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**IMPROVING ARCHITECTURAL PANEL
PROGRAMMING FOR INCREASING USER
SATISFACTION IN INDUSTRIALIZED HOUSING
IN MALAYSIA**

BY

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**A thesis submitted in fulfilment of the requirement
for the degree of Doctor of Philosophy
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ABSTRACT

The aim of this research is to investigate using both quantitative and qualitative methods, how adaptability are acquired and what factors are important to programme the architectural panel in order to enhance adaptability of industrialized housing in Malaysia. The previous studies show the gap between design standard and user's need for industrialized housing in Malaysia is still exists. The problems identified are related to the architectural design and its adaptability as well as modification over the life-cycle of the house. Thus the research focuses on the concept of support and infill to increase design quality and users' satisfaction in the house. Adaptability in a broader sense includes innovative participatory process for a better means of personalization of the home. However, renovation and extension works are currently limited in industrialized housing. The preliminary study shows that the adaptable design depends on the varying factors such as form and function of architectural panel and attitude of the users. The method used in this study was based on the assumption that the degree of quality of industrialized housing in Malaysia could be improved by architectural programming towards adaptability as Japan had done in their experimental housing of NEXT21 in Osaka. Therefore, the case study on adaptability was carried out at Japan to identify the criteria of adaptability to be applied into industrialized housing in Malaysia. Consequently, the case study on industrialized housing was carried out in Malaysia to identify the Performance Index of Satisfaction (PIS) of the users. Data for case study were retrieved from a review of documents as well as information of the projects, questionnaires survey, and observation. Nowadays in Malaysia, there are many building systems which providing a large variety of architectural precast panel component. The findings confirmed that the architectural panel could contribute for the improvement of adaptability by formulating Architectural Programming. The programming is supports by Adaptability Model from quantitative analysis (user's satisfaction for internal spaces), and qualitative analysis (form and function of architectural panel) of that space. Finally, the innovative solution of programming for architectural panel in industrialized housing and other recommendations for architects regarding adaptability complete the thesis.

ملخص البحث

يرمي هذا البحث إلى اختبار كيفية اكتساب القدرة على التكيف، ومعرفة أهم العوامل لبرمجة هيئة الصناعة المعمارية؛ من أجل تعزيز التكيف مع السكن في المنازل المصنعة في ماليزيا، وذلك باستخدام منهجي الاختبار الكمي والنوعي. وقد ظلت الدراسات السابقة تشير إلى أن هناك فجوة بين مستوى التصميم وحاجة المستخدم للمنازل المصنعة في ماليزيا. وكانت المشكلات التي برزت ذات علاقة بالتصميم المعماري والعملية التكيفية، بالإضافة إلى التعديلات على مدى الدورة الحياتية للمنازل. ويركز هذا البحث على مفهوم الدعم إلى جانب البناء في الفسحة بين المنازل لرفع درجة نوعية التصميم المعماري إرضاءً لمستخدمي هذه المنازل. ويتضمن المعنى الواسع للقدرة على التكيف تحديث عملية المشاركة وصولاً إلى أفضل الوسائل لتحقيق الخصوصية للسكان في البيت. ومع ذلك صارت عملية التحديث وتوسيع الأعمال في هذا المجال تجري على نحو محدود. وقد أبرزت الدراسات الأولية أن التصميم القابل للتكيف يعتمد على عوامل متعددة مثل شكل ووظيفة الهيئة المعمارية، واتجاهات مستخدمي هذه المنازل. ويقوم منهج الدراسة الحالية على افتراض أن درجة نوعية المنازل المصنعة في ماليزيا يمكن تحسينها اعتماداً على البرمجة المعمارية الموجهة نحو التكيفية كما قامت بها اليابان في إسكانها التجريبي (NEXT 21) في أوساكا. ولهذا فقد أجريت دراسة حالة في اليابان حول التكيف للتعرف على معايير القدرة على التكيف لتطبيقها في سكن المنازل المصنعة في ماليزيا. وبناء على ذلك، فقد أجريت أيضاً في ماليزيا دراسة حالة حول السكن في المنازل المصنعة لتحديد مؤشر أداء رضا مستخدمي المنازل. وقد تم استرجاع بيانات دراسة الحالة من مراجعة الوثائق والمستندات، ومن معلومات المشروعات، ومن استبيانات المسح الميداني ثم الملاحظات. توجد في ماليزيا اليوم كثير من أنظمة معمارية يمكن أن تكون مصدراً لمجموعة كبيرة ومتنوعة من المكونات المعمارية. وقد أكدت النتائج أن الهيئة المعمارية يمكن أن تساهم في ترقية العملية التكيفية أي القدرة على التكيف من خلال صياغة برمجة معمارية، وهذه البرمجة تدعمها نموذج القدرة على التكيف من التحليل الكمي (رضا المستخدمين للمساحة الداخلية)، وكذلك من التحليل الكيفي (شكل والوظيفة المعمارية) لتلك المساحة. وأخيراً، فإنه بالحل المبتكر للبرمجة المعمارية في سكن المنازل المصنعة، وغيرها من التوصيات للمهندسين المعماريين حول القدرة على التكيف يكتمل البحث الحالي.

