المستخلص

يعد توفير السكن لذوى الدخل المحدود أحد التحديات الرئيسية التي تواجه الحكومات في البلدان النامية، بما فيها دولة السودان. ويمكن أن تعزى مشكلة الإسكان الحادة في السودان إلى عدد من المشاكل منها الافتقار إلى التمويل ونقص مواد البناء، ونقص القوى العاملة ذات الخبرة، ومحدودية تكنولوجيا البناء ومدى استيعابها، وسوء وسائل النقل وغيرها من المشاكل.

وتهدف الدراسة إلى دراسة إمكانية إستخدام تكنولوجيا البناء الصناعية كحل بديل لحل مشكلة مساكن ذو الدخل المنخفض السودان.حيث تتألف المنهجية من خلفية نظرية (استعراض البيانات - المؤلفات) والمقابلات، ودراسة الحالة، واستبيانات الدراسات الاستقصائية، والتحليل والتقييم. وأخيراً، تم إستخدم إستبيانات الدراسة الاستقصائية في تطبيق المصفوفة المطورة من خلال تقييم أداء أنظمة البناء التقليدية والصناعية، وفقاً لكل عامل من عوامل المعايير المحددة. وتم تحليل البيانات كماً ونوعاً لتحديد جدوى أي من نظامي البناء لإسكان الفقراء في السودان. وتتألف الدراسات الاستقصائية على ثلاثة جوانب، وهي: تطوير إطار التحليل، وصياغة وإجراء/إصدار المقابلات والاستبيانات. مصفوفة الجدوى المقارنة للمعايير المتعددة (MCCFM) هي أداة التحليل المعتمدة للتحليل والمقارن بين نظامي البناء التقليدى والصناعى ويعتمد المسح الميدانى علي أداة التحليل MCCFM، حيث تضيف المقابلات جانبا من جوانب الأهمية وتوفر الاستبيانات جانبا من جوانب الأداء. والدراسات الاستقصائية هامة إذ يجب تحليل العوامل من خلال أدائها لأي من نظامي البناء.

ويتألف هدف تحليل البيانات علي ثلاثة جوانب، والهدف من تحليل البيانات هو: تطبيق إطار التحليل، رسماً بيانياً للنتائج والتعليق والتحليل على النتائج. ويتطلب تطبيق إطار التحليل معالجة البيانات التي تم الحصول عليها من المقابلات والاستبيانات وتطبيق هذه البيانات في أداة التحليل MCCFM بحيث تستمد قيمة نهائية تعكس قيمة الجدوى. وكما هو واضح، تعكس المقابلات الأهمية في حين تعكس الاستبيانات الأداء. تتم معالجة البيانات الأولية التي يتم جمعها من المقابلات عن طريق تحويل البيانات إلى معايير تناسبية، ثم ضرب القيم في مقابل متوسطات فئة العامل الأساسي المعنية ثم ضربها مرة أخرى مقابل قيمة العامل الأساسي. وMCCFM يضاعف قيم الأهمية مع قيم الأداء; ويتم ذلك لكل عامل من عوامل المعايير ولكل نظام بناء على التوالي. وهدف تحليل البيانات يتكون من ثلاثة جوانب هي تطبيق إطار التحليل، ورسم بياني للنتائج والتعليقات والتحليلات على النتائج. تطبيق إطار التحليل يستلزم معالجة البيانات التي تم الحصول عليها من المقابلات والاستبيانات وتطبيق هذه البيانات في أداة تحليل MCCFM بحيث تستمد قيمة نهائية تعكس قيمة الجدوى، وتظهر النتيجة درجة لكل عامل لكل نظام بناء. ويتم ذلك لكل من المصفوفات الثلاثة (الحكومة والمقاول والمستخدم النهائي). وتعكس النتيجة قيمة كل نظام بناء مع المعايير ذات الصلة. يتم تجميع هذه الدرجات معاً للحصول على نقاط نهائية لكل مجموعة من المصفوفات الثلاثة، ثم يتم جمع هذه الدرجات معاً لاستنباط نتيجة نهائية للدراسة بأكملها. ويعتبر نظام البناء ذو الأعلى درجة الخيار الأفضل.

