

**Developing a life cycle assessment model
for measuring sustainable performance
of buildings in China**

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degree of Doctor of Philosophy

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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 fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student:

Date: 7 July 2014

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Contents

| | |
|--|-------------|
| Acknowledgement | ii |
| List of Abbreviations and Acronyms | viii |
| List of Figures | x |
| List of Tables | xii |
| | |
| 1 Introduction | 1 |
| 1.1 Introduction | 1 |
| 1.2 Background to the research | 1 |
| 1.3 Problems definition | 4 |
| 1.4 Research aims and objectives | 7 |
| 1.5 Research scope | 10 |
| 1.6 Research methodology | 11 |
| 1.7 Significance of the research | 12 |
| 1.8 Structure of the thesis | 12 |
| 1.9 Summary | 15 |
| | |
| 2 Sustainability and triple bottom line | 17 |
| 2.1 Introduction | 17 |
| 2.2 The sustainability concept | 17 |
| 2.3 The triple bottom line of sustainability | 22 |
| 2.3.1 The concept of triple bottom line | 22 |
| 2.3.2 Comparing triple bottom line approach with impact assessment | 23 |
| 2.4 An overview of triple bottom line for building assessment | 26 |
| 2.4.1 Environmental assessment approaches | 26 |
| 2.4.2 Economic assessment approaches | 44 |
| 2.4.3 Social assessment approach for assessing building | 54 |
| 2.5 Summary | 60 |

| | | |
|----------|---|------------|
| 3 | Sustainable building and sustainable assessment | 61 |
| 3.1 | Introduction | 61 |
| 3.2 | Impact of building on the environment | 61 |
| 3.3 | An overview of sustainable building performance assessment methods | 64 |
| 3.3.1 | Building performance modeling | 65 |
| 3.3.2 | Sustainable building assessment tools | 68 |
| 3.4 | Sustainable building development and assessment in China | 71 |
| 3.4.1 | The development of sustainable building and legal systems | 71 |
| 3.4.2 | The development of sustainable building assessment tools | 77 |
| 3.5 | A critique of sustainable building assessment tools | 90 |
| 3.6 | Summary | 97 |
| | | |
| 4 | Building process and building life cycle performance | 99 |
| 4.1 | Introduction | 99 |
| 4.2 | Building phases and activities | 99 |
| 4.3 | The evaluation of environmental, economic and social impacts related to the building process | 105 |
| 4.3.1 | Inception and design phase | 106 |
| 4.3.2 | Construction phase | 108 |
| 4.3.3 | Operation phase | 111 |
| 4.3.4 | Demolition phase | 114 |
| 4.4 | Assessing building performance on a life cycle perspective | 116 |
| 4.5 | Summary | 120 |
| | | |
| 5 | Research methodology and data collection | 121 |
| 5.1 | Introduction | 121 |
| 5.2 | Research methodology | 121 |
| 5.2.1 | Qualitative methods | 122 |
| 5.2.2 | Quantitative methods | 123 |
| 5.2.3 | Mixed method strategies | 125 |
| 5.3 | Data-collection processes and instruments | 127 |
| 5.4 | Research methods used in the construction industry | 129 |
| 5.5 | Research design | 133 |
| 5.6 | Summary | 136 |
| | | |
| 6 | Data analysis and discussions | 138 |
| 6.1 | Introduction | 138 |
| 6.2 | Data collection process | 138 |

| | | |
|----------|---|------------|
| 6.2.1 | Questionnaire survey | 139 |
| 6.2.2 | Interview | 145 |
| 6.3 | Data analysis - questionnaire survey | 146 |
| 6.3.1 | General background | 147 |
| 6.3.2 | Sustainable building development in China | 150 |
| 6.3.3 | Ways to improve current situation of green building development in China | 153 |
| 6.3.4 | Opinion about the sustainable assessment tools in China | 154 |
| 6.3.5 | The most widely used sustainable assessment tools in China | 156 |
| 6.3.6 | Building life cycle stages | 157 |
| 6.3.7 | The pillars of sustainable impacts | 160 |
| 6.3.8 | Identifying indicators for the assessment of building performance | 160 |
| 6.3.9 | Summary of questionnaire survey and inspiration for the Interview | 163 |
| 6.4 | Data analysis - interview | 165 |
| 6.4.1 | Background of interview | 165 |
| 6.4.2 | The problems of sustainable building development in China | 167 |
| 6.4.3 | The current used sustainable assessment tools in China | 170 |
| 6.4.4 | The stage division in building life cycle | 171 |
| 6.4.5 | The assessment indicators in three pillars in different stages | 173 |
| 6.5 | Summary | 174 |
| 7 | Developing a building sustainable score model for assessing building performance from a life cycle perspective | 176 |
| 7.1 | Introduction | 176 |
| 7.2 | Conceptual model | 176 |
| 7.3 | Indicators evaluation | 179 |
| 7.3.1 | Assessment details of indicators | 179 |
| 7.3.2 | Indicator Evaluation | 188 |
| 7.4 | Weights of the indicators | 195 |
| 7.5 | Building Sustainable Score (BSS) model | 200 |
| 7.6 | Summary | 203 |
| 8 | Case studies and model verification | 204 |
| 8.1 | Introduction | 204 |
| 8.2 | Background information of case studies | 204 |
| 8.2.1 | Case study No 1: A low rise office building in suburban industrial area | 205 |