ABSTRAK

Matlamat kajian ini adalah menyiasat secara menggunakan kaedah kuantitatif dan kualitatif, bagaimanakah dan apakah faktor-faktor penting yang perlu ada pada panel yang telah diprogramkan untuk bangunan supaya ianya dapat meningkatkan kesesuaian terhadap perumahan berindustri di Malaysia. Kajian sebelum ini menunjukkan wujudnya jurang antara reka bentuk piawai dan keperluan pengguna untuk perumahan berindustri di Malaysia. Masalah-masalah yang dikenal pasti adalah berkaitan dengan reka bentuk seni bina dan penyesuaian serta pengubahsuaian ke atas bangunan kediaman. Oleh itu, kajian ini lebih tertumpu pada konsep sokongan dan pengisian untuk meningkatkan kualiti reka bentuk dan kepuasan pengguna di dalam bangunan kediaman. Kebolehsesuaian dalam erti kata yang lebih luas adalah suatu proses penyesuaian inovatif untuk menambahbaik keperluan peribadi seseorang terhadap rumah yang didiaminya. Walau bagaimanapun, pengubahsuaian dan kerja-kerja penambahan adalah terhad dalam perumahan berindustri. Kajian awal menunjukkan bahawa kesesuaian reka bentuk bergantung kepada faktor yang berbeza-beza seperti bentuk dan fungsi panel serta sikap pengguna. Kaedah yang digunakan dalam kajian ini adalah berdasarkan kepada andaian bahawa tahap kualiti perumahan berindustri di Malaysia boleh diperbaiki secara pengaturcaraan seni bina ke arah kebolehsesuaian seperti yang telah dilakukan oleh Jepun dalam perumahan eksperimen NEXT21 di Osaka. Oleh itu, kajian kes tentang kebolehsesuaian telah dijalankan di Jepun untuk mengenal pasti kriteria kebolehsesuaian supaya dapat diaplikasikan ke dalam perumahan berindustri di Malaysia. Oleh yang demikian, kajian kes perumahan berindustri telah dijalankan di Malaysia untuk mengenal pasti Petunjuk Prestasi Kepuasan (PIS) pengguna. Data untuk kajian kes diperolehi dari sorotan dokumen serta maklumat tentang projek, kajian soal selidik dan pemerhatian. Terdapat pelbagai sistem bangunan di Malaysia yang menyediakan komponen panel konkrit pratuang yang beraneka jenis. Dapatan kajian ini mengesahkan bahawa panel-panel ini boleh menyumbang ke arah menambahbaik kebolehsesuaian dengan merangka Pengaturcaraan Seni Bina. Pengaturcaraan ini disokong oleh Model Kebolehsesuaian yang diperolehi dari analisis kuantitatif (kepuasan pengguna terhadap ruang dalaman), dan analisis kualitatif (bentuk dan fungsi panel seni bina) ruang tersebut. Penyelesaian inovatif terhadap pengaturcaraan seni bina panel dalam perumahan berindustri serta cadangan untuk arkitek mengenai kebolehsesuaian mengakhiri tesis ini.

