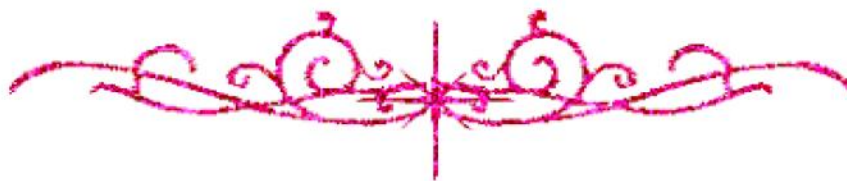


بسم الله الرحمن الرحيم





شبكة المعلومات الجامعية التوثيق الالكتروني والميكرو فيلم



جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

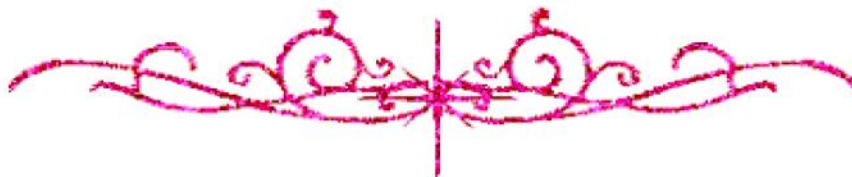
قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار





بعض الوثائق الأصلية تالفة





بالرسالة صفحات
لم ترد بالأصل





Cairo University

**DEVELOPING A RETROFITS' APPLICATION
VARIABLES MODEL (RAVM)
AS A DECISION- MAKING TOOL FOR ENVELOPE
RETROFITS APPLIED TO EXISTING OFFICE
BUILDINGS IN CAIRO/EGYPT**

By

Shereen Omar Mohamed Galal Khashaba

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

**In
Architectural Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

**DEVELOPING A RETROFITS' APPLICATION
VARAIBLES MODEL (RAVM)
AS A DECISION- MAKING TOOL FOR ENVELOPE
RETROFITS APPLIED TO EXISTING OFFICE
BUILDINGS IN CAIRO/EGYPT**

By

Shereen Omar Mohamed Galal Khashaba

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Architectural Engineering

Under the Supervision of
Prof. Dr. M. Moemen Afify

.....
Professor of Architecture
Department of Architecture
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

**DEVELOPING A RETROFITS' APPLICATION
VARAIBLES MODEL (RAVM)
AS A DECISION- MAKING TOOL FOR ENVELOPE
RETROFITS APPLIED TO EXISTING OFFICE
BUILDINGS IN CAIRO/EGYPT**

By

Shereen Omar Mohamed Galal Khashaba

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Architectural Engineering

Approved by the
Examining Committee

Prof. Dr. M. Moemen Afify

Thesis Main Advisor

Prof. Dr. Ayman Hassan Mahmoud

Internal Examiner

Prof. Dr. Yasser Mansour,

Professor of Architecture, Faculty of Engineering, Ain Shams University.

External Examiner

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

Engineer's Name: Shereen Omar Mohamed Galal
Date of Birth: 01/10/1987
Nationality: Egyptian
E-mail: Shereen_omar@cic-cairo.com
Phone: 01062199125
Address: 40 Al-Mekkias st. – Manial El-Roawda
Registration Date: 01/10/2014
Awarding Date:/....../2020
Degree: Doctor of Philosophy
Department: Architectural Engineering



Supervisors:

Prof. Dr. M. Moemen Afify

Examiners:

Prof. Dr. Yasser M. Mansour (External examiner)
Faculty of Engineering – Ain-Shams university
Prof. Dr. Ayman Hassan Mahmoud (Internal examiner)
Prof. Dr. M. Moemen Afify (Thesis main advisor)

Title of Thesis:

**DEVELOPING A RETROFITS' APPLICATION VARIABLES MODEL
(RAVM) AS A DECISION- MAKING TOOL FOR ENVELOPE
RETROFITS APPLIED TO EXISTING OFFICE BUILDINGS
IN CAIRO/EGYPT**

Key Words:

Office buildings, External envelope, Decision-making, Retrofit variables,
Cairo/Egypt.

