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# Adaptability Model for Precast Panel Housing: Case Study at Teacher's Quarters in Malaysia

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**Abstract**

The preliminary idea to this research come from the Construction Industry Master Plan that is to transform and industrialized the Malaysian construction industry to a more systematic and mechanized system. The development of adaptable housing is still in its infancy stage in Malaysia. Adaptable housing with open systems offers the possibility of using products from different manufacturers. Understanding the user's needs, designing solutions and developing architectural programming for adaptable housing may enhance the usage of Industrialized Building System (IBS) in housing. This research is a continuation from a previous research carried out by Asiah et al (2009). The objectives of this paper: first, to study about the level of satisfaction of users in Teacher's Quarters, and; second, the application of concept of adaptability in housing using IBS. The questionnaires were distributed to the tenants of teachers' quarters in the urban, suburban and rural area of Selangor and Perak. The teacher's quarters which were constructed during 1998 to 2002 remain as the biggest housing in Malaysia constructed using IBS. The research examined the needs and level of satisfaction of residents for every internal space of the quarters such as the living area, dining area, kitchen, bedroom and bathrooms. Most of respondents are dissatisfied with the spaces in their house. Although all five spaces are equally important but have varying impact on adaptability varies. Thus study reviewed all spaces in an integrated manner in accordance to the conceptual model proposed in this study. The model is considered as a part of criteria in developing architectural programming for adaptable housing in the future.



*Key-word:* - adaptability, IBS, teachers' quarters, internal space and architectural programming

## 1. Introduction

This paper presented a research as a continuation from a previous studies carried out by Asiah et al (2009). The objectives are to study about the level of satisfaction of users in housing using Industrialized Building System (IBS). The questionnaires were distributed to the tenants of teachers' quarters in Selangor and Perak. The teacher's quarters which were constructed during 1998 to 2002 remain as the biggest housing constructed using IBS in Malaysia. The research examined the needs and level of satisfaction of residents for every internal space such as the living area, dining area, kitchen, bedroom and bathrooms. The result of the study is considered as a part of criteria for adaptable design of housing using IBS in future.

## 2. Adaptibility and Industrialized Building System in Malaysia

The adaptability of buildings is inextricably linked with the coordinating and preferred size of the component for residential buildings. According to Habraken (2005) adaptable house must distinguish between two different decision-making levels i.e. support and infill to ensure that buildings can be optimally modified to meet changing for future use. While Industrialized Building System (IBS) is a construction process that utilizes techniques, products, components or building systems which involved prefabricated components and on-site installation. The Construction Industry Development Board (CIDB) of Malaysia has defined IBS as "a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works" (CIDB, 2003). The idea of using IBS in Malaysia was first mooted during the early sixties when the Minister of Housing and Local Government of Malaysia visited several European countries and evaluated their building systems performance. From the structural classification, there are five IBS main groups identified that have been used in Malaysia as follows:

- Pre-cast Concrete Framing, Panel and Box Systems
- Steel Formwork Systems
- Steel Framing Systems
- Prefabricated Timber Framing System
- Block Work System

Essiz & Koman (2006) found that design demands in artistic and technical aspects are increasing towards industrialization. According to Zulkefle (2010), the combination of building standards together with functional and aesthetic designs could utilize the full advantage of IBS without creating lifeless buildings and environment. Erman (2002) claimed that aesthetic considerations became an inseparable part of building components without putting its primary function aside. On the other hand, the MS 1064 Part 10 as the standard of reinforcement concrete components for Modular Coordination (MC) played an important role for architectural design by utilizing precast concrete. In addition, the feasibility of joints and connections can be improved with the Concept VII of Joints and Tolerance in Modular Design Guide (CIDB, 2009). Therefore, the possibility of the application concept of adaptability for home design could be realized (Zulkefle 2010).

