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

Jiani Liu

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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

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

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List of publications during candidature

Journal paper

Liu, J., Ding, G.K. & Samali, B. 2013，'Building Sustainable Score (BSS)—A Hybrid Process Approach for Sustainable Building Assessment in China', *Journal of Power and Energy Engineering,* Vol.1, Issue 5, pp. 58-62.

Conference paper

Liu, J., Ding, G.K. & Samali, B. 2011, 'Quantifying and assessing impacts of building processes in a triple bottom line approach', SB11 Helsinki, Helsinki, Finland, October 2011 in *World Sustainable Building Conference*, ed Huovila, Pekka, Finish Association of Civil Engineers RIL & VTT Technical Research Centre of Finland, Helsinki, Finland, pp. 554-563.

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.