Summary:

The building envelope has tangible impacts on energy consumption; thus, it is the most effective building layer to apply green retrofits. The decision-making process of selecting retrofit measures to apply is complex, it involves many objectives that are quantifiable and others that can't be quantified. Retrofit analysis simulation tools can be used to identify some of these objectives like energy savings, but they are not enough to rely on; because there are other variables like the availability of the retrofits in the Egyptian market, and the installation process difficulty/duration which are not identified. Thus, the research aims to improve the energy efficiency in office buildings constructed in Egypt by applying retrofit measures to the existing building's envelope; By developing an optimized decision-making model for retrofits application in the Egyptian market based on a mathematical framework to support decision makers' selection according to their objectives. Then applying this model to two case studies representing the majority of office buildings in Cairo, to investigate its applicability and compare its results with the simulation tools'.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Shereen Omar Mohamed Galal Khashaba

Date:

Signature:

Dedication

I would like to dedicate this thesis to my family. A special feeling of gratitude to my loving mother and sister.

I also would like to dedicate this thesis to my father's Soul — who is always in my heart.

And special dedication to Saleem Mohamed Farahat, my nephew new family member, Mohamed Farahat and Asmaa Farahat.

Acknowledgments

Firstly, I sincerely thank God for being able to complete my thesis. I would like to express my sincere gratitude to my thesis director and supervisor, ***Prof. Dr. Mohamed Moemen Afify*** for all the guidance, support, and encouragement he gave me throughout the process of writing this thesis, publishing and during the years of study.

I also wish to thank Dr. AlMoataz-Bellah Gamal, Dr. Amr El-Gohary, Dr. Matreen Mohamed, Dr. Asmaa Farahat, Eng. Mohamed Farahat, Arch. Mohamed Yasser Arafat, and Eng. Ahmed Geneid for their effective support.

Special thanks to Dr. Heba Hassan Professor of Architecture in Beni-Suef university for her effective help, support, and valuable information. Special thanks to Dr. Mahmoud Abd-ElRazik for his guidance in the simulation process using the design builder tool.

Last but not least, I would like to thank my family, especially my mother and sister for supporting me throughout my life. Special thanks to my dearest friend Dr. Noha Fathy El-Gamal for supporting me in all ways, Dr. Nihal Abd El-Gawwad, and Dr. Yasmeen El-Semary for their encouragement, and all my colleagues.

Table of Contents

DISCLAIMER	I
DEDICATION	II
ACKNOWLEDGMENTS	III
TABLE OF CONTENTS	IV
LIST OF TABLES	VII
LIST OF FIGURES	IX
NOMENCLATURE	XII
ABSTRACT	XIII
CHAPTER (1): INTRODUCTION AND REVIEW OF LITERATURE	
1	INTRODUCTION 1
1.1	THE RESEARCH PROBLEM 2
1.2	RESEARCH QUESTIONS 4
1.3	THE RESEARCH OBJECTIVES 5
1.3.1	Environmental objectives: 5
1.3.2	Economic objectives: 5
1.3.3	Social objectives: 5
1.3.4	Technical objectives: 5
1.4	THE RESEARCH HYPOTHESIS 6
1.5	THE RESEARCH SCOPE 6
1.6	RESEARCH SIGNIFICANCE 7
1.7	THE RESEARCH METHODOLOGY 7
CHAPTER (2): OFFICE BUILDINGS IN CAIRO	
2	INTRODUCTION 10
2.1	OFFICE BUILDING 11
2.2	HISTORICAL BACKGROUND ON OFFICE BUILDINGS IN CAIRO 11
2.3	OFFICE BUILDINGS IN CAIRO FROM 1976 TO 1986 13
2.4	OFFICE BUILDINGS IN CAIRO FROM 1986-PRESENT 14
2.5	OFFICE (ADMINISTRATIVE) BUILDINGS IN CAIRO SAMPLES 18
2.6	THE DEVELOPMENT OF OFFICE BUILDINGS DESIGN IN CAIRO 30
2.7	THE DEVELOPMENT OF OFFICE BUILDINGS ENVELOPE DESIGN IN CAIRO 31
2.8	SUMMARY 32
CHAPTER (3): BUILDINGS ENVELOPE GREEN RETROFITS	
3	INTRODUCTION 33
3.1	BUILDING ENVELOPE 34
3.2	BUILDING ENVELOPE COMPONENTS 35
3.3	EXISTING BUILDINGS GREEN RETROFITS 37
3.4	BUILDING ENVELOPE GREEN RETROFITS 39
3.4.1	Opaque Elements of Building Envelope 39
3.4.2	Fenestration Elements of Building Envelope “glass” 44
3.5	BENEFITS OF GREEN RETROFITS 50
3.5.1	Benefits directly to the building owner 50
3.5.2	Benefits directly to the tenants 51
3.5.3	Benefits directly to the investors 51
3.5.4	Benefits directly to the contractors 52
3.6	BARRIERS TO GREEN RETROFITS 52