A basic interpretation of adaptability is the refitting of a physical environment as the result of a new circumstance. Friedman (2002) defined adaptability for homes 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". However, homes in Malaysia have followed another path. It has always been conceived as something necessarily static and safe. What happened to the "machine à habiter" that Le Corbusier proposed at the beginning of the 20th century? According to Jacqueline (2009), the problems arose from 'social engineering' resulting in ill-matched homes and users. Therefore, the organized and accessible standard such as MS 1064 as a design guideline to MC is crucial in promoting IBS as well as adaptability towards Open Building System in Malaysia. Thus, the adaptability should be reconfigured in a relatively straightforward manner at the designing stage as occupant living requirements change over time. The potential for change in a house during its use is an important factor in the design of housing

environment. A critical mistake was ill-adapted or mismatches to change during use and become outdated, because they cannot meet either new standards or new expectations of the users.

## 3. Open Building System

Building with open systems offers the possibility of using products from different manufacturers. Compare with closed systems, the open system is not allotted to a single building, but it based upon the combination of various prefabricated building parts. When designing with an open building system, the architect determines the function of the building components and select potential manufacturer. Thus, a Dutch Architect, Neil John Habraken founded the Foundation for Architects' Research or *Stiftung Architekten Research* (SAR) which led to the development of Open Building System. He has proposed a radical new approach in the design and production of frame structures and built-in fixtures by dividing house into two parts: support and infill. Support (base building) is the communal parts of the building containing the structure, services, etc. and infill (fit-out) as the private portion of the building that is tailored to the needs of the occupants, and is flexible enough to cater changes over time (Friedman, 2002; and Staib et al, 2008). The layouts were to be open-plan, with only kitchen and bathroom locations being fixed; the remaining areas could be individually designed by the users. This approach brings the idea of the contemporary proposals for the Japanese Metabolists and Operation Breakthrough. Open Building System was defined as a free interchangeability of components of different products and technologies (Warszawski, 1999; and Friedman, 2002), split the building into key elements such as structure, services, cladding and fit-out (Gann et al., 1999; and Kendall & Teicher, 2000). In order to minimize assembly difficulties, the elements are should be standardized, dimensionally coordinated and rules of classification decided upon (Staib et al, 2008). These could lead to new forms of organizing the production process using prefabricated elements.

In the building industry, a standardized modular dimensions are used in the manufacture of construction elements to ensure the different manufactures employ the same dimensions. However, in the political terms, the need to develop housing using prefabricated building methods was recognized in the form of industrial building. For instance, the experimental housings of Steidle's at Germany in 1970-72 (Staib, 2008), of George Maurios at France in 1975 (Kendall & Teicher, 2000), and of NEXT21 at Japan in 1994 (Asiah & Zulkefle, 2011). The systems allow flexibility and variation which encourages residents to fit-out, use and alter their housing as shows in Figure 1 as follows.

i) Housing experiment of Genter Straβe at Munich, Germany (Staib, 2008)

ii) Housing experiment of NEXT21 at Osaka, Japan (Asiah & Zulkefle, 2011)

Figure 1
Experimental Housing for Open Building System at Germany and Japan

Open Building System was also popular in the Netherlands and Finland, but its adoption has been hindered by major changes in the design and construction that often resulted in an increase in the construction cost. From the beginning of the 1960s, countless rigid systems were developed for the applications of renovation using prefabricated Open Building System such as ENTRA and MOBIT. Consequently, in the early 1970s, the Finnish BES system for housing used a basic design unit and a multi-module of 12M (Warszawski, 1999). It employed slabs, walls, bathroom, staircase and several components of standard dimension, as shows in Figure 2 as follows.