APPROVAL PAGE

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Zulkefle bin Ismail

Signature.....

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TABLE OF CONTENTS

Abstract.....	ii
Abstract in Arabic.....	iii
Abstract in Malay.....	iv
Approval Page.....	v
Declaration.....	vi
Declaration of Copyright.....	vii
Acknowledgements.....	viii
Table of Contents.....	ix
List of Tables.....	xiii
List of Figures.....	xv

CHAPTER 1: OVERVIEW OF THE RESEARCH

1.0 Introduction.....	1
1.1 Background Information on the Study.....	2
1.2 Statement of the Research Problem.....	7
1.3 Research Objectives and Questions.....	9
1.4 Research Design.....	10
1.4.1 Research Assumption.....	10
1.4.2 Selection of an Appropriate Approach to Address the Research.....	11
1.4.3 Organization of the Research.....	12
1.5 Significance of the Study.....	12
1.6 Scope and Limitation.....	13
1.7 Form of the Thesis.....	14

CHAPTER 2: ADAPTABLE ARCHITECTURE FOR INDUSTRIALIZED HOUSING

2.0 Introduction.....	16
2.1 Concept and Definition.....	17
2.2 Adaptable Architecture.....	19
2.2.1 Adaptation of Space to Human Needs.....	20
2.2.2 Adaptation to the Individual and to the Collective.....	21
2.2.2.1 Cyclic Activity Patterns.....	22
2.2.2.2 Fluctuation and Evolution of Activity Patterns.....	23
2.2.3 Adaptation of Activities.....	24
2.2.3.1 Affordance.....	24
2.2.3.2 Intention.....	26
2.2.3.3 Affect.....	27
2.2.4 Adaptation to Anticipated Changes.....	29
2.3 Architectural Transformation.....	32
2.3.1 Adaptation by Reconfiguration.....	33
2.3.2 Adaptation by Flexibility/Adjustable.....	40
2.3.2.1 Soft Flexibility.....	42
2.2.3.2 Hard Flexibility.....	43
2.2.3.3 Non-Flexibility.....	45

2.4	Flexible Construction.....	47
2.4.1	Open Building System.....	51
2.4.2	Experimental Industrialized Housing.....	57
2.5	Architectural Programming.....	61
2.5.1	Terminology.....	61
2.5.2	History and Development of the Programming Method.....	65
2.5.3	Programming by Computer.....	66
2.5.3.1	Functional Programming.....	66
2.5.3.2	Attractors Programming.....	67
2.5.3.3	Relations Programming.....	68
2.5.4	The Organizational Methodology of Adaptable Architecture.....	68
2.6	Summary.....	74

CHAPTER 3: RESEARCH METHODOLOGY

3.0	Introduction.....	75
3.1	Research Strategy.....	76
3.1.1	Quantitative and Qualitative Study.....	77
3.1.2	Case Study.....	82
3.1.3	Model Building.....	84
3.2	Study Design.....	86
3.3	Source of Data and Activities for Case Study.....	90
3.3.1	Preliminary Interviews with Expert in Construction Industry.....	91
3.3.2	Primary Source Material and Documentary Evidence.....	92
3.3.3	The Questionnaire.....	94
3.3.4	Participant Unstructured Observation.....	97
3.3.5	Summary of Data Collection for Case Study.....	100
3.4	Method of Data Analysis.....	101
3.4.1	Questionnaire Survey.....	103
3.4.2	Document Review and Observation.....	107
3.5	Architectural Panel Programming.....	108
3.6	Summary.....	112