| | | |
|----------|---|------------|
| 8.2.2 | Case study No 2: A medium rise office building in CBD | 207 |
| 8.2.3 | Case study No 3: A medium rise green building in a new development area | 209 |
| 8.3 | Assessment details of case studies | 213 |
| 8.3.1 | Economic assessment - LCC approach | 213 |
| 8.3.2 | Environmental assessment - The value score and LCA approach | 216 |
| 8.3.3 | Social assessment - The value score approach | 223 |
| 8.4 | Weighting system in the BSS model | 225 |
| 8.4.1 | AHP method | 226 |
| 8.4.2 | Model calculation | 229 |
| 8.5 | The results compared with other assessment tools | 237 |
| 8.5.1 | Assessing the three projects using LEED | 237 |
| 8.5.2 | Assessing the three projects using ESGB | 240 |
| 8.6 | The benefits of BSS | 241 |
| 8.7 | Summary | 243 |
| 9 | Summary and Conclusions | 244 |
| 9.1 | Introduction | 244 |
| 9.2 | Summary of research | 244 |
| 9.3 | Review of aims and objectives | 245 |
| 9.3.1 | Reviewing current environmental building assessment tools | 245 |
| 9.3.2 | Reviewing building processes and phases of a building | 246 |
| 9.3.3 | Reviewing the environmental, economic and social impacts related to building processes | 247 |
| 9.3.4 | Reviewing the current condition of green building design and construction in China | 249 |
| 9.3.5 | Reviewing the model development and verification | 250 |
| 9.4 | The outcome of the BSS model | 252 |
| 9.5 | Contribution to knowledge | 252 |
| 9.6 | Research limitations | 253 |
| 9.7 | Recommendations for further research | 254 |
| 9.8 | Conclusions | 256 |
| | Reference | 257 |
| | Appendices | 281 |

List of Abbreviations and Acronyms

| Acronym | Definition |
|----------------|--|
| AHP | Analytical Hierarchy Process |
| BEPAC | Building Environmental Performance Assessment Criteria |
| BREEAM | Building Research Establishment Environmental Assessment Method |
| BRI | Building Related Illness |
| BSS | Building Sustainable Score |
| CASSBE | Comprehensive Assessment System for Built Environment Efficiency |
| CBA | Cost-Benefit Analysis |
| CF | Carbon Footprint |
| CSR | Corporate Social Responsibility |
| DEP | Direct Energy Path |
| DGNB | Deutsche Gesellschaft für Nachhaltiges Bauen |
| EF | Ecological Footprint |
| EIA | Environmental impact assessment |
| EIO-LCA | Economic Input-Output LCA |
| EMS | Environmental Management Systems |
| EoL | End-of-Life |
| ESGB | Evaluating Standard for Green Buildings |
| FCA | Full Cost Accounting |
| FCP | Full Cost Pricing |
| GB Tool | Green Building Tool |
| GFA | Gross Floor Area |
| GHG | Greenhouse Gas |
| GOBAS | Green Olympic Building Assessment System |

| | |
|------|--|
| HLF | Health Footprint |
| HVAC | Heating, Ventilation and Air Conditioning |
| ISO | International Organization for Standardization |
| LCA | Life Cycle Assessment |
| LCA* | Life Cycle Accounting |
| LCC | Life Cycle Cost |
| LCCA | Life Cycle Cost Assessment |
| LEED | Leadership in Energy and Environmental Design |
| MFA | Material Flow Accounting |
| MOC | Ministry of Construction (China) |
| SAT | Sustainable Assessment Tool |
| SBS | Sick Building Syndrome |
| SD | Sustainable Development |
| SDA | Sustainable Development Ability |
| SDV | Sustainable Development Value |
| SEA | Strategic Environmental Assessment |
| SF | Social Footprint |
| SIA | Social Impact Assessment |
| TBL | Triple Bottom Line |
| TCA | Total Cost Accounting |
| VS | Value Score |
| WF | Water Footprint |
| WHO | World Health Organization |
| WLC | Whole Life Costing |