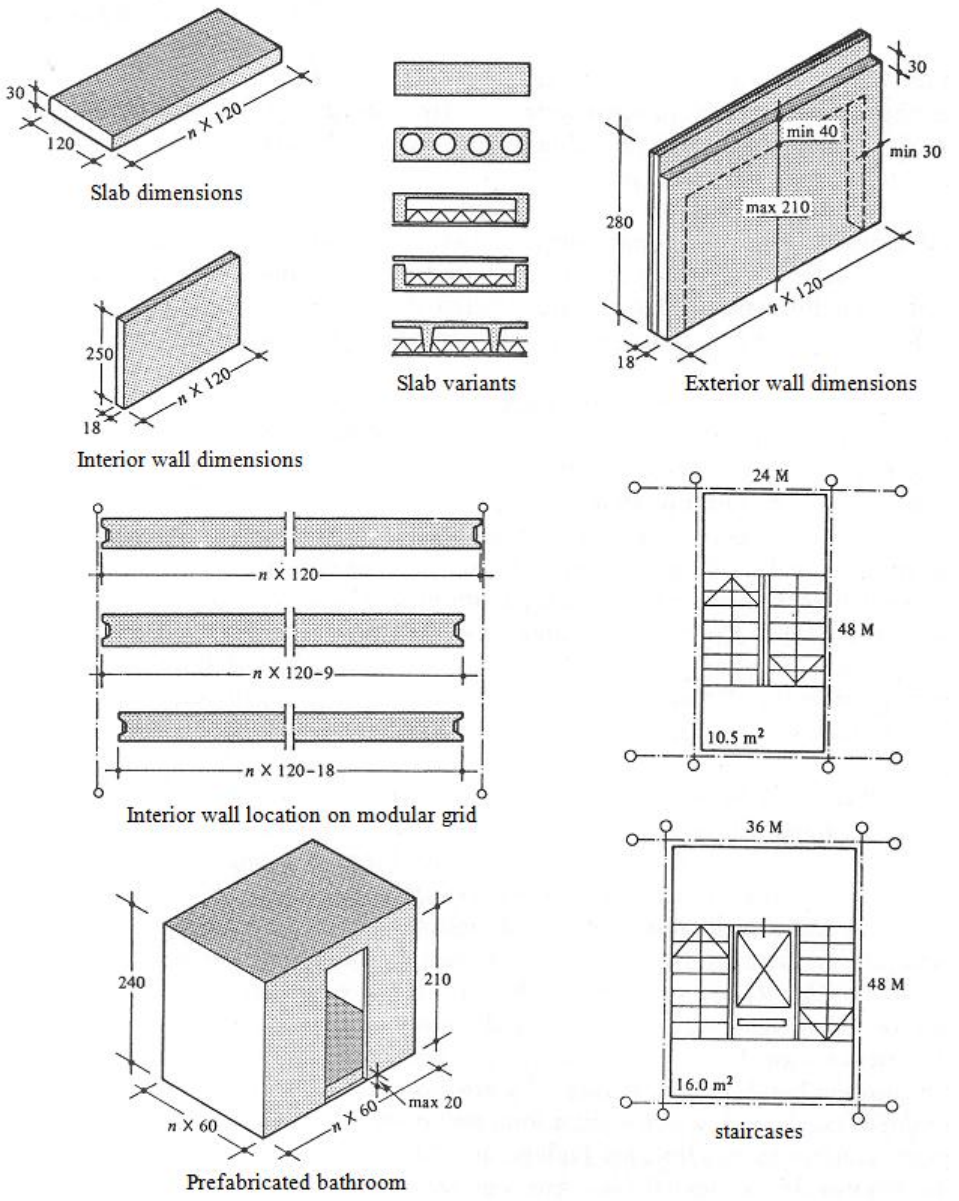
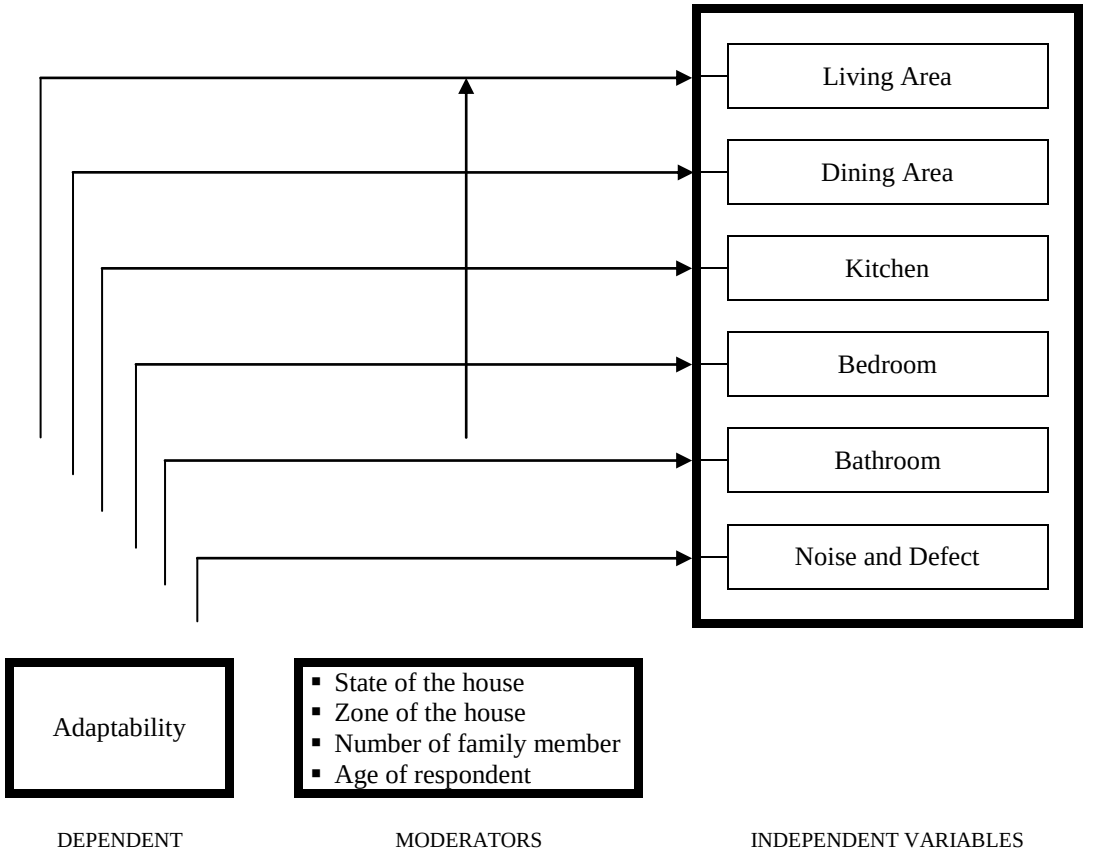



