ADAPTABILITY OF TEACHER'S QUARTERS USING IBS IN MALAYSIA

Zulkefle Ismail and Asiah Abdul Rahim
International Islamic University Malaysia

ABSTRACT
The objective of this paper is to identify the Performance Index of Satisfaction (PIS) on adaptability of housing using Industrialized Building System (IBS) in Malaysia. Preliminary research identified that the attitude of the individual towards design standard and user's need depends on many varying factors such as physical area and psychological feeling of the internal spaces. The study focuses on the housing using IBS by identifying level of user's satisfaction and the conditions for adaptability to be applied into the house. Adaptability in architecture is defined 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. The ability of modifications to suit new conditions or the design will allow for any additions to make building more flexible. This will ease for renovation and extension thats currently limited in housing using IBS. A case study was carried out at eleven Teacher's Quarters using IBS in Malaysia. The Performance Index of Satisfaction (PIS) is utilized in the analysis as a systematic manipulation of the factors and the variables of design. The findings confirmed the requirements and potential for physical adaptabilities in Teacher's Quarters. The conceptual model was revised based on user's satisfaction of internal spaces in the house. Transforming the architectural dictums from "form follows function" to "form accommodates change" by estimating the sociological impact of professional and practice attitudes and mindsets should be encouraged towards successful implementation of adaptable housing using IBS in Malaysia.

Keywords: Performance Index of Satisfaction (PIS); Industrialized Building System (IBS); Adaptability; Internal Spaces; Teacher's Quarters.

INTRODUCTION
The aim of this paper is to identify the Performance Index of Satisfaction (PIS) on adaptability of housing using Industrialized Building System (IBS) in Malaysia. To address the objectives, the research looking at the aspect of IBS could be contributed to the adaptable design of housing in Malaysia. Urban life has its convenience and modern-day life its comfort. The user's satisfaction of the spaces has led to the need for IBS to be

successful in order to achieve adaptability. It is likely that this will result in greater use of partnering arrangements and post-occupancy evaluation to gauge customer satisfaction. In order to attain a higher level of satisfaction regarding our comfort, we must approach technology from a new conceptual viewpoint – to further transform and enhance housing. In order to discover what progress has been made in developing the concept of adaptability, the relevant literature in the field of architectural research has been reviewed.

The research begins at the concept and definition of adaptable architecture and the IBS-housing development in Malaysia as a background study. Base on this study, the conceptual model was designed by taking into consideration the questionnaire that has been used by Asiah et al. (2009) in their previous studies on IBS-housing in the Klang Valley. A case study was carried out at eleven Teacher's Quarters using IBS in Malaysia. Finally, the revised model takes into consideration all the major findings from the analyses and considered as a solution for adaptability to be used in Malaysia.

ADAPTABLE ARCHITECTURE

Adaptability refers to the capacity of buildings to accommodate substantial change. Over the course of a building's lifetime, change is inevitable, both in the social, economic and physical surroundings, and in the needs and expectations of occupants. Adaptation and flexibility have played an important role in experimental architectural projects in the Industrial era.

A concept of adaptability appears during the programming phase and is applied and used during the design and planning, construction, inhabitancy and renewal phases (Davison et al., 2006). The concept stems from the theories developed by Habraken (1976). On the subject of adaptability he writes,

> *Adaptability and variety must give those who finally occupy the support building maximum choice without requiring technical expertise or excessive effort on the part of the resident* (11-12).

Adaptability is broadly interpreted with definitions referring to "change of use", maximum "retention" of original structure and fabric, and extending "useful life" (Ball, 2002; Mansfield, 2002; Douglas, 2006; Bullen, 2007). Frequently, terms like renovation, refurbishment, remodeling, reinstatement, retrofitting, rehabilitation, and recycling of buildings are incorporated. Adaptability can occur within use and across use; for example, an office can undergo adaptation and remain an office (within use adaptation) or it may change use to residential and be classed as across use adaptation (Ellison and Sayce, 2007).

The basic definition of adaptability in architecture is proving occupants with forms and means that facilitate a fit between their space needs and the constraints of their homes either before or after occupancy (Friedman, 2002; Hinte and Neelen, 2003). However, the definition of certain basic properties of adaptability which are of relevance to architectural system such as IBS are summarized as follows:

i. They are composed of interrelated sub-systems organized in levels (Nijs et al., 2010).
ii. They are capable of exchange with their environment (Richard, 2010; Del Aguila, 2010).
iii. Their openness is the basis of their stability (Lawson and Ogden, 2010; Girmscheid, 2010).
iv. The organization into independent component sub-assemblies contributes to their adaptability (Eguchi et al., 2010; Iturralde, 2010; Giurdanella and Zanelli, 2010).

Since the home evolves through different stages and needs over its lifecycle thus the contributions of adaptability improvements by each of the users vary accordingly. The designers are expected to play the central role for the improvement (Rosli, 2004).

