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Indoor Environmental Regulation hrough Preference and Behaviour of Inhabitants in Houses

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Abstract

Regulating the indoor environment for comfort and energy savings requires appropriate attitude and human behaviour of the house inhabitants. The aim of this study is to identify people's main concerns when building or choosing a home. The research intends to determine how human behaviour regulates the indoor environmental conditions in houses towards achieving comfort and energy savings. A questionnaire survey was conducted through convenient sampling method with approximately 125 respondents. The results indicated the preferences for comfort and inhabitants' attitude and behaviour in regulating the indoor environment.

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Keywords: Human behaviour; comfort; energy savings; house

1. Introduction

'Baiti Jannati', 'Rumahku Syurgaku' or 'My home, My heaven' is a concept that has been propagated in Malaysia since 1992 for inhabitants to regard the home as a place of refuge. As a reflection of heaven, a place of refuge, should accommodate the needs of human behaviour and provide comfort. This concept has been adopted by many agencies, be it government agencies, developers, private companies and sole proprietors. The focus of these agencies are mainly on social conditions; i.e. by recommendations on the

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number of rooms and size of spaces. In line with this concept, Tenaga Nasional Berhad (TNB) as an electric utility has extended assistance through Baiti Jannati Program to assist the poor to own comfortable homes with basic amenities since 2008. The involvement of TNB on this matter has include sustainability issues and involved energy use in buildings. An important issue to maintain comfort in the home is the cost factor that has a major portion contributed to the energy sector. Residential sector in Malaysia has been recorded to emit 2,347,538 tonne of CO2 and projected to increase up to 11,689,308 by 2020. Therefore, the importance of energy in assisting the provision of comfort is undeniable in these days, especially in the urban area due to the given environmental conditions. Due to the heat island effect in the urban areas, cooling of the indoor spaces, especially in houses has become a prevailing issue. The idea is to achieve comfort with minimal use of energy in the houses. The tendency and inclination to rely on air-conditioning effect the energy demand and emissions of CO2. The cooling needs and reliance on the air-conditioning has exacerbate rather than mitigate climate change.

Hence, a home should be designed in view of energy efficiency that relies mainly on attitude and behaviour of the inhabitants. It is important to gauge the attitude of house inhabitants in regulating the indoor environment. What are the attitude of the house inhabitants towards energy efficiency? How do they control the indoor environment to achieve comfort? What are the steps taken? What are the preferences of inhabitants in achieving comfort? What affects their choices in achieving thermal comfort? What are the influencing factors? These questions are inevitable to understand how the above concept of Baiti Jannati can be realised and the determine the attitude and behaviour of the house inhabitants. Appropriate human behavior of the inhabitants are integral in regulating the indoor environment to achieve comfort and energy savings. This research intend to answer the questions posed in order to understand and suggest appropriate indoor environment that suits the attitude and behaviour of house inhabitants. In short, a house should be a place of refuge that support the need of human comfort and behavior, and, in turn the inhabitants have the ability to regulate their indoor environment.

2. Literature Review

This research looks into issues of respondents' preferences, attitude and behaviour to achieve comfort in houses. The literature review indicate the area of focus for this research. The focus area encompasses human attitude and behavior, comfort and expectations in houses.

Human behaviour is the anticipated as the main factor that governs the quest for comfort in the houses. Many researches have been conducted to determine how human behaviour has influenced different sectors of energy savings of both commercial and residential building (Bell et al.,1996; Wilk, 1999; Lutzenhiser, 1993). Ibrahim and Noor Hanita (2014) have forwarded that major issues in households energy use are: architectural (design) issue, appliances/services (technology) efficiency issue and the human (behavioural) issue. The study done in Nigeria focused on the said issues to determine the factors that effects energy efficiency on pre-determined housing samples. The survey questionnaire are also accompanied with interviews with the inhabitants to gauge their experiences and behaviour in the houses. The results of the study indicated that there are strong correlation between attitude and behaviour to energy efficiency in the houses. It is interesting to note that the study found that age and level of education of the respondents are the influncing factors towards the occupants attitude to energy savings. In addition, Diez-Nicholas (2006) forwarded that preceding human behaviour is the attitude factor. According to him, attitude preceded behaviour and propagated that it as instrumental collective responses of the population to achieve the best adaptation possible to their environment. Factors such as education/ awareness and social status may have implication on energy efficiency awareness but not necessarily determine it (Abdul Majid and Hussaini, 2011).

Achieving comfort is one of the underlying factors in the regulation of an indoor environment. Vischer (2007) proposed three levels of comfort considerations including physical, functional and psychological. The basic physical comfort factor adopted by Vischer is that a home should provided shelter from physical treat in the environment. This basic definition can be elaborated further if physical comfort is discussed in detail; where physical comfort can relate to thermal, visual and spatial qualities. Human preferences to a conducive environment have been studied in many areas; i.e. thermal comfort and daylighting. In achieving energy efficiency, users' perception of the important consideration for the environment will be in terms of lighting and space (Nadzirah et.al, 2012).