Figure 2
The Finnish BES System Components from Finland.
Source: Warszawski (1999)

**4. User's Satisfaction of Internal Spaces in Teacher's Quarters**

The project was known as Privatization Project for the development and construction of teachers' quarters for Ministry of Education, Malaysia. The project was launched in 1998 and consists of 10,000 units of apartments on 107 sites for teachers' quarters throughout Malaysia. Each apartment unit has 3 bedrooms, 2 bathrooms, a living room, a dining room, and a balcony. Durability is a key point in preventing the deterioration of structures and members of the Teacher's Quarters (as shows in Figure 4) over time for the safety, comfort and health of the users. According to Asiah et al (2009), most of the users in Malaysia are fairly satisfied with their house finishing, such as noise transmission from outside to the room, and the defect of building's component. Crack remains the highest case of defect occurred for the houses in Malaysia, especially for single and double storey terrace housing. In addition, most of Malaysian prefers to improve their house by doing renovation and extension. In the other hand, they are preferred to be different from their neighbour and varieties in their needs through time. Based on the problem statement, the research objectives were developed as follows**.** to develop a model for adaptability of IBS-housing that considers the satisfaction of users and their demographic background and to develop an instrument for measuring adaptability of IBS-housing. 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 Klang Valley. This model shows adaptability as dependent variable. Six independent variables and three moderators were used for the study. The six independent variables were living, dining, kitchen, bedroom, bathroom, and noise and defect. Supporting hypotheses were formulated base on this model. The finalized conceptual model for this study was developed using the factor approach to better understand the relationship between causes and effects (Figure 3).



VARIABLES

Figure 3:
A Conceptual Model of Adaptability

Figure 4:
Teacher's Quarters at Redang Panjang, Selama, Perak Darul Ridzuan.