However, architects are seen to have significant roles as they are responsible for the most design problems of the house. Housing with an adaptability features is one which is able to respond effectively to changing household needs without requiring costly and energy intensive alterations. Therefore, Austin (2007) illustrates the priority for adaptability of the house in the United Kingdom in Figure 1 as follows:

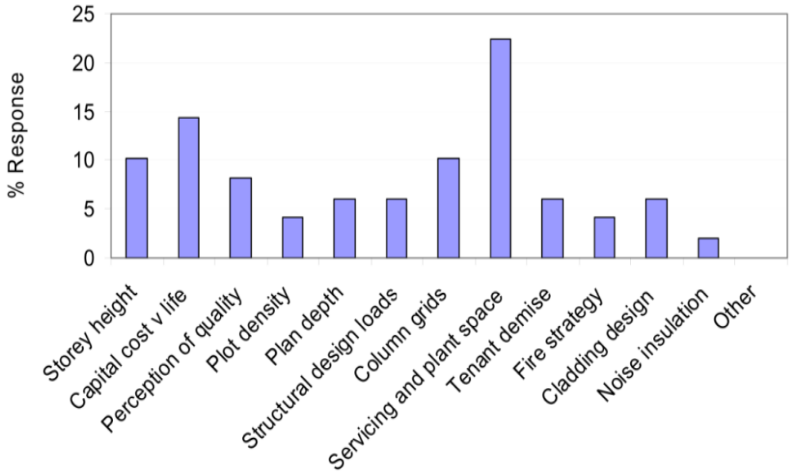


Figure 1 Priority for adaptability *(Austin, 2007)*.

In this study the term adaptable architecture is used as a general definition of an architecture from which specific components can be changed in response to external stimuli (the user and/or the environment). The definition of the different terms of adaptation is explained below:

i. Flexible – The components of the building are changeable with an external force (Brand, 1995; and Leupen 2002). The different possibilities of change are limited.
ii. Active – The action must be undertaken by the user or environment (Blok & Herwijnen, 2006). Active adaptation requires electricity as basic technique.
iii. Dynamic – The dynamic adaptation such as computer technology was ready for use in housing since around 1980 (Giddens, 1990).
iv. Interactive – The building component has to ability to have a two way conversation between the user and system which needed for interactive relations (von Stamm, 2003).
v. Intelligent – The adjustment or transformation of the building component is selected by the system as a

reaction on the external stimuli (Mollaert et al., 2000; Block and van Mele, 2003).

vi. Smart – The system with knowledge of Ambient Intelligence that anticipate on the users' desires or environment without conscious meditation (Collier and Thelen, 2003).

HISTORICAL CHRONOLOGY OF IBS IN MALAYSIA

IBS in Malaysia has begun in early 1960's when Ministry of Housing and Local Government of Malaysia visited several European countries and evaluate their housing development program (Thanoon *et. al.* 2003). After their successful visit in 1964, the government had started first project on IBS aim to speed up the delivery time and built affordable and quality houses. About 22.7 acres of land along Jalan Pekeliling, Kuala Lumpur was dedicated to the project comprising seven blocks of 17 storeys flat there are 3000 units of low-cost flat and 40 shops lot. This project was awarded to JV Gammon and Larsen & Nielsen using Danish System of large panel of prefabricated system (CIDB, 2003).

Among the earliest housing development project using IBS was Taman Tun Sardon, Penang. IBS pre-cast component and system in the project was designed by British Research Establishment (BRE) for low cost housing in tropical countries. Nonetheless, the building design was very basic and not considering the aspect of serviceability such as the need of wet toilet and bathroom (Rahman and Omar, 2006). Between 1981 and 1993, Perbadanan Kemajuan Negeri Selangor (PKNS) a state government development agency acquired pre-cast concrete technology from Praton Haus International based on Germany to build low cost house and high cost bungalow in Selangor (CIDB, 2003; Hassim et al., 2009). There are two types of construction system which have been introduced by them, large panel systems and skeleton systems. The large panel systems consist of Solid Panel System 0 (SPS 0), Solid Panel System 1 (SPS 1), Solid Panel System 2 (SPS 2), Hollow Panel System (HPS) and Double Panel System (DPS) are shown in Figure 2 as follows:

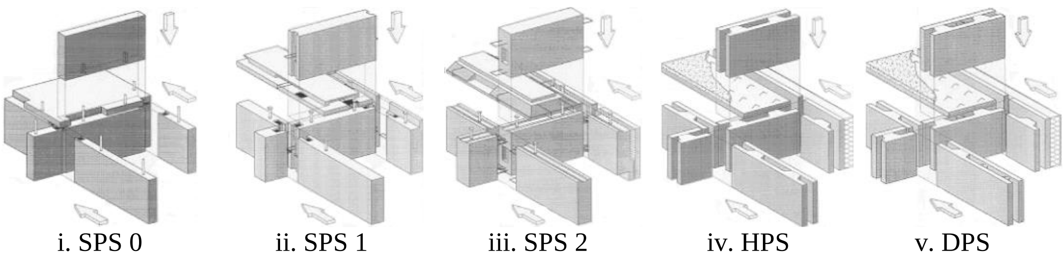


Figure 2 Large Panel System of Praton Haus International, Germany
(http://www.praton.de/pc_const_sys.htm, 2006)