وتوصي الدراسة بأن تعتمد الحكومة تكنولوجيا البناء الصناعي كحل فعال وبديل لإسكان الفقراء في السودان. كما تهدف الدراسة إلى دعم المبادرات الحكومية لإيواء الفقراء في السودان. إن العمل البحثي المقدم في هذه الدراسة حقيقي ولم يسبق له مثيل في السودان، ونتائج الدراسة قابلة للنقاش إلى حد كبير بسبب أهميتها، وأهميتها لأهداف الإسكان المدعوم من الحكومة، وآثارها الفعالة على المبادرة، وأدائها للإسكان لذوي الدخل المنخفض في السودان.

الكلمات الرئيسية: الإسكان الاجتماعي، نظام البناء التقليدي، نظام البناء الصناعي، الأدوات التحليلية، التنمية المستدامة.

Abstract

Housing provision for the poor is one of the major challenges facing governments in developing countries including Sudan. The acute housing problem in Sudan can be due to a number of limitations including lack of finance, shortages of processed building materials, lack of experienced labor force, limited construction technologies, and poor transportation means.

The aim of this research is to investigate the potential of industrialized building technology for low-cost housing provision in Sudan. The methodology consists of a theoretical background (2nd hand data - literature review) and 1st hand data (interviews, case study, and survey questionnaires); analysis, and evaluation. Finally, a survey questionnaire is used to apply the developed matrix through rating the performance of conventional and industrialised building systems according to each factor of the identified criteria. Data will be analysed quantitatively and qualitatively to identify the feasibility of either building system for housing the poor in Sudan.

The study surveys are comprised of three aspects; developing the analysis framework, formulating and conducting/issuing, both the interviews and the questionnaires. The Multi-Criteria Comparative Feasibility Matrix (MCCFM) is the analysis tool adopted for comparative analysis between the two building systems. The survey is based on the MCCFM tool as the interviews add an aspect of importance and the questionnaires provide an aspect of performance. The survey is important as the factors must be analysed through the performance of either building system.

The Data analysis objective is comprised of three aspects, thus; applying the analysis framework, graphing the results, and commentary, and analysis on the results. Applying the analysis framework entails the processing of the data obtained from the interviews and questionnaires and applying such data into the MCCFM analysis tool so that it derives a final value that reflects the value of the feasibility. The MCCFM multiplies the values of importance with the values of performance; this is done for each factor of the criteria and for each building system respectively.

The conclusions score for each respective factor of each building system. This is done for each of the three matrices (government, contractor, and end-user). The score reflects the value of each building system with the respective criteria. These scores are summed up together to derive a final score for each perspective group, then those scores are summed together to derive a final score for the whole study. The building system with the highest score is deemed the best option.

The study recommends that the government adopt industrial building technology as an effective and alternative solution for housing the poor in Sudan. The study also aims to support government initiatives to house the poor in Sudan .The research work presented in this study is real and has never been done before in Sudan. The results of the study are highly debatable because of its importance, its importance to government-subsidized housing objectives, its effective effects on the initiative, and its performance for low-income housing in Sudan.

Keywords: Social housing, Conventional construction system, industrial construction system, analytical tools, sustainable development.

Acknowledgement

First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

In my journey towards this degree, I have found a teacher, a friend, an inspiration, a role model and a pillar of support in my Guide, my supervisors **Prof. Dr. Awad. H. Saad** the vice manager of Sudan University of Science and Technology. He has been there providing his heartfelt support and guidance, inspiration and suggestions in my quest for knowledge. He has given me all the freedom to pursue my research, while silently and non-obtrusively ensuring that I stay on course and do not deviate from the core of my research. Without his valuable guidance, this thesis would not have been possible and I shall eternally be grateful to him for his assistance.