## 5. Methodology

The methodology used in this research will be survey using questionnaires. Stratified random sampling will be used. In this sense the method is very economical, offers accurate results while offering a degree of representative and it is very useful. Assessing the adaptability of teachers' quarters is a complicated process, sometimes interactional and sometimes individualistic. Studying how adaptability could be developed requires methods of research that can capture the multiplicity of activities that make up the learning process as well as permit an understanding of the organizational environment that influences these activities. This methods able to answer the research questions as mentioned earlier. Table 1 provides a summary of tools utilized and subjects used to address the respective research questions.

Table 1:
Research questions, research tools, and site/subject for the study

| CODE | RESEARCH QUESTION | TOOLS | SITE/SUBJECT |
|---|---|---|---|
| RQ1 | What are the levels of satisfaction in order to enhance adaptability in teachers' quarters and how are the satisfactions ranked? | Survey questionnaire | 233 tenants from 10 teachers' quarters at Perak and Selangor |
| RQ2 | What is the relationship between satisfactions and adaptability, and any differences in adaptability and satisfactions based on the background of tenants in teachers' quarters? | Survey questionnaire | 233 tenants from 10 teachers' quarters at Perak and Selangor |

In order to answer the quantitative research questions and to meet the specific research objectives, the sample characteristic of the dependent and independent variables as well as the hypotheses developed were analysed using various statistical techniques. The normal sequence for statistical analysis is to conduct factor analysis first to delete redundant items, followed by reliability analysis to ensure that the data is reliable for further analysis, i.e., descriptive and inferential analyses. In this study, two non-parametric tests for multiple independent samples were used which are the Mann Whitney U and Kruskal-Wallis tests. The Mann Whitney U is the non-parametric tests for two independent samples. It is useful for determining whether the values of a particular variable differ between two groups. The Kruskal-Wallis test is a one-way analysis of variance by ranks. It tests the null hypothesis that multiple independent samples (more than two) come from the same population.

## 6. Findings

Based on Research Question 1, there was only one hypothesis to be tested using Kendall's coefficient of concordance based on the outcomes from the survey. The Kendall's coefficient of concordance (*W*) was computed to measure the level of consensus among tenants for the factors proposed. The Kendall's coefficient of concordance and *p*-value for scored ranking were 0.233 and 0.000 respectively. Since the *p*-value was less than 0.05, the study was found to be statistically significant and consistent. Based on the finding, the orders of importance for the five factors are kitchen, dining area, bathroom, bedroom, and living area.