**CHAPTER 4: QUANTITATIVE DATA ANALYSIS & INTERPRETATION:
USER’S SATISFACTION ON WALK-UP APARTMENTS**

4.0	Introduction.....	113
4.1	Factor Analysis.....	113
4.1.1	Measure of Sampling Adequacy.....	114
4.1.2	Using Rotated Factor Matrix to Group the Variables.....	119
4.2	Reliability Analysis.....	123
4.3	Levels of Satisfaction for Internal Spaces.....	125
4.4	The Relationship between Satisfaction and Adaptability.....	126
4.4.1	Correlational Analysis.....	126
4.4.2	Difference of Mean Analysis.....	130
4.4.2.1	The Mann-Whitney U Tests.....	130
4.4.2.2	The Kruskal-Wallis Tests.....	132

4.5	The Factor Affecting the Design for Adaptability.....	142
4.5.1	The Dwelling Form [F].....	143
4.5.2	Internal Space [P].....	143
4.5.3	Technical Defects [T].....	143
4.5.4	User's Satisfaction [S].....	144
4.6	Performance Index for Satisfaction of Adaptability.....	146
4.6.1	First Step.....	146
4.6.2	Second Step.....	150
4.6.3	Third Step.....	152
4.6.4	Fourth Step.....	153
4.7	Summary.....	155

**CHAPTER 5: QUALITATIVE DATA ANALYSIS AND INTERPRETATION:
ARCHITECTURAL PANEL PROGRAMMING**

5.0	Introduction.....	156
5.1	Design and Manufacturing of Architectural Panel.....	157
5.2	Physical Form of the Panel.....	167
5.2.1	Node Element.....	168
5.2.1.1	Plumbing.....	170
5.2.1.2	Mechanical and Electrical (M&E) Accessories.....	172
5.2.2	Surfaces.....	175
5.2.2.1	External Wall.....	175
5.2.2.2	Internal Wall.....	180
5.2.2.3	Floors.....	182
5.2.3	Spaces.....	185
5.3	Functional Requirement of the Panel.....	187
5.3.1	Physical Connections Between Panel and Panel.....	187
5.3.1.1	Typical Dry Joint (Teachers' Quarters and Dahlia.....	188
5.3.1.2	Wet Vertical Joints (O-Stable Panel System).....	190
5.3.2	Physical Connections for Supported Beams and Slabs.....	191
5.3.3	Energy and Matter Flow Connections.....	193
5.3.4	Interconnecting Architectural Panel and People.....	194
5.4	Architectural Panel Programming for Adaptability.....	195
5.4.1	Adaptability Model.....	196
5.4.1.1	Building Structure.....	197
5.4.1.2	Functional Requirements of the Space.....	198
5.4.2	Flexibility of Floor Plan.....	200
5.4.3	Functional Requirements of the Panel.....	202
5.4.3.1	Transparency.....	202
5.4.3.2	Open Building System.....	203
5.4.3.3	Uniqueness of Panel.....	204
5.4.3.4	Design Standard.....	205
5.4.3.5	Stratification of Design System.....	205
5.4.4	Transformation of Construction Industry.....	206
5.4.4.1	Facilitation of Transformation of Adaptable Housing.....	207
5.4.4.2	Standardization Between Architectural Panel.....	208
5.4.4.3	Evolution of Panel in Industrialized Housing.....	208