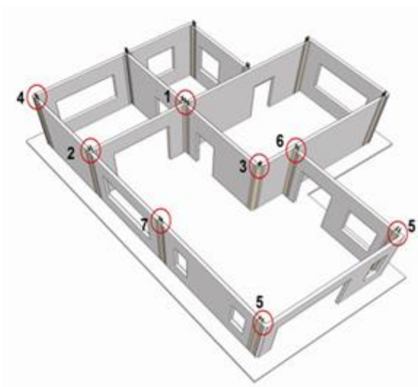
Other large panel systems in Malaysia include Taisei Marubeni System (Japanese system) used in Shah Alam, Ingeback System (Swedish system) in high-rise building (Sarja, 1998; Hassim et al., 2009). IBS was implemented in Taman Maluri, Pandan Jaya and Wangsa Maju using metal-formwork system (Sarja, 1998). Setia Precast Sdn Bhd, a wholly owned subsidiary of SP Setia Bhd has established a firm reputation as Malaysia's leading IBS specialist in precast technology for high-rise residential apartment. In the last decade, they had successfully constructed more than 10,000 units of residential apartments up to 18 storeys in Klang Valley, Sungai Petani and Putrajaya (CIDB, 2008).

Between 1998 and 2002, Encorp Berhad and Leighton introduced precast concrete walls and precast planks using Cessma Panel System (Asiah and Zulkefle, 2012) in the development of 10,000 units of teachers' quarters on 107 sites throughout Malaysia. A total of 4,700 units of the teachers' quarters were completed by Sunway Precast Industries Sdn. Bhd. and the remaining units were completed by Leighton and Hume Industries Sdn. Bhd. The project comprised low-rise (4 and 5-storey high) apartment complexes (see Figure 3) were designed by NRY Architects Sdn. Bhd. Each apartment unit has 3 bedrooms, 2 bathrooms, a living room, a dining room, a balcony and a courtyard (CIDB, 2008).

i. Kuantan, Pahang ii. Ipoh, Perak

Figure 3 Teachers' Quarters using IBS in Malaysia.

Starting in 2006, O-Stable Panel System has been widely used as IBS system in double storey bungalow and terrace houses at Selangor and Putrajaya (Asiah et al., 2012). The prefabricated component was supplied for bungalow houses at Shah Alam and Putrajaya. Baktian Sdn. Bhd. was the manufacturer for those systems as shows in Figure 4 as follows:



1) Cross-joint
2) T-joint
3) L-joint
4) Precast panel with L-joint
5) Precast panel with 2L-joint
6) Precast panel with T-joint
7) I-joint

O-Stable Panel Sdn. Bhd.

Patent No: MY-114346-A, MY-135260-A, MY-138022-A
http://www.ostap.com.my

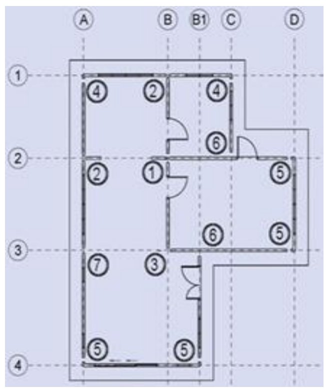


Figure 4 Plan of Standard Detail of Wet Vertical Joints *(Baktian Sdn. Bhd., 2011)*

THE CONCEPTUAL MODEL

The research problem was derived from preliminary study which included an extensive analysis of literature and visits to prefabricated housing in Malaysia, United Kingdom and Japan, where discussion were undertaken with their stakeholders. Ozaki (2002) identified the gap between house design standard and user's need as what Tipple (2000) considers as housing stress. From all these early investigations it was identified that the attitude of the individual towards the question of design standard and user's need depends on many varying factors such as the following:

i. The physical area required for day to day activities of the individual, as part of the family, and the family as a whole.
ii. The psychological feeling of space required for the individual and the family which is often culturally defined.

Then, the conceptual model for Teacher's Quarters was designed by taking into consideration the questionnaire that has been used by Asiah et al. (2009) in their previous studies on IBS-housing in Klang Valley. This model shows adaptability as dependent variable. Six independent variables and three moderators were used for the study. The five (5) independent variables were living, dining, kitchen, bedroom, and bathroom. The finalized conceptual model for this study was developed using the factor approach to better understand the relationship between causes and effects (see Figure 5).