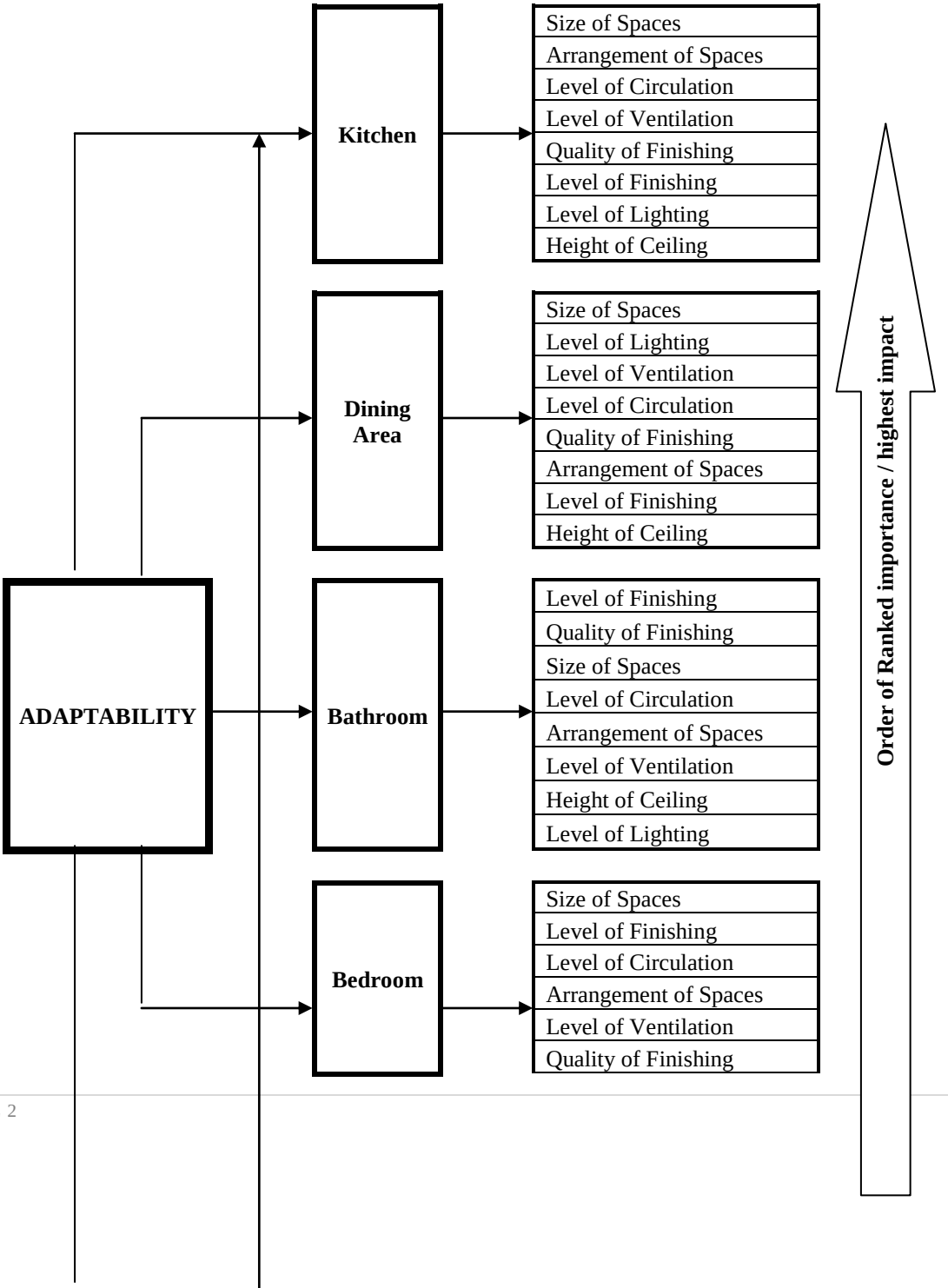
With regards to the first part of Research Question 2, a correlational analysis was performed between adaptability and the other five variables: living area, dining area, kitchen, bedroom, and bathroom. Based on the correlational analysis, all five variables were significantly and positively correlated with adaptability. The highest Pearson correlation value was 0.254 for bedroom, while the lowest Pearson correlation value was 0.205 for bathroom. To address the second part of Research Question 2, the Mann Whitney U and Kruskal Wallis tests were conducted to test differences of mean ranking of items related to adaptability.

In this study, the difference in ranking of certain attribute of adaptability is highest for tenants with aged from 21 to 30 for the family activities (breakfast, lunch, dinner, etc), and family gathering (interaction between non-neighbourhood), while tenants in age from 31 to 40 years old for the activity of teaching, learning and studying (preparing lesson plan), and social meeting (interaction between neighbourhood) in their house.

The difference in ranking is also highest for certain attribute of adaptability for the quarters located at rural area as follows:

- KIP Sungai Setar, Parit Buntar, Perak Darul Ridzuan
- KIP Matang Jelutung, Bagan Serai, Perak Darul Ridzuan
- KIP Simpang Empat, Semanggol, Perak Darul Ridzuan
- KIP Redang Panjang, Selama, Perak Darul Ridzuan

The main contribution of this study is to revised adaptability model which is shown in Figure 5. The revised model takes into consideration all the major findings from the quantitative analysis. The revised model also ranked variables and its related items from highest to lowest as well as maximum to minimum impact respectively.