3.6.1	High initial cost	52
3.6.2	Lack of awareness	53
3.6.3	Split benefits	53
3.6.4	Risk and uncertainty	53
3.6.5	Lack of experienced workforce	53
3.6.6	Lack of product information	53
3.6.7	Availability of products or technologies	53
3.6.8	Lack of coordination in government policies affecting buildings	54
3.6.9	Lack of research investments	54
3.6.10	Organizational dynamics	54
3.7	SUMMARY	56
CHAPTER (4): AIDING SIMULATION TOOLS AND DECISION ANALYSIS METHODS		
4	INTRODUCTION	57
4.1	BUILDING ENERGY SIMULATION TOOLS	59
4.2	SIMULATION TOOLS SELECTION	61
4.3	DECISION ANALYSIS METHODS	68
4.3.1	Value engineering method	68
4.3.2	Decision matrix approach	69
4.3.3	Decision tree approach	69
4.3.4	Influence diagram approach	70
4.3.5	Analytic Hierarchy Process (AHP)	70
4.3.6	Objective hierarchy approach	72
4.3.7	Alternatives focused thinking (AFT)	72
4.3.8	Value Function Method	73
4.4	SUMMARY	77
CHAPTER (5): RETROFIT APPLICATION VARIABLES MODEL (RAVM) DEVELOPMENT		
5	INTRODUCTION	80
5.1	ON-LINE SURVEY TO DETERMINE THE MAIN VARIABLES OF RETROFITS	80
5.1.1	Survey Population of Concern	81
5.1.2	Sampling Method	81
5.1.3	Survey Results	81
5.2	(RAVM) DEVELOPMENT	82
5.2.1	Identifying the decision	82
5.2.2	Create objectives and variables tree hierarchy	83
5.2.3	Obtain Evaluation Measures	85
5.2.4	Saving rate	85
5.2.5	Develop a SDVF Applying the Direct Rating Approach	89
5.2.6	Assign Weight to the Value Hierarchy	95
5.2.7	Additive Value Function (AVF)	97
5.2.8	The Variables Value Indicator Matrix (VVIM)	98
5.2.9	Final RAVM	98
5.2.10	RAVM Limitations	100
5.3	SUMMARY	100
CHAPTER (6): RETROFIT APPLICATION VARIABLES MODEL (RAVM) APPLICATION		
6	INTRODUCTION	101
6.1	BASICS FOR CASE STUDY SELECTION AND ANALYSIS	102
6.2	RETROFIT ALTERNATIVES	103

6.3	CASE STUDY [1] - NILE (GIZAH) TOWER OFFICE BUILDING	105
6.3.1	Apply direct rating value functions of variables to the alternatives	107
6.3.2	VVIM of the retrofit alternatives applied to the Nile Tower	118
6.4	CASE STUDY [2] - 238 OFFICE BUILDING	121
6.4.1	Apply direct rating value functions of variables to the alternatives	122
6.5	SUMMARY	136
CHAPTER (7): CONCLUSIONS AND RECOMMENDATIONS		
7	DISCUSSIONS, CONCLUSIONS AND FINDINGS	138
7.1	NOTIFICATIONS ABOUT THE [RAVM] MODEL	141
7.2	ADVANTAGES OF [RAVM]	143
7.3	DISADVANTAGES OF [RAVM]	143
7.4	LIMITATIONS OF [RAVM]	143
7.5	THE RAVM SIGNIFICANCE	144
7.6	RAVM PROCESSING AND RESULTS IN MATLAB	144
7.7	FUTURE STUDIES	144
7.8	RECOMMENDATIONS	145
REFERENCES		
8	REFERENCES	147
APPENDICES		
A.	BUILDINGS' RETROFIT ANALYSIS SIMULATION TOOLS REVIEW	153
B.	ON-LINE SURVEY	164
C.	SURVEY RESULTS	166
D.	LIFE SPAN OF DIFFERENT MATERIALS USED IN THE OFFICE BUILDING EXTERNAL ENVELOPE	169
E.	SPREAD SHEET OF SAVING RATE CALCULATION FOR DIFFERENT ALTERNATIVES	171
F.	"MATLAB" PROGRAM PROCESSING AND VISUALIZATION FOR THE RAVM MODEL	175