5.4.5	Strategies for Architectural Panel Programming.....	209
5.4.5.1	Feasibility Study.....	209
5.4.5.2	Modularity.....	210
5.4.5.3	Extensibility.....	211
5.4.5.4	Independence of Technology.....	212
5.5	Summary.....	213
CHAPTER 6: RECOMMENDATIONS AND CONCLUSION		
6.0	Introduction.....	214
6.1	Response to Research Questions.....	215
6.1.1	What are the level of satisfaction in order to enhance.....	216
6.1.2	What aspect of design could be contributed to the adaptable.....	217
6.1.3	How the architectural panel can improve the adaptability in.....	218
6.1.3.1	Summing Up User's Perception.....	218
6.1.3.2	Design for Flexibility.....	218
6.1.3.3	Technological Advancement.....	219
6.1.3.4	Architectural Programming.....	219
6.1.4	How the Architectural Programming could enhance the.....	219
6.2	Towards Realization of Architectural Programming.....	221
6.3	Adaptive Future of Architecture.....	223
6.6	Conclusion.....	224
REFERENCES	232
APPENDICES		
Appendix A:	Questionnaire.....	256
Appendix B:	Checklist and Evaluation Form.....	263
Appendix C:	Case Study on Adaptable Housing in Japan.....	266
Appendix D:	Case Study on Industrialized Housing in Malaysia.....	303

LIST OF TABLES

<u>Table No.</u>		<u>Page No.</u>
2.1	Type of change of user requirements, terms of change and characteristics	21
2.2	Other Infill System	50
2.3	The terminology used in the architectural programming approaches	62
3.1	Comparison between a qualitative and quantitative method	77
3.2	Type and utility of data from each data collection activity	100
3.3	A Likert five-point scale in questionnaire	103
3.4	Research purpose and technique of data analysis for the study	104
4.1	Kaiser-Meyer-Olkin and Bartlett's Test	114
4.2	Communalities	115
4.3	Extraction method using Principal Component Analysis – Total Variance Explained	117
4.4	Rotation Factor Matrix – Varimax with Kaiser Normalization	121
4.5	Item analysis of the Cronbach's Alpha and reliability coefficients for all the constructs	123
4.6	Test Statistics	125
4.7	Ranks	125
4.8	Reliability coefficients for all the constructs	127
4.9	Pearson correlation analysis	129
4.10	Mean ranks and statistics for Mann Whitney U tests	131
4.11	Mean ranks and statistics for Kruskal Wallis tests	132
4.12	Mean ranks and statistics for Kruskal Wallis tests	134
4.13	Mean ranks and statistics for Kruskal Wallis tests	140

4.14	The Merit value (V) of the Possible Solutions of the Conventional Housing Type F1	148
4.15	The Merit value (V) of the Possible Solutions of the Industrialized housing Type F2	149
4.16	The average and relative weighting scores of level of satisfaction in the dwelling unit	150
4.17	The average and relative weighting scores of the dwelling unit type	151
4.18	The average scores of the Space (P)	152
4.19	The relative weighting scores of the Space (P)	153
4.20	The values of the Performance Index of Satisfaction in walk-up apartment	154

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
2.1	Levels of decision making	18
2.2	Priority for adaptability	22
2.3	Type of complaint reported by owner to the HBA	25
2.4	Shearing layers of change in buildings	27
2.5	Future state possibilities for anticipated changes	30
2.6	Concepts for exterior walls as “Domino”	35
2.7	Bottle-rack principle in the Unite d'Habitation at Marseille, France	36
2.8	Matura Infill System	37
2.9	Nakagin Capsule Tower	38
2.10	NEXT21 adaptable prototype at Osaka	40
2.11	An example of family evolution from MHLG	42
2.12	Modular nature and sliding walls at Steelhouse	44
2.13	Illustration of Longford House	46
2.14	Categorization of Open Building System	52
2.15	The Finnish BES System components from Finland	54
2.16	Isometric views of Diagoon Houses, Delft, The Netherlands	55
2.17	Structural Layout and variation of plan of Diagoon Houses, Delft, The Netherlands	56
2.18	Experimental Housing for Open Building System	58
2.19	Construction system shell for housing Genter Straße in Munich, Germany	59
2.20	ManuBuild demonstration building in Madrid, Spain	70
2.21	Cocoon + transparent	71

