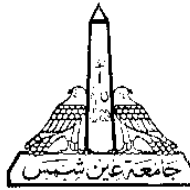


ملاحظات:



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Structural Engineering

LIFECYCLE COSTING ASSESSMENT FOR APPLICATION OF SUSTAINABLE SCHOOL BUILDINGS IN EGYPT

A Thesis submitted in partial fulfillment of the requirements of the degree of
Doctor of Philosophy in Civil Engineering
(Structural Engineering)

By

Gehad Fathy Mohamed Abdel Aziz

B.Sc. in Civil Engineering (Structural Engineering) Faculty of Engineering, Ain Shams University, 1996

M.Sc. in Civil Engineering (Structural Engineering) Faculty of Engineering, Ain Shams University, 2004

Supervised By

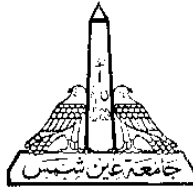
Prof. Dr. Tarek Mohamed Attia

Professor of Construction and Project
Management, Housing and Building
National Research Center

Prof. Dr. Aly Sherif Abdel Fayad

Professor of Structural Engineering and
Construction Management, Ain Shams
University – Faculty of Engineering

Cairo – (2022)



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Structural

LIFECYCLE COSTING ASSESSMENT FOR APPLICATION OF SUSTAINABLE SCHOOL BUILDINGS IN EGYPT

By

Gehad Fathy Mohamed Abdel Aziz

B.Sc., in Civil Engineering (Structural Engineering) Faculty of Engineering, Ain Shams University, 1996

M.Sc.in Civil Engineering (Structural Engineering) Faculty of Engineering, Ain Shams University, 2004

Examiners' Committee

<u>Name, Title, and Affiliation</u>	<u>Signature</u>
Prof. Osama Ahmad Hosny Professor of Construction Engineering – School of Science and Engineering - American University in Cairo	-----
Prof. Khaled Ahmad Hamdy Professor of Structural Engineering Dept. - Project Management Faculty of Engineering - Ain Shams University	-----
Prof. Aly Sherif Abdel Fayad Professor of Structural Engineering Dept. - Project Management Faculty of Engineering - Ain Shams University	-----
Prof. Tarek Mohamed Attia Professor of Construction and Project Management Housing and Building National Research Center	-----

Date: / /2022

الله

بسم الله الرحمن الرحيم
بسم الله الرحمن الرحيم

قُلْ أَطِيعُوا اللَّهَ أَطِيعُوا الرَّسُولَ
قُلْ إِنَّمَا أَعِظُكُمْ بِمَا عَلَّمْتُكُمْ
الْحَكِيمَ

صَلَّى اللَّهُ عَلَيْهِ وَسَلَّمَ



STATEMENT

This thesis is submitted as partial fulfillment of Doctor of Philosophy in Civil Engineering, Structural Engineering, Faculty of Engineering, and Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Name: Gehad Fathy Mohamed

Signature:

Date:

Researcher Data

Name: Gehad Fathy Mohamed Abdel Aziz

Date of Birth: December 26, 1973

Place of Birth: Cairo, Egypt

Last academic degree: Master of Science

Field of specialization: Civil Engineering - Structural Engineering.

University issued the degree: Ain Shams University- Faculty of engineering.

Date of issued degree: 2004.

Current Job: Engineering Manager – Hill International



Ain Shams University
Faculty of Engineering
Department of Structural Engineering

Abstract of the Research for Doctor Degree of Philosophy in
Civil Engineering in Structural Engineering.

Submitted by:

Gehad Fathy Mohamed Abdel-Aziz

Title of thesis: **LIFECYCLE COSTING ASSESSMENT FOR APPLICATION OF
SUSTAINABLE SCHOOL BUILDINGS IN EGYPT**

Student Name: **Gehad Fathy Mohamed Abdel Aziz**

Supervisors: **Prof. Aly Sherif Abdel Fayad** (Professor of Structural engineering)
- Ain Shams University – Faculty of Engineering).
Prof. Tarek Mohamed Attia (Professor of Structural Engineering
– Housing and Building National Research Center).