Furthermore, comfort can also be through aesthetic, visual and thermal comfort, and flexibility in the use of spaces. Aesthetics is seen as another factor considered by homeowners. Masran et. al (2012) discussed how homeowners renovated their houses to achieve different aesthetical preferences. The authors suggested that people are expressive towards their aesthetic preferences, although it is interesting to note that 32% of the case study have opted for modern tropical style. This option has the potential of being interpreted purely as a style preference or a reaction towards the given tropical environment. In achieving comfort, tropical style buildings incorporated large overhangs, pitched roof, large openings for natural ventilation and daylight, and sun shading devices. These factors contributed to thermal and visual comfort of the inhabitants. In addition, tropical architecture also has open plans or minimal partitions to allow for cross ventilation and flexible use of space.

Sociocultural factors such as privacy also contributed to comfort of the inhabitants. Zaiton and Ahmad Hariza (2012) stated that ideally house designs should meet and support the needs of a family in terms of the activity system, privacy and social interaction. These needs need to be seen in line with the requirements to regulate the indoor environment for comfort purposes too. Different regions have unique architectural solution as a reaction to a given environment. Architecture in each region gives us precious lessons of the perception, behavior and specific solutions to the natural environment which formed the regional specific culture (Hoang, 2013).

All factors discussed laid the criteria for a comfortable house. Nevertheless, the current houses faced problems in achieving desired comfort. Zaiton (2007) studied the modifications made by the inhabitants of two storey low cost housing to meet comfort means due to the need for more space and privacy. She also added that the house inhabitants also have to seek a balance or sacrifice the privacy or thermal factors to achieve comfort. The discussion was also discussed by Noor Hanita et al. (2009) in looking at the responsive strategies versus the cultural and religious dimensions in the architecture of Malay traditional houses. The inhabitants chose between having privacy by limiting or closing openings, or thermal comfort by opening the doors and windows to allow for cross ventilation. The matter also has been further discussed by Noor Hanita et al. (2004) to discuss the equalibrium between social and climatic considerations in design new houses. Moreover, Ahmad Ezanee et al. (2012) studied factors that influenced the performance of low cost public housing and dissatisfaction among the inhabitants. The researchers found that the residents who live in public housing highlighted their dissatisfaction in terms of natural lighting, air circulation, garbage and noise among other facilities and social conditions. However, the study covered many aspects of the living conditions but did not deal in detail on the environmental conditions or the regulation of the indoor environment.

3. The Aim and Objectives

The aim of this paper is to discuss people's main concerns given the choice of specifying their needs in designing and habituating a home. The objectives of this study are to identify people's main concerns when building or choosing a home. The research intends to determine the main concern of house inhabitants; comfort, privacy, aesthetic or flexibility? Furthermore, the research also expects to ascertain

the awareness of of people on energy savings and energy efficiency. The research also investigates the importance of energy efficiency to homeowners. Understanding the concerns represent the respondents preferences when building or choosing a home. The research determines how the house inhabitants control the indoor environment to achieve comfort. The prefences of the inhabitants by using different means will be recorded. It is hypothesized that the level of education and age of the respondents relate to the awareness and behavioural conduct of homeowners. In addition, the research intends to determine how human behaviour regulates the indoor environmental conditions in houses towards achieving comfort and energy savings.

4. Methodology

The regulation of comfort can be achieved through inhabitants behavioural actions and choices in the houses. The research is conducted through questionnaire survey to identify how the respondents plan to adapt to a given condition in achieving comfort. A questionnaire survey was conducted through convenient sampling method with approximately 125 respondents. The survey administered consist of demographic data of the respondents and choice of dependent variables on regulation of the indoor environment.

5. The Results

The results indicated the respondents' preferences for comfort and awareness on energy savings. These findings are important parameters to be considered in understanding the human behaviour in regulating the indoor environment and designing comfortable houses. Figure 1 shows that the preference for comfort (64%) and privacy (47%) are important considerations to achieve in house design. The concept of comfort in this question is generic where comfort can be described in terms of thermal, visual or audio comfort. Comfort issue is more important to the respondents in comparison to the aesthetic and flexibilty factors. This shows that the respondents are more concern on the quality of living and sustainabilty of the houses. The survey results showed that the respondents choose thermal comfort as the most important consideration at 67%, visual comfort (25.6%) and audio comfort (5.6%).