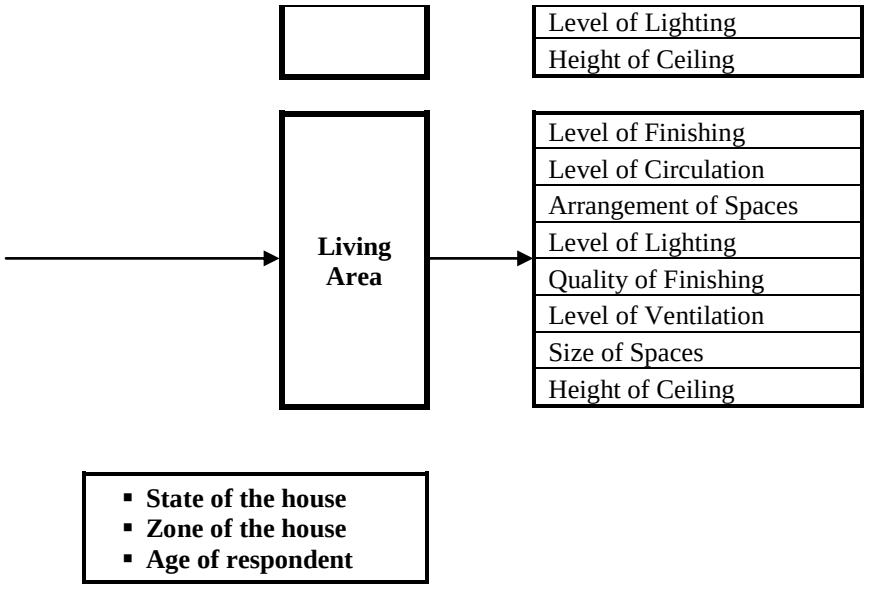



Figure 5:
Revised Adaptability Model

The rigour in testing of hypotheses and propositions makes this a valid model to assess adaptability and the satisfaction among users of IBS-housing in Malaysia. However, this model has its shortcomings as it is based on surveys which are snapshots of perceptions at a particular point of time. Further to this, the rapid evolution of adaptability in design stage could further affect the applicability of this model beyond this study.

A major methodological contribution of the study is the development of a survey instrument for measuring adaptability among users of IBS-housing. Recognising the inadequacy of the existing instruments, this instrument was developed by modifying the existing instruments for measuring user's satisfaction in the previous study in 2009 at Klang Valley. The questionnaire has been content validated through exploratory factor analysis, and criterion validated through the hypothesis testing, where the relationships with other variables in the theoretical model were tested with significant relationships. Moreover, the items in the instrument have shown a high level of reliability.

This study indicated that the tenants were highly dissatisfied with size of spaces, and they were basically eager to achieve the highest possible adaptability level. At the moment, the building industry is not organized to provide this need to the users. The industry should take advantage from the current technology of IBS towards adaptability in order to achieve the ultimate objective for the creation of effective and innovative products for the housing.

The requirement for building adaptability is becoming increasingly relevant from both commercial and sustainability perspectives. It may also be more amenable to incremental growth and thus to introduction of innovative technologies and policies. As the matter of policy, whilst adaptability needs further emphasis as an important component in the IBS-housing developmental effort, the flexibility of building should also be given greater emphasis. The building is usually divided in support and infill with regard to flexibility. The infill undergoes changes when flexibility is applied. However, daily building practices reveal that the applied solutions have not been satisfying until today. The application of changes to products and product platforms based on user requirements is a common practice.

Housing policy for IBS-housing is based on the tacit assumption that new residential dwellings must be of a high architectural quality and of a high standard with respect to building technology and that they ought to manifest themselves in a contemporary idiom. Additional, new dwellings ought to be designed with some kind of experimentation in mind, taking a point of departure in the surroundings' urban character and potentials. These aims pose great demands – and not only on the architectural trade. The demands are imposed on the entire construction branch, on the authorities and on the users, who exert their influence on the market as a consequence of supply and demand.