Keywords: **LEED, GPRS, Sustainability, School, LCA, WLCC, LCC**

Abstract

Egypt has an overpopulation problem. The population reached 102 million in early 2020, according to the Central Agency for Public Mobilization and Statistics (CAPMAS, (2020)). The annual population increases by 2.5 percent and is expected to reach 151 million people by 2050. Number of students in Egypt is big to the number of classrooms, especially with the high increase of overpopulation. Egypt has 24 million students up to grade 9 distributed on 45000 governmental schools and 7500 private schools as per CAPMAS, (2020). Today the private sector shares the government in constructing the educational buildings. The building and construction sector is one of the most important areas of intervention. It provides opportunities to limit the environmental impact and contribute to the achievement of sustainable development goals. Nowadays, green buildings have a high impact on society. Now designers are known that fresh air improves the indoor environment, and water savings are important. Green building is well-known because of their environmental benefit.

Green construction is a method of wisely using resources to create high-quality, healthier, more energy-efficient homes, educational buildings, and commercial buildings. Sustainable design is finding the balance between high-quality construction and low environmental impact. Viewing sustainable building as a process is important because green-building success isn't just a matter of building with green materials. Still,

the green building combines materials and processes to maximize efficiency, durability, and savings. Continuous building maintenance will increase the building's life span.

This thesis introduces an analytical study to measure the green level for the educational buildings and develop the green target assessment using LEED and GPRS systems. More than 100 educational conventional and green alternative buildings are investigated. Many conventional educational buildings don't meet the minimum green level that why upgrading the school is performed by changing many parameters in the design to meet the minimum green level requirements for each LEED/GPRS level.

Analysis of the Lifecycle costing elements is performed. The initial costs, energy, water costs, running cost and environmental impact costs are analyzed and are analyzed. The associated premium initial cost for LEED / GPRS levels is defined for the educational buildings. The whole lifecycle cost present value for the conventional and the green alternatives are analyzed using the deterministic and stochastic methods. The best-fit regression analysis is used to develop LCC forecasting models. A case study and verification of the forecasting models could be achieved in this research. Sensitivity analysis is to assess the uncertainty linked to lifecycle cost elements.

The research will provide the best alternative selection for the educational conventional and green buildings that meet the sustainability criteria and verify the minimum overall lifecycle cost. The alternatives are compared using a net present value for the deterministic and stochastic methods. The selection was verified using the risk assessment with an efficient frontier analysis procedure. The selection will assist the engineers, real estate developers, tenants, and school owners in selecting education buildings that meet the sustainability criteria and minimum overall lifecycle cost.

Acknowledgement

I want to extend my deep thanks to the people who supported me and provided their guidance during the work. A special thanks to my advisors Prof. Dr. Aly Sherif Abdel Fayad, Professor of Structural Engineering & Construction Management, and Prof. Tarek Mohamed Attia, Professor of Construction and Project Management, for their support of the research and inspiring me all the way. I wouldn't have been able to complete this research without their guidance.

Thanks to all the people who provided me with vital data to form my thesis. Also, all thanks to the thesis committee members for their effective involvement and support of the work.

Finally, I would like to thank my mother my family for their constant encouragement and support of all things I have done in my life.

Gehad Fathy Mohamed

Jan. 2022

Table of Contents

1. INTRODUCTION

1.1	Background	1
1.2	Problem Statement	2
1.3	Thesis Goals	3
1.4	Thesis structure	3

2. LITERATURE REVIEW

2.1	General	5
2.2	Sustainable buildings	5
2.2.1	Green Buildings Construction and Benefits	5
2.2.2	Development of Sustainability Assessment Techniques	6
2.2.2.1	LEED Categories and Criteria	6
2.2.2.2	LEED Implementations in Buildings	6
2.2.2.3	Green Pyramids Rating System (GPRS)	7
2.3	Lifecycle Costing	8
2.3.1	Costing Components	8
2.3.2	Lifecycle Costing Mathematical Models	8
2.3.2.1	Annual Worth Value Approach	9
2.3.2.2	Net Present Value Approach	9
2.3.3	Lifecycle Cost Elements and Allocation	10
2.3.4	LCC Forecasting Models	10
2.3.4.1	Deterministic Analysis Method	10
2.3.4.2	Stochastic Analysis Method	10
2.3.5	Application of Lifecycle Cost on the Educational Buildings	11
2.3.6	Assessment of Educational Buildings Lifecycle	11
2.4	Implementation of LCC in Educational Buildings	11