I would like to thank a number of people who have contributed to the final result of my study in many different ways. Special thanks are due to **Dr. Khadiga M. Osman**, who provided exceptional support and guidance. Also, I convey special thanks to **Dr. Mohammed Mahdi**, for his abundantly helpful and offered invaluable assistance, support and guidance throughout this dissertation. Also, I wish to express my deepest gratitude to my colleagues at the Technology Science University College of Architecture and Spatial Planning for the all the information they provided.

It would be inappropriate if I omit to mention the names of my dear friends Isam Hassan, Ahamed Altayeb Hassan, Ayman Hamed, and Hisham Ali who have, in their own ways, kept me going on my path to success, assisting me as per their abilities, in whatever manner possible and for ensuring that good times keep flowing. I would like also to express gratitude to all my colleagues in and out of the Sudan for their enormous help in collecting the surveys and their participation in the questionnaires and their support.

My deepest love and gratitude to my family, my parents, brothers, my wife, and my lovely daughter Lujain and Layan for inseparable support, encouragement, unwavering faith and endless love, through the entire period of my study.

Finally, completing a PhD is of course a long journey throughout a battlefield, and I would not have been able to come to its end without the support and assistance of many people. I am attempting to convey my appreciation for those people who directly or indirectly contributed to the completion of my dissertation, and I am apology for not mentioning them personally one by one.

Dedication

To all those who I love, and to all those who are looking for better future, I dedicate this work.

With my love.

Omer

Table of contents

Contents			Page No.
Abstract (Arabic)			i
Abstract (English)			ii
Acknowledgement			iii
Dedication			iv
Table of Contents			v
List of Figures			x
List of Tables			xi
Chapter 1		**General Introduction**	1
1	1.1	Introduction	1
	1.2	Background	1
	1.3	Research Aim and Objectives	2
	1.4	Research Motivation and Rationale	3
	1.5	Problem Statement	3
	1.6	Research Question	4
	1.7	Research Hypothesis	4
	1.8	Research Methodology	5
	1.9	Research Originality and Achievements	9
	1.10	Guide to the Dissertation	10
Chapter 2		**Housing Situation in Sudan**	13
2.1	Introduction		13
2.2	General Background		13
2.3	Sudan Situation		14
	2.3.1	Population and Urbanization in the Sudan	16
	2.3.2	Sudan Civil Wars and Conflicts	18
	2.3.3	War Effects	18
	2.3.4	The Housing Situation in Sudan	19
2.4	Khartoum State Situation		24
	2.4.1	Khartoum State Urban Housing policies	25
	2.4.2	The impact of migrations on the state of Khartoum	27
	2.4.3	The stages of housing development in Khartoum State	27
	2.4.4	Low-cost public housing in Khartoum	28

	2.4.5	Housing and construction Fund - Khartoum State	29
	2.4.6	Housing and Construction Fund Methodology	30
	2.4.7	Financing of housing and reconstruction fund projects	31
	2.4.8	The lack of housing for the poor in the Khartoum state (1993-2017)	31
2.5	Summary		32
Chapter 3		**Building System for Low-Cost Housing in Sudan**	33
3.1	Introduction		33
3.2	Building Materials and Technologies for Housing in Sudan		33
3.3	Materials and Construction Techniques for Housing in The Sudan		43
3.4	The building systems in Sudan		44
3.5	Structural building system		45
	3.5.1	Conventional Construction Method	45
	3.5.2	Cast in-situ building systems	47
	3.5.3	prefabricated building systems	47
	3.5.4	The composite construction method	48
3.6	Summary		48
Chapter 4		**Industrialised Building Systems**	49
4.1	Background history of IBS		49
4.2	Application of IBS		51
4.3	Typical Classification of IBS		52
	4.3.1	The Frame System	54
	4.3.2	Panel System	54
	4.3.3	Box System	56
4.4	Benefits of IBS Component		57
	4.4.1	Cleaner and Safer Construction Site	57
	4.4.2	Faster Construction	57
	4.4.3	Greater Un-Obstructed Span	58
	4.4.4	Lower Total Construction Costs of Ownership	58
	4.4.5	Modular Coordination	58
	4.4.6	Just-In-Time Philosophy	60
4.5	Sequence of Construction for IBS Method		63
4.6	The Selection of an Industrialised System		65