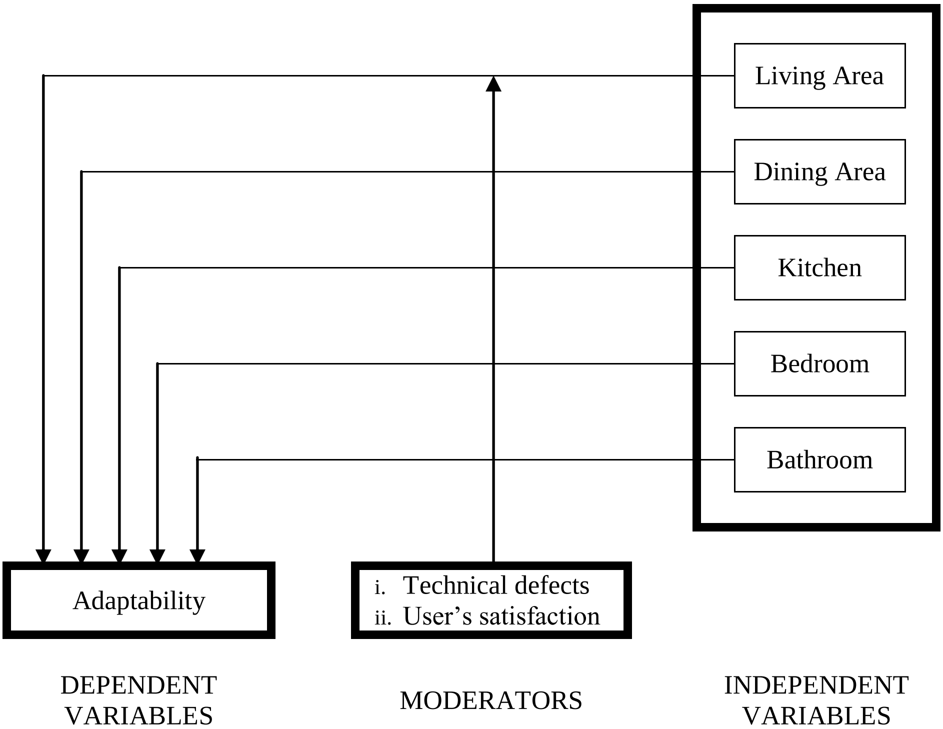


Figure 5: A conceptual model of adaptability for Teacher's Quarters

RESEARCH METHODOLOGY

In this research, a questionnaire was used to obtain the necessary information on occupant's preferred activities, satisfaction with the building layout, and problems that they face in carrying out activities inside the buildings. The questionnaire survey provided a practical foundation for the adaptability study. It is to measure the need of occupants in order to identify whether the using of IBS will be a solution for the adaptability of architectural design for housing in Malaysia. The questionnaire that divided into three (3) sections to facilitate data collection was explaining in further as follows:

i. Section One (general questions) – The questions intended to identify the respondents who stay in the Teacher's Quarters. The analysis will be stratified based on the technical defects and user's satisfaction.

ii. Section Two (level of satisfaction) – This section was divided into four (4) parts of user's satisfaction as follows:
    - Housing layout and its relationship to activities.
    - Internal Environmental Quality (IEQ).
    - Circulation and accessibility in the house.
    - Durability and performance of finishing.

iii. Section Three (activities in the house) – Indicators for different types of activities have been carried out in the Teacher's Quarters such as follows:
    - Day to day activities of the individual and the whole family.
    - Celebration on holidays and family occasions such as kenduri.
    - Social activities such as meeting with relatives and friends.

To test the factors affecting the design for adaptability, the Performance Index of Satisfaction (Laila, 1980) is utilized in the analysis. It is a systematic manipulation of the factors and the variables of design.

PERFORMANCE INDEX FOR SATISFACTION

The quantitative merit value (V) must be assigned to each specific solution that's results from the possible combinations of design variables. The design variables construct the building's design structure – what it is, how it is constituted. Here, the analysis will directly answer the Research Question: *What aspect of IBS could be contributed to the adaptable design of housing in Malaysia*.

The estimations of relative value of each level of satisfaction listed above called goal weight constants (r_i). It was derived from the study done by Asiah et al., (2009) and is assumed for this study only. It is to be expected that these goal values may differ from individual to individual, according to differences in location and component. A score value (S_i) for each design goal are on a scale in which $S_i \leq 100$, and the total sum of the goal weight constants is equal to 1.00. Table 1 shows the percentage of score and weight of constant for each user's satisfaction.

Table 1: The percentage of score and weight of constant for each user's satisfaction

	Percentage of Score (S)	**Weighting of constant (r)**
Quality of finishing [S1]	36.2	0.4
Level of ventilation [S2]	69.5	0.7
Level of lighting [S3]	69.5	0.7
Height of ceiling [S4]	77.0	0.8
Level of finishing [S5]	36.2	0.4
Level of circulation [S6]	56.0	0.6
Arrangement of spaces [S7]	46.8	0.5
Size of spaces [S8]	84.6	0.8

The total means (M_i) of merit value for each specific solution V_i was computed based on the constant (c_i) multiplied by mean of score (m_i) of each satisfaction for T_i where:

$$M_i = \sum_{i=1}^{n} c_i m_i = \sum_{i=1}^{n} T_i$$

A merit value V = 100 effectively satisfies the adaptability of space inside the unit, and a merit value V = 50, for instance, is not likely to satisfy the requirement of adaptability. The weighting score of each variable is computed by using the following formula:

$$Sw = \frac{Sa}{Sa_{max}} \text{, where } Sw \leq 1.00.$$

$$Tw = \frac{Ta}{Fa_{max}} \text{, where } Tw \leq 1.00.$$

$$Pw = \frac{Pa}{Pa_{max}} \text{, where } Pw \leq 1.00.$$

Tables 2 summarize these given merit values for each specific solution in Teacher's Quarters. The types of defects are obviously different in each category because of the differentiation in location and component.