3. METHODOLOGY AND ANALYSIS TOOLS

3.1	Introduction	12
3.2	Research Methodology	12
3.3	Investigated Educational Buildings	12
3.4	Lifecycle Cost Elements for the Educational Buildings	14
3.5	Selection Methodology for Best Alternative	17
3.6	Lifecycle Cost Elements for Conventional Educational Buildings	20
3.6.1	Construction Costs	20
3.6.2	Energy Consumption and Cost	20
3.6.3	Operating and Maintenance Costs	20
3.6.4	Major Repair Costs	21
3.6.5	Calculation of Educational building cost impact on the Environment	21
3.6.6	Salvage Value	21
3.7	Lifecycle Cost for Sustainability Educational Buildings	21
3.7.1	Lifecycle cost Elements for Green Educational Buildings	21
3.8	Developing of LCC Forecasting Models for the Educational	22
3.9	Research Techniques and Measurements Tools	22
3.9.1	Sustainability Measurement Tools	22
3.9.2	Regression Analysis -Best Fits	23
3.9.3	Risk Analysis and Tools	25
3.10	Selection Best Alternative	26

4. ANALYTICAL STUDY FOR SUSTAINABILITY ASSESSMENT FOR EDUCATIONAL BUILDINGS

4.1	Introduction	33
4.2	Target Green score	33
	4.2.1 Green Assessment Target for LEED system	33
	4.2.2 Green Assessment Target for GPRS system	33
4.3	Green Categories Selection Criteria and Prioritization	34
4.4	Evaluation of LEED Alternatives and Results	34
	4.4.1 Integrated process Assessment Category	34
	4.4.2 Location and transportation Category	35
	4.4.3 Sustainable sites Category	35
	4.4.4 Water efficiency Category	36
	4.4.5 Energy and Atmosphere Category	37
	4.4.6 Material and Resources Category	37
	4.4.7 Indoor Environmental Quality Category	38
	4.4.8 Innovation in Design Category	39
4.5	Evaluation of GPRS Alternatives and Result	39
	4.5.1 Sustainable sites Category	39
	4.5.2 Energy efficiency Category	40
	4.5.3 Water efficiency Category	41
	4.5.4 Material and resources Category	42
	4.5.5 Indoor Environmental quality Category	42
	4.5.6 Management Protocols Category	43
	4.5.7 Innovation and added value Category	43
4.6	Greywater treatment plants LEED/GPRS system	44
4.7	Solar electric panels LEED/GPRS system	45
4.8	Results & Summary	47

5. DETERMINISTIC ANALYSIS OF LIFECYCLE COST ELEMENTS

5.1	Introduction	48
5.2	Conventional Educational Buildings Initial Costs	48
	5.2.1 Forecasting Model	50
	5.2.2 Regression Model	52
5.3	Energy and Water Costs for the Conventional Educational Buildings	55
	5.3.1 Energy Consumption Rates and Costs	55
	5.3.2 Water Consumption Rates and Costs	56
	5.3.3 Conventional Educational Buildings Major Repairs Costs	58
	5.3.4 Conventional Educational Buildings Operating and Maintenance Costs	58
	5.3.5 Conventional Educational Buildings Environmental Impact Costs	59
	5.3.6 Salvage Value of School Buildings	59
5.4	Green Educational Buildings using LEED System	60
	5.4.1 Initial Costs for LEED building	60
	5.4.2 Energy Costs for LEED Educational Buildings	66
	5.4.3 Water Consumption Costs LEED Educational Buildings	67
	5.4.4 Operating and Maintenance Costs for LEED Educational Buildings	70
	5.4.5 Major Repairs Costs for LEED Educational Buildings MR	70
	5.4.6 Environmental Impact Costs for LEED Educational Buildings EIC	71
	5.4.7 Salvage Value for LEED Educational Buildings	71
5.5	Sustainable School Buildings using GPRS System	71
	5.5.1 Initial Costs for GPRS Educational building	71
	5.5.2 Energy Costs for GPRS educational building	76