4.7	Sustainable Development:		65
	4.7.1	Environmental Sustainability	69
	4.7.2	Social Sustainability	70
	4.7.3	Economic Sustainability	70
4.8	Comparison between IBS & CBS		71
	4.8.1	Costs	72
	4.8.2	Material Price Hikes	75
	4.8.3	Rapid Production and Onsite periods	75
	4.8.4	Weather problems	75
	4.8.5	Modular and Standardisation:	75
	4.8.6	Lean Construction	76
	4.8.7	Stigma	76
	4.8.8	Re-sell Value	76
4.9	Overview of characteristics:		77
4.10	Classification for Types of IBS Used in Sudan		78
4.11	Obstructions to the Implementation of IBS in Sudan		78
4.12	Summary		80
Chapter 5		**Method Applied**	81
5.1	Introduction		81
5.2	The sources of the criteria identification		82
5.3	Questionnaires		86
	5.3.1	Purpose and Objectives of Questionnaires	86
	5.3.2	Reasoning for Questionnaires	87
	5.3.3	Design of Questionnaire	87
	5.3.4	Questionnaire Structure	89
	5.3.5	Pretesting the Questionnaire	92
5.4	Interviews		93
	5.4.1	Purpose and Objectives of the Interviews	93
	5.4.2	Reasoning for Interviews	94
	5.4.3	Selecting the Interview Sample	94
5.5	The results of the questionnaires		94
5.6	Development of the MCCFM Analysis Frameworks		95
	5.6.1	Mechanism of the MCCFM Analysis Tool	98
	5.6.2	The Analysis of the MCCFM	101
5.7	Summary		103
Chapter 6		**Analytical Framework, Process and Results**	105

6.1	Introduction		105
6.2	Response Rate		105
6.3	The Profile of Respondents		106
6.4	Methods of Analysis		107
6.5	Interviews Analysis		107
	6.5.1	Analysis of Government Interviews	107
	6.5.2	Analysis of Contractor Interviews	109
	6.5.3	Analysis of End-User Interviews	112
6.6	Questionnaires Analysis		114
	6.6.1	Analysis of Government Questionnaires	114
	6.6.2	Analysis of Contractors Questionnaires	117
	6.6.3	Analysis of End-User Questionnaires	122
6.7	MCCFM An6lysis		125
	6.7.1	Analysis of Government MCCFM	125
	6.7.2	Analysis of Contractors MCCFM	130
	6.7.3	Analysis of End-User MCCFM	136
6.8	Conclusions from Questionnaires and Interviews		141
6.9	MCCFM Result		144
6.10	Summary		147
Chapter 7		**Conclusions and Recommendations**	149
7.1	Conclusions		149
7.2	Research Process Conclusion		149
7.3	Research Findings		152
7.4	The Value to Industry		153
7.5	Recommendations		154
	7.5.1	Research Recommendations	154
	7.5.2	Other Research Recommendations	155
	7.5.3	Recommendations for Further Research	156
References			157
Appendixes			176
	Appendix 1	Total Population (Thousands) 1950-2050	176
	Appendix 2	Population Distribution by Main Geographical Areas	176
	Appendix 3	Population Distribution by Region of Origin (Former 9 Regions)	177
	Appendix 4	Population Distribution by State of Enumeration	178