Table 2: The merit value (V) of the possible solutions for Teacher's Quarters.

P	T	S1	S2	S3	S4	S5	S6	S7	S8	N	Ta	Pa	Tw	Pw
P1	T1	56	55	53	57	52	53	61	53	116	55.15	58.40	0.87	1.00
	T2	63	64	62	65	59	60	62	64	156	62.52		0.99	
	T3	58	63	55	58	40	40	58	53	6	52.81		0.83	
	T4	66	64	63	64	59	60	63	64	126	62.85		0.99	
	T5	66	64	60	66	53	54	63	60	38	60.85		0.99	
	T6	63	66	65	68	56	63	63	62	63	63.26		1.00	
	T8	64	59	60	65	58	59	61	60	95	60.75		0.96	
	T9	52	52	52	50	43	47	53	43	58	49.02		0.77	
P2	T1	50	46	45	55	48	45	49	41	116	47.43	48.45	0.75	0.83
	T2	54	51	51	62	55	53	49	44	156	52.44		0.83	
	T3	35	30	35	58	35	30	45	35	6	37.81		0.60	
	T4	56	50	50	62	56	52	52	48	126	53.37		0.84	
	T5	54	47	51	63	49	49	59	50	38	52.78		0.83	
	T6	52	50	51	65	53	50	57	45	63	52.69		0.83	
	T8	54	49	47	60	54	48	50	43	95	50.64		0.80	
	T9	42	40	36	51	44	41	38	31	58	40.40		0.64	
P3	T1	44	44	49	52	45	43	40	32	116	43.56	44.39	0.69	0.76
	T2	45	44	49	57	46	46	44	30	156	45.17		0.71	
	T3	23	20	25	38	23	23	28	10	6	23.44		0.37	
	T4	48	49	54	59	50	50	50	38	126	49.83		0.79	
	T5	48	48	55	59	50	50	50	44	38	50.44		0.80	
	T6	50	51	56	58	53	48	45	39	63	50.01		0.79	
	T7	52	49	57	64	54	52	52	42	135	52.80		0.83	
	T8	46	42	52	56	48	45	45	30	95	45.50		0.72	
	T9	39	38	45	48	39	38	37	26	58	38.75		0.61	
P4	T1	51	49	52	52	47	48	51	43	116	49.12	53.01	0.78	0.91
	T2	56	56	58	62	55	56	59	54	156	56.96		0.90	
	T3	48	43	43	53	48	40	40	38	6	43.75		0.69	
	T4	57	56	58	61	54	55	58	52	126	56.36		0.89	
	T5	60	58	58	63	54	54	61	57	38	58.08		0.92	
	T6	58	61	64	62	55	57	57	50	63	58.15		0.92	
	T8	56	55	58	61	55	54	57	50	95	55.97		0.88	
	T9	41	44	48	53	44	46	50	39	58	45.69		0.72	
P5	T1	45	49	54	51	46	51	48	48	116	49.03	52.65	0.78	0.90
	T2	51	54	59	60	50	57	55	55	156	55.08		0.87	
	T3	35	50	50	55	43	45	53	48	6	47.19		0.75	
	T4	51	54	60	59	50	57	55	56	126	55.33		0.87	
	T5	49	52	62	59	48	61	58	59	38	55.94		0.88	
	T6	47	54	60	55	48	54	53	50	63	52.56		0.83	
	T7	56	57	65	64	53	58	59	59	135	59.10		0.93	
	T8	53	52	59	59	52	53	55	53	95	54.48		0.86	
	T9	41	43	51	47	42	47	47	43	58	45.16		0.71	
Sa		50.83	50.52	53.26	58.00	49.19	49.81	52.14	46.21					
Sw		0.88	0.87	0.92	1.00	0.85	0.86	0.90	0.80					

From Table 4, the height of ceiling (S4) has been found most acceptable on the level of satisfaction in adaptable housing, followed by level of lighting (S3), arrangement of spaces (S7), quality of finishing (S1), level of ventilation (S2), level of circulation (S6), level of finishing (S5) and size of spaces (S8).

