....	165
Figure 6.21. Normalised Predictive Performance of Single ANN, DT and Hybrid Model vs. Normalised Actual Energy Data.....	165
Figure 7.1. Optimisation Procedure Diagram.....	168

Figure 7.2. Convergence Performance of GA.....	168
Figure 7.3. Average Distance between Individual Results.....	169
Figure 7.4. AI and BIM Integration Framework (AI-enabled BIM-inherited EED).....	170
Figure 7.5. Database Exchange, Optimisation and Switching Back Process.....	172
Figure 7.6. ODBC Database Structure.....	174
Figure 7.7. The Database Update Process.....	175
Figure 7.8. BIM Model of the Baseline Case Study.....	177
Figure 7.9. Layout of the Baseline Case Study.....	177
Figure 7.10. Monthly Electricity Consumption (wh) for Baseline Model.....	180
Figure 7.11. Monthly Total Energy Consumption (wh) for Baseline Model.....	181
Figure 7.12 Database Development and Exchange Processes of the Case Study.....	182
Figure 7.13. Matlab Interface during the Operation Process.....	183
Figure 7.14. Monthly Electricity Consumption (wh) for Optimised Model.....	185
Figure 7.15. Monthly Total Energy Consumption (wh) for Optimised Model.....	186
Figure 7.16. Validation Procedure and Results.....	188
Figure 7.17. Concept of Reliability Threshold.....	189
Figure 7.18. Optimisation Reliability Test.....	190
Figure 7.19. Regression of the Baseline Model.....	192
Figure 7.20. Regression Sensitivity of Different Scenarios.....	193

## List of Tables

Table 2.1. Information Theory Paradigms.....	18
Table 2.2. BIM and Sustainable Design Archetypes.....	30
Table 3.1. Pervious Review and Content Analysis Studies on Energy Efficiency in Built Environment.....	49
Table 3.2. Frequency of Publications in the Primary Outlets with More Than One Record.....	58
Table 4.1. The Framework of the Mixed Methods Approach.....	93
Table 4.2. Mapping the Applicable Research Instruments with Research Objectives and Questions.....	96
Table 5.1. The Identified Variables from Literature.....	105
Table 5.2. Respondents Profile.....	108
Table 5.3. 35 Extracted Variables through a Quick Textual Analysis Method in Round 1.....	111
Table 5.4. Normative Assessment Results.....	114
Table 5.5. Results of Round 2 Questionnaires.....	118
Table 5.6. The Concordance Measurement for the Round 2.....	120
Table 5.7. Results of Round 3 Questionnaires.....	121
Table 5.8. The Concordance Measurement for the Round 3.....	122
Table 6.1. Model Parameters Specifications based on ASHRAE 90.1-2007.....	128
Table 6.2. User Profile.....	129
Table 6.3. Cities Chosen for Simulation.....	130
Table 6.4. Climatic Data of the Selected Cities.....	131
Table 6.5. Descriptive Statistics of the Developed Dataset (*Categorical Parameters).....	138
Table 6.6. ANN Training Algorithms Applied.....	144
Table 6.7. Different Training Algorithms Performance.....	144
Table 6.8. Performance Summary for the Classification Algorithms.....	157
Table 6.9. Number of Observations and Data Ranges for Each Class.....	158

Table 7.1. Baseline Case Study Specifications.....	178
Table 7.2. User Profile.....	179
Table 7.3. Optimised Baseline Construction Specifications.....	184
Table 7.4. Paired Sample T-Test Calculations.....	191
Table 7.5. Regression Results of Baseline vs. Sensitivity Analysis Scenarios.....	194