2.22	Current envelope of KUBIK in Germany	71
2.23	Experimental capabilities of KUBIK	72
2.24	Industrialized systems for facades, building roof and underground floor of KUBIK	73
3.1	A conceptual model of adaptability	85
3.2	Research Design	89
3.3	The research design: relationship of data collection and data analysis	102
3.4	Schematic diagram for evaluating floor plans and establishing criteria for adaptability	110
4.1	The factors and the variables of designing adaptable housing affecting the level of satisfaction	145
5.1	‘I’ shape panels with door or window opening	159
5.2	Combination types of precast concrete wall panels	160
5.3	Fencing’s mould	162
5.4	Perspective view of the formwork	163
5.5	Formwork and mould of O-Stable Panel System at factory	164
5.6	Cross sectional view of the formwork	165
5.7	The hole located in the upper part of the precast wall panel	169
5.8	Raised floor in a housing unit at NEXT21, Osaka, Japan	171
5.9	Detail of embedded services in architectural precast wall panel	172
5.10	Position of embedded services architectural precast wall panel in industrialized housing	173
5.11	Grid pattern for NEXT 21 at Osaka, Japan	176
5.12	Temperature profile of O-Stable Panel System	177
5.13	Pre-programmed structural separation element as a part of Infill Unit	178
5.14	Precast load bearing wall for infill element	179
5.15	Interior of various housing units in the NEXT21 at Osaka, Japan	181

5.16	Flexible piping system in NEXT21 at Osaka, Japan	184
5.17	Pre-programmed structural separation element	185
5.18	Second phase experiment of NEXT21: Before and after remodeling	186
5.19	Horizontal and vertical dry joints of architectural panels for industrialized housing	188
5.20	Joint design for precast wall panels	189
5.21	Butt and Miter Corner Vertical Joints	189
5.22	Direct bearing connections of precast wall panels on the foundation	192
5.23	Revised adaptability model	196
5.24	Floor plans of NEXT21 at Osaka, Japan	201
5.25	Architectural programming for industrialized housing using modules	211

CHAPTER ONE

OVERVIEW OF THE RESEARCH

1.0 INTRODUCTION

The research presented in this thesis stems from a multifaceted need of users in industrialized housing to transform, improve and adapt to their habitats. This need is confronted with inability of contemporary architecture to develop profoundly adaptable architectural living environments. Over its lifetime, a home will accommodate a series of occupants with varying needs and requirements. Even a family who reside in the same house for half a century or more will change dramatically over time. As the family changes, so should the house. Add in technological and social advances, and it is clear that for a residence to stand the test of time it must be able to stand the test of change.

This opening chapter is intended to present to the reader the background of the research design of the study under consideration. The chapter is divided into six (6) sections. The first section introduces general ideas in the field of adaptable house that have particular relevance to the research. A statement of the research problem is provided in the second section by identifying problem areas in this field, and outlines the objectives of the research along with its scope and limitations. The third section illustrates the research objectives and questions, followed by the research design and significance of the study that were chosen to address the research problem adequately. Scope and limitation will be presented in the final section of this chapter. The background information presented in this chapter is derived, as indicated in the text, from various related literature.

1.1 BACKGROUND INFORMATION ON THE STUDY

The advancement of technology has touched every part of our lives over the last century – including construction industry. A conventional construction is the result of many factors which can be technological or social, and this gap still exists between manufacturing and construction industries in Malaysia. However, construction industries practically continue to produce residential buildings in conventional ways. Therefore, in the last decade, industrialized construction was promoted to enhance the importance of prefabrication rather than conventional construction.

Construction industry in Malaysia began in the early days of Federation of Malaya in 1948, together with the formation of the various states in the country. The construction of the Malay traditional house mainly relies on its strength of a complex jointing system made rigid by the use of timber wedges (Wan Hashimah, 2005). According to Rodd (2003), timber that is relatively light-weight has always been at what might be regarded as the cutting edge of the building technology of the era. However, Kamaluddin (2009) claimed that concrete is the material of choice for residential buildings in Malaysia by a significant margin.