List of Figures

| | | |
|------------|--|-----|
| Figure 1.1 | The structure of research | 16 |
| Figure 2.1 | The relationship of three pillars in SD | 21 |
| Figure 2.2 | The LCA framework | 27 |
| Figure 2.3 | Cost accounting methods | 45 |
| Figure 2.4 | The relationship among the three types of LCC | 49 |
| Figure 3.1 | LEED certified projects in China by August 2011 | 79 |
| Figure 3.2 | Distribution of the LEED certified projects in China (2004 - 2011) | 80 |
| Figure 3.3 | Number of registered projects in different LEED systems | 81 |
| Figure 3.4 | Number of certified projects in different LEED systems | 81 |
| Figure 3.5 | Distribution of LEED certified projects by building types | 82 |
| Figure 3.6 | Registered LEED projects by provinces in 2011 | 83 |
| Figure 3.7 | Distribution of the ESGB certified projects | 87 |
| Figure 3.8 | Distribution of ESGB certificated buildings by building types and levels | 88 |
| Figure 3.9 | Distribution of ESGB certified projects by provinces by 2011 | 90 |
| Figure 4.1 | The divisions of building phases | 102 |
| Figure 5.1 | Breadth vs. depth in research | 133 |
| Figure 5.2 | Research flow | 137 |
| Figure 6.1 | Experience distribution | 149 |
| Figure 6.2 | The current situation of sustainable building development in China | 151 |
| Figure 6.3 | The projects which used sustainable assessment tools among the projects they participated in | 155 |
| Figure 6.4 | The most widely used SATs in China | 156 |
| Figure 6.5 | The stage division | 158 |
| Figure 7.1 | The conceptual model for BSS | 178 |
| Figure 7.2 | The flow of AHP method | 196 |

| | | |
|------------|---|-----|
| Figure 8.1 | The location of the three cases in Guangdong Province, China | 205 |
| Figure 8.2 | The general layout of case 1 | 206 |
| Figure 8.3 | The general plan of case 2 | 208 |
| Figure 8.4 | The plan of case 3 | 210 |
| Figure 8.5 | The LCC component of case 1, 2, and 3 | 216 |
| Figure 8.6 | The value score of social impacts for three cases | 225 |
| Figure 8.7 | The score of different stages in three cases | 234 |
| Figure 8.8 | BSS for three cases | 235 |
| Figure 8.9 | The sustainable score in four stages and three pillars in three cases | 236 |

List of Tables

| | | |
|------------|---|-----|
| Table 2.1 | Comparison of various approaches in building assessment | 25 |
| Table 2.2 | Summary of LCA approach for the assessment of building performance | 29 |
| Table 2.3 | Research on input-output framework used in EF | 34 |
| Table 2.4 | Calculation units for GHG in CF | 38 |
| Table 2.5 | A comparative study of the three consumer-based approaches | 42 |
| Table 2.6 | Summary of different forms of economic approaches | 46 |
| Table 2.7 | Life cycle cost analysis on buildings | 47 |
| Table 2.8 | Comparison of three types of LCC | 50 |
| Table 2.9 | Economic life of building components | 51 |
| Table 2.10 | Methods to calculate the social impacts | 59 |
| Table 3.1 | The key features of selected four SATs | 70 |
| Table 3.2 | The development of legal system for sustainable buildings in China | 73 |
| Table 3.3 | Standards and guidelines for green buildings in China | 76 |
| Table 3.4 | The assessment details in Technical Assessment Handbook for Ecological Residence | 85 |
| Table 3.5 | Sustainable assessment tools and their applicable phases | 94 |
| Table 4.1 | The stage-division of a construction project across its life cycle and the major activities in each stage | 104 |
| Table 4.2 | Summary of the building stages and the relevant sustainable impacts | 117 |
| Table 5.1 | Summary of advantages and limitations of qualitative methods | 123 |
| Table 5.2 | Summary of advantages and limitations of quantitative methods | 125 |
| Table 5.3 | Characteristic of quantitative, qualitative and mixed methods | 126 |
| Table 5.4 | Advantages and limitations of different data-collection processes | 128 |
| Table 5.5 | Research methods used in construction industry | 132 |
| Table 6.1 | The component of the participants | 146 |