The possible solutions are reevaluated by calculating the values of the Performance Index of Satisfaction (PIS). These values are obtained from the equation: PIS = Pw x Sw. The results are shown in Tables 3 as follows:

Table 3: The values of the Performance Index of Satisfaction in Teacher's Quarters

P	**Pw**	**S1w**	**S2w**	**S3w**	**S4w**	**S5w**	**S6w**	**S7w**	**S8w**
		0.88	0.80	0.87	1.00	0.86	0.79	0.84	0.78
P1	1.00	0.88	0.80	0.87	1.00	0.86	0.79	0.84	0.78
P2	0.83	0.73	0.66	0.72	0.83	0.71	0.66	0.70	0.65
P3	0.76	0.67	0.61	0.66	0.76	0.65	0.60	0.64	0.59
P4	0.91	0.80	0.73	0.79	0.91	0.78	0.72	0.77	0.71
P5	0.90	0.79	0.72	0.78	0.90	0.77	0.71	0.76	0.70

The performance index of satisfaction is not an absolute value for every solution, but rather a means of comparing and ranking each solution with the others. The performance index here is an indicator for sustainable house. It must be noted that there is only one solution in which PIS = 1.00, this solution is in efficiency unit size (P_1S_4). It is clear that as the value of PIS approaches 1.00, the solution accomplishes a higher degree of adaptability and satisfies with design. It was identified that the living area the best space among others. The optimal height of ceiling in the space is allows for good ventilation of the unit. All indexes are more than 0.5 which mean that most of respondents satisfied with all spaces in their house especially for living area. The user's satisfaction for every internal spaces base on PIS is ranks as follows:

i. Height of ceiling (1.00)
ii. Quality of finishing (0.88)
iii. Level of lighting (0.87)
iv. Level of finishing (0.86)
v. Arrangement of spaces (0.84)
vi. Level of ventilation (0.80)

vii. Level of circulation (0.79)
viii. Size of spaces (0.78)

DISCUSSION ON FINDINGS

As Malaysian households prefer to be different from their neighbours and have varieties in their needs through time, the housing using IBS should provide adaptability which can display different features from one dwelling unit to another. Here, designers' responses are both direct (when asked what aspect of IBS could be contributed to the adaptable design of housing in Malaysia) and indirect (extrapolated from comments about projects). Floor to floor height was found to be the most critical design parameter and, on average, ranged from 2.8m to 3.0m. The Performance Index of Satisfaction (refer to Table 5) shows a higher degree of adaptability for living area which implies that the height of ceiling in the space is allows for good ventilation. However, the typical concern of the structural floor height of IBS-housing are still not large enough due to the demand for raised flooring to equip the latest service devices, making them difficult to renew.

While the most explicit parameters were floor to floor height and structural grid. All practices mentioned the importance of services and the capacity to be able to subdivide services to a minimum floor area due to greater demand to partition larger spaces for more individual control. This is the case of the NEXT21 in Osaka where the services needed to be subdivided for each individual residential unit. A final aspect considered by the practices was the standardization and reuse of materials allowing for more efficient resource management and improved future availability.

The significant contribution of this study is to revised adaptability model which is shown in Figure 6. The revised model takes into consideration all the major findings from the. The revised model also ranked variables and its related items from highest to lowest as well as maximum to minimum impact respectively.

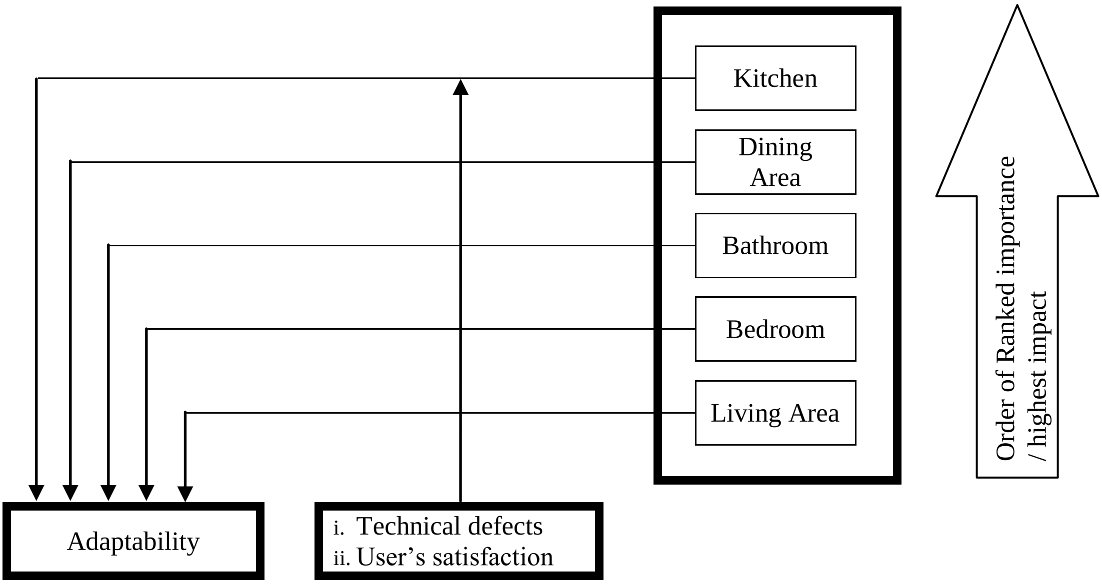


Figure 6: Revised adaptability model for Teacher's Quarters

CONCLUSION AND RECOMMENDATIONS

There is a great reliance of technology such as IBS to satisfy the evolving needs of users and their environment. However, to serve sustainable development, IBS has to preserve, yet enhance the building quality rather than limit it. This balance is possible through the powers of adaptability.