5.5.3	Water Consumption Costs GPRS Educational Buildings	78
5.5.4	Operating and Maintenance Costs for GPRS Educational Buildings	79
5.5.5	Major Repairs Costs for GPRS Educational Buildings	81
5.5.6	Environmental Impact Costs for GPRS Educational Buildings	81
5.5.7	Salvage Value for GPRS Educational Buildings	81
5.6	Analysis of Lifecycle Cost	81
5.6.1	Defining of LEED/ GPRS Groups and Alternatives	81
5.6.2	Determination of Lifecycle Costing Elements	83
	5.6.2.1 Conventional Educational Buildings	83
	5.6.2.2 Green Educational Buildings	83
5.6.3	Analysis Methods of Lifecycle cost	83
	5.6.3.1 Deterministic Analysis	83
5.7	Output Results	84
5.7.1	Total Life Cycle Costs in PV	89
5.7.2	Selection of the LEED/ GPRS certificates levels alternatives	94
5.7.3	Initial Costs Impact	94
5.7.4	Running Costs Lifecycle Present Value Impact	95
5.7.5	Energy and Water Costs Present Value Impact	99
5.7.6	Environmental Impact Costs (EIC) Present Value Impact	103
5.7.7	Salvage Value	105
5.8	Best Alternatives of the Educational buildings	107
5.9	Conclusion	109

6. STOCHASTIC ANALYSIS OF LIFECYCLE COST ELEMENTS AND CASE STUDY

6.1	Introduction	111
6.2	Stochastic Analysis	111
	6.2.1 Stochastic Analysis Parameters	111
6.3	Output Results	113
	6.3.1 Effect of Initial Costs Parameter	113
	6.3.2 Effect of Running Costs Parameter	116
	6.3.3 Effect of Environmental Impact Parameter	117
	6.3.4 Effect of Salvage Value Parameter	119
6.4	Sensitivity Analysis for LCC-PV for conventional and green buildings	120
6.5	Selection of Best Alternative using the Stochastic Analysis	122
6.6	Risk Analysis and Assessment	123
6.7	Case Study	125
6.8	Conclusion	131

7. SUMMARY, CONCLUSION AND RECOMMENDATIONS FOR FUTURE STUDIES

7.1	Summary	133
7.2	Conclusions	133
7.3	Recommendations for future studies	135
References		137

List of Figures

<u>Figure No.</u>		<u>Page</u>
Figure (2.1)	Lifecycle cost elements (Dell'Isola 2003)	9
Figure (3.1)	Research Methodology for Non-green Educational Building	13
Figure (3.2)	Research Methodology for green Educational Building	13
Figure (3.3)	Cost Allocation and Elements for Typical Educational Buildings	15
Figure (3.3a)	Data collection method and resources for LCC components	16
Figure (3.4)	The best alternative selection process	17
Figure (3.5)	LCC process for Educational Building	18
Figure (3.6)	LCC process Green Educational Building	19
Figure (3.7)	Analysis Method for Lifecycle cost for Educational Buildings	23
Figure (3.8)	Regression Analysis Process, Neter, (1996)	24
Figure (3.9)	El Nasr school Layout plan - 6 Oct. - Kg school	27
Figure (3.10)	Wahat El Khair school layout plan - School 2 - 6 October- Giza	28
Figure (3.11)	El Bargirl layout plan – school 3- El Monfia	29
Figure (3.12)	International Vision layout plan- school 4 -6 October- Giza	30
Figure (3.13)	El Geal Gadid layout plan - school 5- Cairo- Nasr city	31
Figure (3.14)	Manshieyt Nasr layout plan– Primary/ Secondary schools # 6&7 - Cairo	32
Figure (4.1)	Gray water treatment plant process	42
Figure (4.2)	Cross-section of Horizontal planted greywater filter design	42
Figure (4.3)	Solar panel Geometry	46
Figure (5.1)	Research Educational buildings alternatives	49
Figure (5.2)	Analysis Process for regression model	51
Figure (5.3)	Initial Cost versus Built-up area Curve for the Conventional school	53
Figure (5.4)	Model Verification for the Regression Analysis	53
Figure (5.5)	Normal probability plot Residual analysis Model	54
Figure (5.6)	Annual Energy and water Cost histogram for the conventional alternative	57
Figure (5.7)	Annual Energy Cost versus school built-up area for the conventional alternative	57
Figure (5.8)	Annual Water Cost versus School built-up area for the conventional alternative	57
Figure (5.9)	Scatter Initial Cost regression model for certified LEED alternative.	62
Figure (5.10)	Normal probability plot Residual analysis for Certified LEED alternative	62
Figure (5.11)	Plot validation for the regression model for certified LEED alternative	63
Figure (5.12)	Scatter Initial Cost plot for regression model for silver LEED alternative	63
Figure (5.13)	Plot validation for the regression model for the silver LEED alternative	63
Figure (5.14)	Scatter Initial Cost plot regression model for the gold LEED alternative	65
Figure (5.15)	Plot validation for the regression model for the gold LEED alternative	65
Figure (5.16)	Scatter Initial Cost plot regression model for the platinum alternative	65
Figure (5.17)	Plot validation for the regression model for the platinum LEED alternative	65
Figure (5.18)	Effect of Initial Cost on Sustainability LEED certificate Level	66
Figure (5.19)	Annual Energy Cost for LEED and GPRS alternatives	69
Figure (5.20)	Annual Water Cost for the conventional and LEED alternatives	69
Figure (5.21)	Scatter Initial Cost plot regression model for the Certified GPRS alternative	74
Figure (5.22)	Plot validation for the regression model for the Certified GPRS alternative	74
Figure (5.23)	Scatter Initial Cost plot regression model for the of the bronze GPRS alternative	74
Figure (5.24)	Plot validation for the regression model for the bronze GPRS alternative	74
Figure (5.25)	Scatter Initial Cost plot regression model for the silver GPRS alternative	75
Figure (5.26)	Plot validation for the regression model for the silver GPRS alternative	75
Figure (5.27)	Scatter Initial Cost plot regression model for the gold GPRS alternative	75
Figure (5.28)	Plot validation for the regression model for the gold GPRS alternative	75
Figure (5.29)	Scatter Initial Cost plot regression model for the platinum GPRS alternative	77
Figure (5.30)	Plot validation for the regression model for the platinum GPRS alternative	77