Industrialized housing is not new to Malaysian construction industry. Projects utilizing large architectural precast panels called *Danish Larsen-Neilson System* were undertaken at the Pikeliling Flats in 1966 and *French Estiot System* in Riffle Range Road Flats in Penang after a year. Malaysia adopted the British Precast System where 1,200 units' houses were built in Penang in 1978 and 2,800 units in Lumut in 1980 using *Hazama Gumi System* from Japan. However, its adoption has been limited to the use of proprietary, stand-alone systems rather than open system. Nonetheless, the building design was very basic and did not consider the aspects of serviceability and culture of living such as the need of wet toilet and bathroom.

Following these pilot projects, Malaysia adopted Modular Coordination (MC) that acquired precast concrete technology from the Praton Haus International, Germany and took up numerous housing projects from 1981-1993. Praton Haus International has fit to the production system of which not all factories can produce at that time (Mohd Sufian, 2009). There are two (2) types of construction systems which have been introduced by Praton Haus; architectural large panel systems and skeleton systems.

Connections in such system of reinforced concrete structure are potentially the most critical part of the architectural precast panel (Tan, 2006). Joint are required for durability, fire-proofing and water-proofing for architectural performance, strength, rigidity, and ductility for mechanical efficiency and the ease of handling and clearance for expansion as well as for contraction. Constructively, it is the main factor in controlling the performance of industrialized housing. In addition, it is equally important that the detail design attributed must be able to be constructed. The purpose of connections is to maintain the integrity of the structure under the applied load. According to Elliott (2003), the definition of a connection is the action of forces (tension, shear, and compression) and/or moment (bending and torsion) through an assembly comprising one (or more) interfaces. The design of connection is therefore a function of both the structural elements and of the joints between them.

Essiz and Koman (2006) in their study found that design demands (artistic and technical) increase with each further step towards industrialization. The combination of sociological and ecological standards together with functional and aesthetic designs could utilize the full advantage of industrialization without creating lifeless buildings and environment. Erman (2002) claimed that aesthetic considerations became an inseparable part of the joint without putting its primary function aside.

On the other hand, the mechanical fasteners that have been developed as a substitute for intricate interlocking joints played the major role for industrialization, mechanization and mass production. Feasibility of demountable joints can be improved with the advance working tools. The highly developed electronic working tools enable the prefabrication of intricate interlocking joint (Erman, 2002). Therefore, the concept of adaptability and flexibility for homes could be realized.

Adaptability in general is the ability of individual modifications to suit new conditions. A basic adaptability for homes is defined by Friedman (2002:1) as “providing occupants with forms and means that facilitate a fit between their space needs and the constraints of their homes either before or after occupancy”. Practically, adaptability covers all internal changes in both the availability and the structure of spaces. However, homes in Malaysia have followed another path. It has always been conceived as something necessarily static and safe. What happened to the adaptability and ‘machine à habiter’ that Le Corbusier proposed at the beginning of the 20th century?

The organized and accessible systems such as industrialized housing will no longer be useful except for the lowest commodity products for which competition is weak or nonexistent, or for which there is a public monopoly (Kendall, 2005). Therefore, the Open Building System is vital to avoid monopoly of architectural panel component in Malaysian construction industry. In addition, it will enhancing the ability to access, repair, and modify over the lifecycle of the house. Similarly, the design of interior space can be reconfigured in a relatively straightforward manner as occupant living requirements change over time. Thus, the concept of adaptability and flexibility strongly overlaps in this matter. In fact, the ultimate goal of industrialized housing research is to develop solutions that satisfy both of these principles.

According to Abu Hammad et al. (2008), research and project experience shows significant savings can be made when applying this approach. The potential to develop adaptable architectural panel for industrialized housing in Malaysia needs combination of innovative design and construction methods. It is important for an industry that is constantly alarmed by the increasing cost of building maintenance and lifecycle issues (Construction Industry Development Board [CIDB], 2009b). Hence, it is very significant to select the appropriate building systems and components that require minimum maintenance (Chew and Das, 2008) to form industrialized housing.