The adaptability has a long history from traditional construction to more recent government led initiatives to promote the IBS-housing. Historically, the adaptable attributes found in traditional designs were primarily driven as methods to accommodate the diversity of everyday life at the scale of the component as opposed to increasing the longevity of the housing. The sustainability agenda has brought by the principles established of the Malay traditional housing design which provides an interesting starting point for adaptability. Its revival has been brought by a top-down approach of reinstating adaptable principles into the quality of construction of IBS. However, it needs to be matched with the mindsets of professionals or a customer driven demand of the market by society.

It is apparent that technology of IBS has a major impact on design and construction of housing in Malaysia. Some policy improvement plans for revitalizing adaptable housing emerged from this study. As adaptability in IBS-housing is a new concept and approach, the government's active support and publicity were chosen as the most important factors for the success in the construction industry. It was agreed that consumer attitude toward the concept of adaptable housing urgently needed to be changed to accommodate them. It was viewed that systematic research and Malaysian mentality should be sufficiently considered through short and long-term roadmaps for adaptable housing. It is suggest to propose the architectural programming for adaptable housing by preparing the standardized design plans, as well as developing IBS, economic support and an accurate demand appraisal.

Finally, research into adaptability requires the effective communication between professionals and with clients and users. Expanding the adaptability towards residential open building will link the manufacturers to a multitude of contextual dimensions for the success of IBS. Like many other system in housing, the programming benefits from a mutual understanding, good relationships, communication and integration amongst designers. Whilst economic and regulatory obstacles are commonly cited, we should not underestimate the sociological impact of professional and practice attitudes and mindsets – shifting architectural dictums from form follows function to form accommodates change.

REFERENCES

Asiah Abdul Rahim, Ismawi Zain, and Saodah Wok (2009). *Users perception on housing using IBS in Malaysia: Case study in Klang Valley*. Unpublished research report, Construction Industry Development Board, Kuala Lumpur.

Asiah Abdul Rahim and Zulkefle Ismail (2012). Adaptability model for panel housing: Case study at Teacher's Quarters in Malaysia. Paper presented in *the International*

Conference on Islamic Built Environment. Universitas Islam Bandung, Indonesia.

Asiah Abdul Rahim, Zuhairi Abdul Hamid, Ismawi Hj Zen, Zulkefle Ismail and Kamarul Anuar Mohd Kamar (2012). Adaptable housing of precast panel system in Malaysia. Paper presented in *the ASEAN Conference on Environment-Behaviour Studies.* July 16-18, 2012. Bangkok, Thailand.

Austin, Simon (2007). *Towards adaptable buildings*. Loughborough Innovative Manufacturing and Construction Research Centre. Loughborough University of Technology.

Ball, R.M. (2002). [Re-use potential and vacant industrial premises: revisiting the regeneration issue in Stoke on Trent]. *Journal of Property Research*. vol 19. 93-110.

Block, P. and van Mele, T. (2003). *Scissor hinge deployable membrane structures tensioned by pleated pneumatic artificial muscles*. Vrije Universiteit Brussel, Faculteit Toegepaste Wetenschappen Afdeling Architectuur.

Blok, R and van Herwijnen, F (2006). Quantifying structural flexibility for performance-based lifecycle design of buildings. Paper presented in *the International Conference on Adaptable Building Structures (Adaptables2006)*. Eindhoven, Netherlands. pp 1-16 – 1-20.

Brand, Stewart (1995). *How buildings learn: What happens after they're built*. London: Penguin Books.

Bullen, P.A. (2007). Adaptive reuse & sustainability of commercial buildings. *Facilities*. vol 25. 20-31.

CIDB (2003). *IBS Survey 2003 - A Survey on the Usage of Industrialised Building System in Malaysian Construction Industry*. Kuala Lumpur: Construction Industry Development Board (CIDB)

CIDB (2008). *IBS Implementation in Malaysia*. Kuala Lumpur: CIDB

Collier, R. and Thelen, E. (2003). *User-system interaction based on spoken dialogue in the new everyday*. Rotterdam: 010 Publishers.

Davison, N., Gibb, A.G., Austin, S.A., and Goodier, C.I. (2006). The multispace adaptable building concept and its extension into mass customisation. Paper presented at the *International Conference on Adaptable Building Structures*, the Netherlands: Eindhoven.

Del Aguila, Alfonso (2010). The adaptation of building industrialization in a world subjected to multiple changes. Paper presented at *16th International Conference on Open and Sustainable Building.* Jointly organized by CIB W104 – Open Building Implementation and TECNALIA, Bilbao, Spain.

Douglas, J. (2006). *Building Adaptation*. Massachusetts: Butterworth Heinemann, Stoneham.