Figure (5.31)	Effect of Initial Cost on sustainability GPRS alternatives	77
Figure (5.32)	Annual Energy Cost for the conventional and GPRS alternatives	80
Figure (5.33)	Annual Water Cost for the conventional and GPRS alternatives	80
Figure (5.34)	Analysis process for LCC cost Elements	82
Figure (5.35)	Overall LCC-PV components for conventional and LEED alternatives	91
Figure (5.36)	Overall LCC-PV components for conventional and GPRS alternatives	91
Figure (5.37)	Lifecycle cost present value for the conventional and LEED alternatives	93
Figure (5.38)	Lifecycle cost present value for the conventional and GPRS alternatives	93
Figure (5.39)	Initial costs for the conventional and LEED alternatives	96
Figure (5.40)	Initial costs for the conventional and GPRS alternatives	96
Figure (5.41)	Running cost present value for the various conventional and LEED alternatives	96
Figure (5.42)	Running cost present value for the various conventional and GPRS alternatives	96
Figure (5.43)	Running cost present value versus built-up area for conventional and LEED alternative	98
Figure (5.44)	Running cost present value versus built-up area for conventional and GPRS alternative	98
Figure (5.45)	Energy-water cost present value for the conventional and LEED alternatives	99
Figure (5.46)	Energy-water cost present value for the conventional and GPRS alternatives	99
Figure (5.47)	Energy-water cost present value versus built-up area for the conventional and LEED alternatives	102
Figure (5.48)	Energy-water cost present value versus built-up area for conventional and GPRS alternatives	102
Figure (5.49)	Environmental impact cost present value for the conventional and LEED alternatives.	103
Figure (5.50)	Environmental impact cost present value for the conventional and GPRS alternatives.	103
Figure (5.51)	Environmental impact cost versus built-up area for conventional and LEED alternatives	106
Figure (5.52)	Environmental impact cost versus built-up area for conventional and GPRS alternatives	106
Figure (5.53)	Lifecycle Present salvage cost value for the conventional and LEED alternatives	108
Figure (5.54)	Lifecycle Present salvage cost value for the conventional and GPRS alternatives	108
Figure (5.55)	Total Lifecycle NPV cost vs. the LEED levels for conventional and LEED alternatives	108
Figure (5.56)	Total Lifecycle NPV cost for conventional and GPRS alternatives	108
Figure (6.1)	initial costs probability curve for various conventional and LEED alternatives	115
Figure (6.2)	Sensitivity analysis Diagram for the running cost present value	116
Figure (6.3)	Sensitivity analysis Diagram for the Environmental Impact present value, EIC	117
Figure (6.4)	Sensitivity analysis Diagram for the salvage cost present value	119
Figure (6.5)	Sensitivity analysis Diagram for the overall lifecycle cost present value	121
Figure (6.6)	Mean Value for overall versus standard deviation for conventional and LEED alternatives	124
Figure (6.7)	Mean Value for overall running versus standard deviation for conventional and LEED alternatives	124
Figure (6.8)	Mean Value for overall versus standard deviation for conventional and GPRS alternatives	125
Figure (6.9)	Mean Value for overall running versus standard deviation for conventional and GPRS alternatives	125