As thermal comfort is the most important consideration in choosing a house, regulating the indoor environment by attitude and behaviour is most important (Noor Hanita and Hussaini, 2011 and 2012). The survey results indicated that the respondents chose opening windows (43.2%) over switching on fans or air conditioner (25.6%). The results suggest awareness on energy efficiency through the choice of maintaining thermal comfort. Moreover, the respondents also rely on passive cooling by opening windows rather than relying on modes using electricity. These passive cooling techniques contributes to energy savings and efficiency in the running cost of the houses. Opening design in the houses should be able to maximise ventilation of the indoor environment that will in turn contribute to thermal comfort. In achieving visual comfort, the respondents regulate daylighting through controlling the window openings (54.4%), curtain (32.8%) and blinds (12.8%). The solution for controlling daylight has relied both on the architectural and interior design decisions. Regulating the indoor environment for comfort; thermal or visual suggest the behaviour and attitude of respondents towards energy efficiency in houses. In addition, majority of the respondents also agreed that passive architecture design considerations are important in building design. Incorporation of other energy efficiency and sustainable systems such as rainwater harvesting, greywater treatment and solar panel were voted agreeable by the respondents. The respondents agree (59.2%) to include essential sustainable and energy efficient systems in contemporary houses. Another half of the respondents voted neutral (36.8%) and disagree (2%) with 3% missing data. The attitude towards the energy efficiency application in the houses is a 3:2 ratio. This suggests that the

awareness towards these system may still be at the initial stage among the respondents. The attitude and behaviour of house inhabitants can be improved upon creation of awareness through education of the young generation.

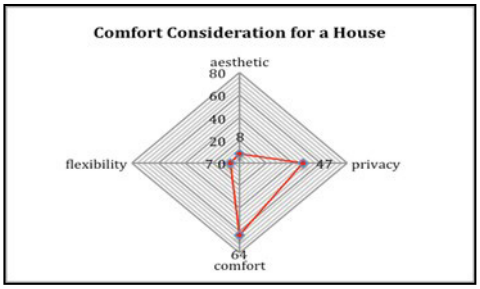

Fig. 1. Comfort Consideration for a House

The results of the survey recorded the independent variable of age and education that provided indicators to the awareness and behaviour of the respondents in regulating the indoor environment (Table 1). The ages of the respondents (figure 2) are grouped into four (4) categories; twenties (age 20-29), thirties (age 30-39), fourteen (age 40-49) and fifties (age 50-59). The percentages of age group for the respondents are 36.8%, 24.5%, 24% and 12.3% for the four age groups respectively. The level of education (figure 3) for the respondents are primary (0.8%), secondary (20.8%), university (69.2%) and others (9.2%). The higher percentages of, the lower age group or, the younger generation and university educated respondents suggest that a higher level of awareness for the importance of energy efficiency in houses (figure 4). Figure 5 supports the above assumptions where 97.6% of the respondents voted that the consideration of energy efficiency in designing homes are most important (45.6%) and important (52%). These figures asserted that the attitude towards energy savings and efficiency is positive among the respondents.