Appendix 5	Ranking of States Size by Population	179
Appendix 6	Population in The Sudan By Type 1956, 1973, 1983 And 1993	179
Appendix 7	Urban Population in The Sudan By Region 1956, 1973 And 1983	180
Appendix 8	Size of Urban Centers in The Sudan For Years 1956, 1973, 1983, 1993 And 2008	180
Appendix 9	Population of The City of Khartoum 1950-2050	181
Appendix 10	Numbers of IDPs Received by Different States	181
Appendix 11	The Questionnaire	181
Appendix 12	The Interview Form	187
Appendix 13	The Questionnaire Table	190
Appendix 14	Analysis of Interviews Responses	191
Appendix 15	Analysis of Survey Questionnaires Responses	192
Appendix 16	MCCFM Summary Matrix	193

List of Figure

Figure No.	Title	Page No.
Figure 1.1	Research Methodology Diagram	**8**
Figure 2.1	Map of The Sudan	**15**
Figure 2.2	Total, Urban and Rural Population of The Sudan 1950-2050	**18**
Figure 2.3	The Sources of Housing Finance	**30**
Figure 3.1	Examples of Roofing Materials and Technologies Applied for Housing in The Sudan.	**39**
Figure 3.2	Structural Building System	**45**
Figure 3.3	Sequence Activities of Conventional Construction Method	**47**
Figure 4.1	Classifications of Industrialised Building Systems (IBS).	**53**
Figure 4.2	Industrial Hall Using Steel Frame System	**55**
Figure 4.3	Arrangement of Box Units into Position Onsite	**56**
Figure 4.4	Principle of Just in Time	**62**
Figure 4.5	Sequence of Activities for IBS Construction Method	**64**
Figure 4.6	Sustainable Development Themes	**68**
Figure 5.1	MCCFM Weighting	**100**
Figure 6.1	Interview Government	**108**
Figure 6.2	Interview Contractor	**110**
Figure 6.3	Interview End-User	**113**
Figure 6.4	Questionnaire Government	**115**
Figure 6.5	Questionnaire Contractor	**118**
Figure 6.6	Questionnaire End-User	**123**
Figure 6.7	MCCFM Government	**128**
Figure 6.8	MCCFM Contractor	**132**
Figure 6.9	MCCFM End-User	**138**
Figure 6.10	MCCFM Final Result	**145**

List of Tables

Table No.	Title	Page No.
Table 2.1	Censuses Population Sizes, Modes of Living and Annual Rates of Growth	**24**
Table 2.2	The Number of Units Implemented During the Different Stages of The Housing Units	**29**
Table 2.3	Illustrates the Efforts of The Khartoum State	**29**
Table 3.1.	Classes Are Distinguished by Specified Criteria, Namely Income Level of Its Residents, Plot Sizes, Service and Construction Standards.	**34**
Table 3.2	Building Materials for Different Residential Areas Classes	**35**
Table 3.3	Walling Materials Used in Different States for Towns with Population Over 20,000 In 1973	**42**
Table 3.4	Roofing Materials Used in Different States for Towns with Population Over 20,000 In 1973	**42**
Table 4.1	Building System Classification According to Structural System.	**54**
Table 4.2	Precast Vs Traditional (Monsted And Percinel, 1982)	**74**
Table 4.3	IBS –CBS Comparison Comparing Industrialised Building System with Conventional System	**77**
Table 5.1	Criteria Identification	**85**
Table 5.2	MCCFM Example	**99**
Table 6.1	Response Rate	**107**
Table 6.2	Interview Government	**108**
Table 6.3	Interviews Contractor	**110**
Table 6.4	Interviews End-User	**112**
Table 6.5	Government Questionnaire	**114**
Table 6.6	Questionnaires Contractor	**118**
Table 6.7	Questionnaires End-User	**123**
Table 6.8	MCCFM Government	**128**
Table 6.9	MCCFM Contractor	**132**
Table 6.10	MCCFM End-User	**138**
Table 6.11	Important Factors with Performance Rating	**142**
Table 6.12	MCCFM Final Result	**144**