## List of Abbreviations

2D CAD	2 Dimensional Computer Aided Drawing
3D	3 Dimensional
AC	Air Conditioning
AI	Artificial Intelligence
API	Application Program Interface
ANN	Artificial Neural Network
ASCE	American Society of Civil Engineering
BIM	Building Information Modelling
CDA	Conditional Demand Analysis
CDE	Common Data Environment
CFD	Computational Fluid Dynamic
DBLink	Database Link
DT	Decision Tree
EED	Energy Efficient Design
EU	European Union
GA	Genetic Algorithm
GB	Green Building
GBS	Green Building Studio
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
IES	Integrated Environmental Solution
IFC	Industry Foundation Class
IFP	Implication for Practice
IT	Information Technology
IS	Information System
LEED	Leadership in Energy and Environmental Design
LoD	Level of Development
MLP	Multilayer Perceptron
MSE	Mean Square Error
ODBC	Open Database Connectivity
POS	Particle Swarm Optimisation
RC	Reinforced Concrete
SVM	Support Vector Machine
TMY	Typical Metrological Year

## **PhD Publications**

S. Banihashemi, G. Ding and J. Wang. 2017. BIM and Energy Efficient Design: 10 Years of Review and Analysis. *Journal of Renewable and Sustainable Energy Reviews*, Elsevier (under review).

S. Banihashemi, G. Ding and J. Wang. 2016. Developing a Hybrid Model of Prediction and Classification Algorithms for Building Energy Consumption Optimisation. *Energy Procedia*, Elsevier, Volume 110, pages 371-376.

S. Banihashemi, G. Ding and J. Wang. 2016. Identification of BIM-Compatible Variables for Energy Optimization of Residential Buildings: A Delphi Study. 40th AUBEA, Cairns, Australia. July 6-8, 2016.

G. Ding and S. Banihashemi. 2016. Carbon and Ecological Foot Printing of Cities. *Sustainable Energy Technologies, Encyclopaedia of Sustainable Technologies*, Elsevier, Volume 2, pages 43-51.

S. Banihashemi, G. Ding and J. Wang. 2015. Developing a Framework of Artificial Intelligence Application for Delivering Energy Efficient Buildings through Active BIM. COBRA, Sydney, Australia. July 8-10, RICS 2015.



## Abstract

Using Building Information Modelling (BIM) can expedite the Energy Efficient Design (EED) process and provide the opportunity of testing and assessing different design alternatives and materials selection that may impact on energy performance of buildings. However, the lacks of; intelligent decision making platforms, ideal interoperability and inbuilt practices of optimisation methods in BIM hinder the full diffusion of BIM into EED. This premise triggered a new research direction known as the integration of Artificial Intelligence (AI) into BIM-EED. AI can develop and optimise EED in an integrated platform of BIM to represent an alternative solution for building design. But, very little is known about achieving it. Hence, an exhaustive literature review was conducted on BIM, EED and AI and the relevant gaps, potentials and challenges were identified. Accordingly, the main goal for this study was set to optimise the energy efficiency at an early design stage through developing an AI-based active BIM in order to obtain an initial estimate of energy consumption of residential buildings and optimise the estimated value through recommending changes in design elements and variables.

Therefore, a sequential mixed method approach was designated in which it entailed conducting a preliminary qualitative method to serve the subsequent quantitative phase. This approach was started with a comprehensive literature review to identify variables applicable to EED and the application of a three-round Delphi to further identify and prioritise the significant variables in the energy consumption of residential buildings. A total of 13 significant variables was achieved and factualised with simulation method to first; generate the building energy datasets and second; simulate AI algorithms to investigate their functionality for energy optimisation. The research was followed with developing the integration framework of AI and BIM; namely AI-enabled BIM-inherited EED to optimise the interdisciplinary data of EED in the integration of BIM with AI algorithm packages. Finally, the functionality of the developed framework was verified using a real residential building and via running comparative energy simulation pre and post-framework application (baseline and optimized case). The outcomes indicated around 50% reduction in the electricity energy consumption and 66% saving in the annual fuel consumption of the case study.

Enhancing BIM applicability in terms of EED optimisation, shifting the current practice of post-design energy analysis, mitigating the less integrated platform and lower levels of interoperability are the main significant outcomes of this research. Ultimately, this research heads

toward the higher diffusion levels of BIM and AI into EED which contributes significantly to the current body of knowledge and its research and development effects on the industry.