Durability is a key point to prevent the deterioration of structures and members of buildings over time and to maintain the safety, comfort and health of the users. According to Asiah et al. (2009), most of the users in industrialized housing in Malaysia are fairly satisfied with their house finishing, such as noise transmission from outside into the room, and the defect of building component. Crack remains the highest case of defect recorded in their houses, especially for single and double storey terrace housing. As for these cases, maintenance of external wall tiles is needed once every 20 – 30 years, simply in terms of masonry joint repair. In addition, most Malaysians prefer to improve their house by doing renovation and extension.

Therefore, the plug and play architectural panel for external walls is suggested as their potential to enhance the durability and waterproofing properties of the connection. The plug and play panel could be fixed manually in place to maintain constant performance quality as well as ease for maintenance and renovation. Since the architectural panels have a fine surface irregularity in order to maintain the high hydrophilic properties, they remain clean for a long period. Unlike painted external walls and siding board external walls, this may considerably reduce the amount of maintenance work, such as waterproofing and repainting, which may be required.

As Malaysian households prefer to be different from their neighbours and have varieties in terms of needs through time, the industrialized housing should provide adaptability for served areas whereas the serving areas can display similar features from one dwelling unit to another. As prefabrication technology is mostly factory-related, the precast components reach for the best practice to implement plug & play concept into industrialized housing in Malaysia. This optimal solution could be offered by a hybrid approach; concentrating on the serving areas in compact factory-made 3D modules called Service Cores (Richard, 2008). On site, the Cores are positioned perpendicularly to the façade, while locally built floors and exterior walls span longitudinally between them to generate the served areas. The Service Core is to housing as what the engine is to the body of an automobile, or to the fuselage of an airplane.

The Service Core approach that considered as a Plug & Play concept will fully meets the adaptability agenda when mechanical (dry) joints are used in order to permit reconfigurations without any demolition. Therefore, the served areas generated between the cores are functionally adaptable, open to a diversity of scenarios and accommodating either loft or partitioned arrangements. The construction of the served areas, and its adaptability to suit changing needs, is a simple activity which deserves to be done locally, both for economic and cultural reasons. The exterior architectural wall panels of plug & play tiles or curtain walls that connected to the Cores constitutes as an open sub-system in terms of materials and forms, and they can play a determinant role in responding to the local culture and harmonizing with the Malaysia Standard.

1.2 STATEMENT OF THE RESEARCH PROBLEM

It can be generally postulated that adaptable architecture does not fully functioning in industrialized housing in Malaysia. Although in the practice of changing mechanical and electrical component is common in buildings services, the architectural panel has not following that path to be dynamic in function. The form of dynamic building alteration is typically automated and top-down controlled using Building Management Systems (BMS). Such form of centralized control is in opposition to the concept of adaptable, which is inherently a bottom-up process. Existing reconfigurable buildings do not exhibit users of their own required for adaptation to take place.

The gap is seen still exists between users and architectural panel of industrialized housing in Malaysia as the adaptable architecture is not fully functioning in residential building. The need to understand the problem between adaptability, architectural panel and industrialized housing are as follows:

- i. ***Lack of comprehensive reference project:*** Various aspects of adaptable architecture have been preliminarily tested in experimental installations (Jia, 1995; Friedman, 2002; Amira, 2006), but have not found their way to commercial applications (Richard, 2005a; Parsley, 2009). Without comprehensive case study, no evaluation of actual usability or performance of adaptable architecture can be made.
- ii. ***Limited flexibility:*** To date only limited in scale and scope of adaptable architectural installations are being developed. These explorations are typically seen as “art” rather than actual architectural or building engineering research. Industrialized construction industry lack of open concept (Habraken, 2008). Architectural panel are not flexible enough towards installation for modification or renovation (Staib et al., 2008).