User's perception about their satisfactions confirmed that Architectural Programming is crucial to be prepared by architects as a solution to achieve adaptability of IBS-housing. The analysis identifies the following ten activities have been carried out in the house:

- Daily family activities (breakfast, lunch, dinner, etc)
- Teaching, learning and studying (preparing lesson plan)
- Family gathering (interaction between non-neighbourhood)
- Social meeting (interaction between neighbourhood)
- Society meeting (interaction between members of society)
- Family ceremony (birthday party or small *kenduri*)
- Family celebration (wedding party or big *kenduri*)
- Open house (Hari Raya, Chinese New Year, Deepavali)
- Discussion and consultation (counselling session)
- Exhibition (critic session or portfolio review evaluation)

However, the wall as a rigid element remains the obstacle therefore affects the structural adaptability. The possibility offered by a wall structure is that openings can be made to bring two spaces in connection, without the loss of structural qualities. Such a structural wall could standard contain openings which are filled by a lightweight infill. In time these infill could be taken out to combine the two spaces. A possible solution can be a development such as an "Architectural Programming of structural separation element". Such element can be designed for a predestined use with a fixed facility program, which supports the concept of flexibility i.e. the principle of the adaptable housing, as shows in Figure 6 as follows.

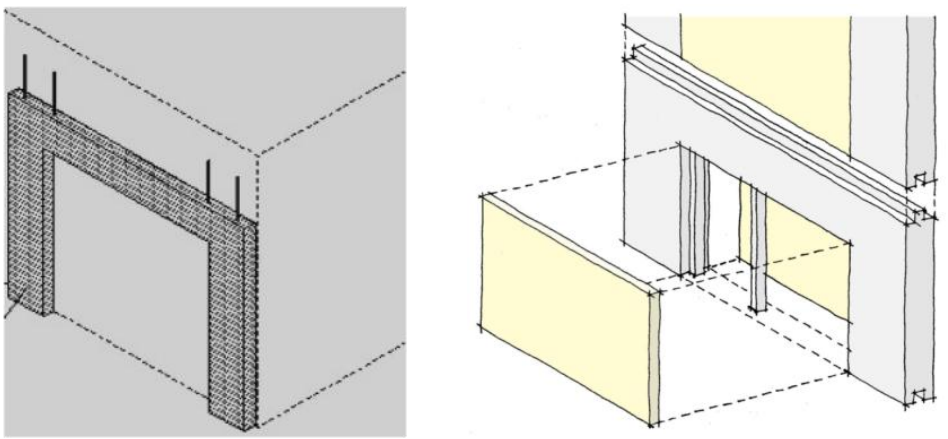


Figure 6:
Architectural Programming of Structural Separation Element as a part of Infill Unit

## 7. Recommendations

From the architectural design perspective, IBS can accommodate new technologies, together with the preparation of Open Building System that urgently needed. All construction player as well as stakeholders must work together during planning, design and pre-construction stage to ease in the implementation of adaptability towards Open Building System in housing through which the regulations should be eased as follows:

- The easing of permits linked to the public and private spaces.
- The easing in sharing facilities as a solution to the step-wise application of adaptable housing design standards that considers remodelling.
- The standard dimension of components according to Modular Coordination.
- The allotment for special repairs as well as the reserve for residential repairs.

Thus, the research recommends Architectural Programming for housing to be carried out at the unit level during its lifespan. Towards the application of Open Building System in Malaysia, the Architectural Programming should considers the elements of support and infill, and the control of services system such as electrical, plumbing and water supply system. Also, the post-construction and maintenance during occupational stage should be considered for ease of inspection and installation of parts for services system. The development of technologies and structures for adaptable housing is being proposed. A few potential lightweight wall structures and ceiling materials with plug-in assembling concept should be further researched. Such would be supported by the technological development of IBS and introduction of new support and infill appropriate for adaptable housing, such as development and distribution of structural forms, and R&D of various interior finishing methods and designs.

## Conclusion

As this is a new concept and approach, the government should actively support and giving publicity as it was the most important factors for the successful. 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 Open Building System which have been considered through IBS Roadmap, was needed in the consciousness of residents through education regarding the maintenance, management, and adaptability. It was also viewed that architectural programming for adaptable housing is needed in preparation of standardized design plans, as well as developing IBS, economic support, and an accurate demand appraisal.

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