Eguchi, T., Schmidt III, R., Dainty, A., Austin, Simon & Gibb, Alistair (2010). The design of adaptable building in Japan. Paper presented at *16th International Conference on Open and Sustainable Building (O&SB 2010)* jointly organized by CIB W104 – Open Building Implementation and TECNALIA, Bilbao, Spain.

Ellison, L. and Sayce, S. (2007). [Assessing sustainability in the existing commercial property stock]. *Property Management*. vol. 25, no. 3. 287-304.

Friedman, Avi (2002). *The adaptable house*. New York: McGraw-Hill.

Giddens, A. (1990). *The Consequences of Modernity*. Oxford: Polity Press.

Girmscheid, Gerhard (2010). Principle precast systems and their application. Paper presented at the seminar ob *the New Perspective in Industrialization in Construction – A State-of-the-Art Report* organized by Eigenverlag des IBB, Zurich, Switzerland.

Giurdanella, Valeria and Zanelli, Alessandra (2010). Temporary building intended as adaptable and reversible building: A sustainable strategy for housing – The recent situation in Italy. Paper presented at the seminar ob *the New Perspective in Industrialization in Construction – A State-of-the-Art Report* organized by Eigenverlag des IBB, Zurich, Switzerland.

Habraken, Neil John (1976). *Variations: The Systematic Design of Supports*. Massachusetts: Laboratory of Architecture and Planning at MIT.

Hassim, S., Jaafar, M. S. and Sazali, S. A. A. H. (2009) The Contractor Perception Towards Industrialised Building System Risk in Construction Projects in Malaysia *American Journal of Applied Sciences*, 6 (5), pp. 937-942

Hinte, E. V. and Neelen, M. (2003). *Smart Architecture*. Rotterdam: 010 Uitgeverij.

Iturralde, Kepa (2010). Research for a construction system fabricated by computer numerical control machinery. Paper presented at *16th International Conference on Open and Sustainable Building (O&SB 2010)* jointly organized by CIB W104 – Open Building Implementation and TECNALIA, Bilbao, Spain.

Laila Ahmad Moharram (1980). *A method for evaluating the flexibility of floor plans in multi-story housing*. Unpublished doctoral disertation. University of Pennsylvania, USA.

Lawson, Mark R. and Ogden, Ray (2010). Prefabricated systems in light steel and modular construction. Paper presented at the seminar ob *the New Perspactive in Industrialization in Construction – A State-of-the-Art Report* organized by Eigenverlag des IBB, Zurich, Switzerland.

Leupen, Bernard (2002). *Frame and generic space: A research on adaptable housing,* (in Dutch, summary in English). Rotterdam: 010 Publishers.

Mansfield, J. R. (2002). What's in a name? Complexities in the definition of 'refurbishment'. *Property Management*. vol. 20, no. 1. 23-30.

Mollaert, M., Hebbelinck, S., Haase, J. (2000). Patterns, membrane and boundary conditions: Bridge between engineering and architecture. Paper presented at the *4th International Colloquium on Structural Morphology*. Delft, The Netherlands. 241-248.

Nijs, Jochem C., Durmisevic, Elma and Halman, Johannes I. M. (2010). Interface design for open systems building. Paper presented at *16th International Conference on Open and Sustainable Building (O&SB 2010)* jointly organized by CIB W104 – Open Building Implementation and TECNALIA, Bilbao, Spain.

Ozaki, R. (2002). 'Mind The Gap': Customers' Perceptions and the Gaps Between What People Expect and What They Are Offered. In *Consumer Choice in Housing*. York: The Joseph Rowntree Foundation.

Rahman, A. B. A. and Omar, W. (2006). Issues and Challenge in the Implementation of IBS in Malaysia. *Proceeding of the 6th Asia Pacific Structural Engineering and Construction Conference (ASPEC 2006)*. 5-6 September 2006. Kuala Lumpur, Malaysia

Richard, Roger-Bruno (2010b). Four strategies to generate individualized buildings with mass customization. Paper presented at the seminar ob *the New Perspactive in Industrialization in Construction – A State-of-the-Art Report* organized by Eigenverlag des IBB, Zurich, Switzerland.

Rosli Mohamad Zin (2004). *Design phase constructability assessment model*. Unpublished doctoral dissertation. Universiti Teknologi Malaysia, Skudai.

Sarja, A. (1998). *Open and industrialised building*. London: E & FN Spoon.

Thanoon, W. A., Peng, L. W., Kadir, M. R. A., Jaafar, M. S. and Salit, M. S. (2003) The essential characteristics of Industrialized Building System in *International Conference on Industrialised Building Systems* Construction Industry Development Board (CIDB) Malaysia, Kuala Lumpur, Malaysia, 10-11 September 2003

Tipple, G. (2000). *Extending Themselves: User-Initiated Transformations of Government-Built Housing in Developing Countries.* Liverpool, England: Liverpool University Press.

Von Stamm, B., (2003). *Managing innovation, design and creativity*. Chichester: Wiley.