List of Tables

<u>Table No.</u>		<u>Page</u>
Table (2.1)	Certification Levels for LEED and Credit Score	6
Table (2.2)	LEED Categories Corresponding and Credit Score	7
Table (2.3)	GPRS Certification Level	7
Table (2.4)	Main Categories of GPRS	8
Table (3.1)	Educational building materials used description using LEED system	14
Table (3.2)	Educational building materials used description using GPRS system	14
Table (3.3)	Educational building internal loads for spaces	20
Table (3.4)	Educational building general data parameters and Location	22
Table (4.1)	Integrated process score for conventional and LEED alternatives	34
Table (4.2)	Location and transportation elements score for conventional and LEED alternatives.	35
Table (4.3)	Sustainable sites elements score for conventional and LEED alternatives	35
Table (4.4)	Water efficiency score for conventional and LEED alternative	36
Table (4.5)	LEED category score for the conventional and the green LEED alternatives	37
Table (4.6)	Material and score for conventional and LEED alternatives	38
Table (4.7)	Indoor environmental quality category score for conventional and LEED alternatives	38
Table (4.8)	innovation in Design score for conventional and LEED alternatives	39
Table (4.9)	Sustainable sites category score for conventional and GPRS alternatives	40
Table (4.10)	Energy efficiency score for conventional and GPRS alternatives	40
Table (4.11)	Water efficiency score for conventional and GPRS alternatives	41
Table (4.12)	Material and resources score for conventional and GPRS alternatives	42
Table (4.13)	Indoor Environmental Quality score for conventional and GPRS alternatives	42
Table (4.14)	Management Protocols score for conventional and GPRS alternatives	43
Table (4.15)	Innovation and added value score for conventional and GPRS alternatives	43
Table (4.16)	Monthly water consumption for LEED alternatives	45
Table (4.17)	Greywater treatment plant capacity and costs	45
Table (4.18)	Annual water consumption for conventional and GPRS alternatives	45
Table (4.19)	Monthly Electrical consumption for LEED alternatives	46
Table (4.20)	Solar Energy panels capacity and cost for gold and platinum alternatives	46
Table (4.21)	Annual energy consumption for GPRS educational buildings alternatives	47
Table (5.1)	Educational buildings Location, Area & Built-up area	50
Table (5.2)	Construction Costs for used Conventional Educational Buildings	50
Table (5.3)	Regression Model analysis parameters	52
Table (5.4)	Standard parameter of the model	52
Table (5.5)	Residual errors of the regression model	52
Table (5.6)	Annual electricity consumption rates for the conventional educational alternatives	55
Table (5.7)	Monthly and annual Energy cost for the conventional educational alternatives	55
Table (5.8)	Annual water costs for the Conventional educational alternatives	56
Table (5.9)	Annual major repair costs for a conventional school alternative	58
Table (5.10)	Annual operation and maintenance costs for a conventional school alternative	59
Table (5.11)	Annual environmental impact cost for a conventional school building	59
Table (5.12)	Standard parameter of the model for certified LEED alternative	61
Table (5.13)	Residual errors of the regression model for certified LEED alternative	61
Table (5.14)	Standard parameter of the model for silver LEED school buildings	61
Table (5.15)	Residual errors of the regression model for silver LEED school buildings	61
Table (5.16)	Standard parameter of the model for gold LEED school building	64
Table (5.17)	Residual errors of the regression model for gold LEED school alternative	64
Table (5.18)	Standard parameter of the model for platinum LEED school alternative	64
Table (5.19)	Residual errors of the regression model for platinum LEED alternative	64
Table (5.20)	Annual energy consumption for different LEED alternatives	67