| | | |
|------------|--|-----|
| Table 6.2 | Summary of general background of participants in questionnaire Survey | 148 |
| Table 6.3 | Age distribution by gender and professionals | 149 |
| Table 6.4 | Experience distribution by professionals | 150 |
| Table 6.5 | Causes for the slow development of green building in China | 152 |
| Table 6.6 | The ways to improve the green building situation | 154 |
| Table 6.7 | Participants who used the SA tools before by age | 155 |
| Table 6.8 | Experience in SAT by occupation | 156 |
| Table 6.9 | The SAT which professionals used | 157 |
| Table 6.10 | Importance of assessing building performance in every single stage by professional | 159 |
| Table 6.11 | Indicators for assessing the buildings' environmental impacts | 162 |
| Table 6.12 | Indicators for assessing the buildings' social impacts | 162 |
| Table 6.13 | The component of the participants | 166 |
| Table 6.14 | The assessment indicators for different stages in three pillars | 174 |
| Table 7.1 | The assessment details of indicators in inception and design stage | 182 |
| Table 7.2 | The assessment details of indicators in construction stage | 184 |
| Table 7.3 | The assessment details of indicators in operation stage | 185 |
| Table 7.4 | The assessment details of indicators in demolition stage | 187 |
| Table 7.5 | Coefficient for demolition waste (kg/m^2) | 195 |
| Table 7.6 | Fundamental scale for developing priority matrix | 197 |
| Table 7.7 | Pair-wise comparison matrix for criterion A_1, A_2, A_3 | 197 |
| Table 7.8 | Random index (R.I.) in AHP | 200 |
| Table 8.1 | Design detail of the three cases | 212 |
| Table 8.2 | Summary of economic assessment for the three case studies | 214 |
| Table 8.3 | The discounted cash flow of operating cost for the three projects (¥) | 215 |
| Table 8.4 | Energy consumed on site in construction stage for case 1 | 218 |
| Table 8.5 | The coefficient for carbon emission in demolition stage | 221 |
| Table 8.6 | Summary of environmental assessment for the three case studies | 223 |

| | | |
|------------|---|-----|
| Table 8.7 | Summary of social assessment for the three case studies | 224 |
| Table 8.8 | Weighting for environmental indicators in inception and design stage | 228 |
| Table 8.9 | Weighting for indicators in three pillars and four stages | 228 |
| Table 8.10 | Building sustainable score in inception and design stage of the three cases | 230 |
| Table 8.11 | Building sustainable score in construction stage of the three cases | 231 |
| Table 8.12 | Building sustainable score in operation stage of the three cases | 232 |
| Table 8.13 | Building sustainable score in demolition stage of the three cases | 233 |
| Table 8.14 | Building sustainable score for three cases | 234 |
| Table 8.15 | LEED evaluation for the three cases | 238 |
| Table 8.16 | The grades for the three cases | 241 |

List of publications during candidature

Journal paper

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Abstract

The construction industry contributes significantly to environmental pollution. The environmental problems caused by construction range from energy and resource consumption to waste emission throughout the building life cycle. With increasing attention being paid to building sustainability performance, numerous environmental assessment tools occurred. They have been developed and used to assist planning and design of sustainable buildings, and help improve overall environmental awareness and achieve the goal of sustainability in the construction industry.

However, with critical reviews on the current tools, they are criticized as being ineffective and inefficient in addressing the building performance issues, as most of them only focus on assessing building performance on environmental criteria and the assessment does not take into consideration economic and social analysis. Sustainability is like a three-legged stool, with each leg representing areas of environment, economy and society. Any leg missing from the ‘sustainability stool’ will cause instability because the three components are intricately linked together. In addition, most current tools have not considered all the building phases in their assessment. As economic, social and environmental impacts associated with project development will vary at different stages throughout its life cycle, sustainable performance should be assessed and incorporated into the building process.

Since the last century, China started to realize the importance of green buildings (CSUS 2012). A national SAT called Evaluation Standards for Green Buildings (ESGB) was launched in 2006 (Ye et al. 2013), and several international tools are adopted in China for assessing building performance. However, sustainable building assessment has significant regional differences and the application of international tools in China still have shortcomings. Moreover, the ESGB is also criticized for not

sufficiently taking into consideration of economic and social issues in building life cycle assessment.

In this research, different phases of a building life cycle are identified, as well as major activities for each phase in order to investigate how they influence the environmental, economic and social impacts. Both qualitative and quantitative methods are adopted in this research. Questionnaire survey and semi-structure interviews were used for data collection. The assessment indicators are generated by the data collection.

An assessment model is established based on the results of data analysis and the literature review. It combines environmental, economic and social assessment to aid decision making. The assessment is integrated into the building life cycle, and the building performance on each stage is also indicated. The assessment details of each indicator are also discussed.

The model is tested and verified by case study. Three projects are used as case studies. The sustainable performance of the three cases in every stage of the building life cycle as well as the overall performance will be analyzed. Quantitative methods and qualitative methods are used for assessing the indicators. The results using the developed model, the Building Sustainable Score (BSS), are also compared with the LEED and ESGB for deeper discussion. The value and innovation of this model are also discussed in this research.