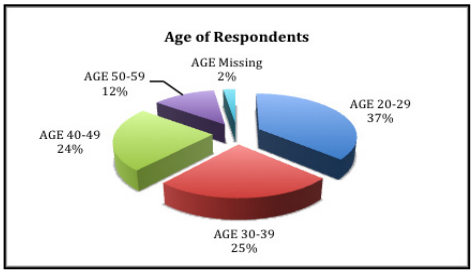

Fig. 2. Age of Respondents

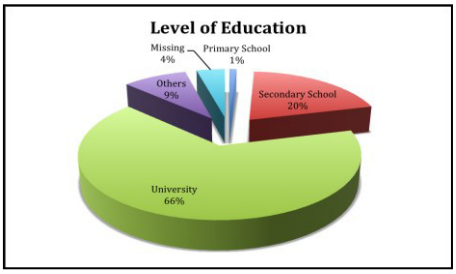

Fig. 3. Level of Education

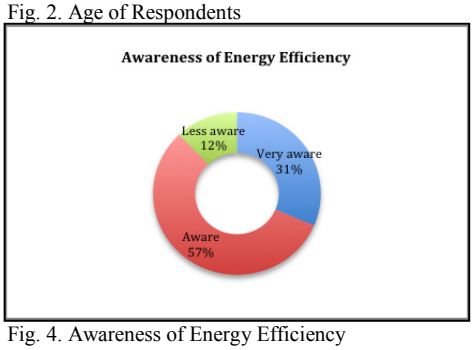

Fig. 4. Awareness of Energy Efficiency

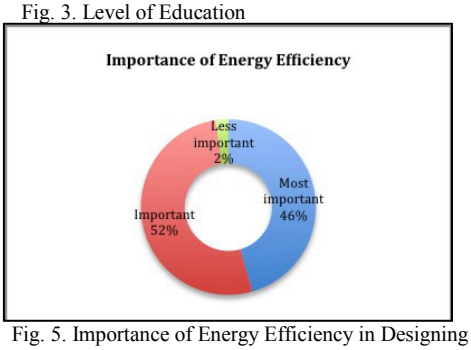

Fig. 5. Importance of Energy Efficiency in Designing Houses

Table 1. Demographic Variables of the Respondents

No	Demographic variables	Description	Frequency	Percentages
1	AGE	20-29	46	36.8
		30-39	31	24.8
		40-49	30	24
		50-59	15	12.3
		Missing	3	2.4
2	Level of Education	Primary School	1	0.8
		Secondary School	25	20
		University	83	66.4
		Others	11	8.8
		Missing	5	4

Table 2 indicates the summary of responses to energy efficiency in houses. Almost 70% of the respondents feel that the thermal comfort is the most important consideration in designing a house. This fact supports that the regulation of the indoor environment is essential in achieving thermal comfort. Regulation of thermal comfort can be executed in various ways; i.e. by opening and closing windows, switching on fans or air-conditioning. These steps goes from a passive energy solution of regulating the openings by closing and opening the windows; to low energy solutions of switching on the fan and to high energy means of using the air-conditioner. In addition, the research also indicates that energy efficiency and occupant behaviour to be approximately 50% of the factors that are most influential in a house design. The results indicate that the constraint or consideration in building a house is construction cost. Hesitation to include some energy efficient fixtures for the home is highly affected by the construction cost of the house.

Table 2. Responses to Consideration of Energy Efficiency

No	Variables	Description	Frequency	Percentage
1	The most important comfort aspect in house design	Thermal comfort	86	68.8
		Visual Comfort	32	25.6
		Audio Comfort	7	5.6
2	Most influenctial factor in house design	Occupant Behaviour	32	25.6
		Energy Efficiency	32	25.6
		Construction Cost	61	48.8

Correlation analyses are performed to further test on the awareness of energy efficiency and regulation of the indoor environment. The independent variables of age and level of education are correlated to the respondents' responses on attitude and behaviour regarding house design. Table 3 shows the correlation results between the age of the respondents and environmental concerns in the home. The results shows significant correlation between respondents' age to the factors influential in house design. Another

significant correlation is also seen between the age factor to the need to include energy efficient and sustainable strategies in house design.

Table 3. Correlations Results (age of Respondents to environmental concerns in houses)

Spearman's rho	Age of respondent	Correlation Coefficient	1.000
		Sig. (1-tailed)	.
		N	122
	1. Consideration of energy efficiency in designing homes	Correlation Coefficient	.029
		Sig. (1-tailed)	.376
		N	122
	2. Aspect of comfort in house design	Correlation Coefficient	-.083
		Sig. (1-tailed)	.183
		N	122
	3. Factors influential in house design	Correlation Coefficient	.170*
		Sig. (1-tailed)	.031
		N	122
	4. Aware of the importance of energy efficiency in houses	Correlation Coefficient	.035
		Sig. (1-tailed)	.351
		N	121
	5. Human behaviour influences energy efficiency practices	Correlation Coefficient	-.048
		Sig. (1-tailed)	.301
		N	121
	6. Passive architectural consideration in house design	Correlation Coefficient	-.021
		Sig. (1-tailed)	.4 08
		N	121
	7. Rain water harvesting, grey water treatment, solar panel, etc. are essential energy efficiency system to be included in the contemporary house design.	Correlation Coefficient	-.171*
		Sig. (1-tailed)	.031
		N	119

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

Correlation is significant at 0.05 level (one-tailed); Spearman's rho correlation test statistics is 0.170 and -0.171 for questions No 3 and 7 describing the preferences for energy efficiency and sustainable strategies have a significant relationship to age factor. 63.1% of the respondents are below 40 years of age where the attitude and awareness towards energy efficiency are higher.

Table 4 shows that the correlation results between the level of education of the respondents and environmental concerns in the home. The results shows significant correlation between level of education to the factors influential in house design. However, there are weak correlation between the education level of respondents to other environmental concerns in choosing a home.

Table 4: Correlations Results (Education Levnel of Respondents to environmental concers in houses)

Spearman's rho	Education Level	Correlation Coefficient	1.000
		Sig. (1-tailed)	.
		N	120
	1. Consideration of energy efficiency in designing homes	Correlation Coefficient	.083
		Sig. (1-tailed)	.185
		N	120
	2. Aspect of comfort in house design	Correlation Coefficient	-.082
		Sig. (1-tailed)	.186

	N	120
3. Factor influential in house design	Correlation Coefficient	.205*
	Sig. (1-tailed)	.012
	N	120
4. Aware of the importance of energy efficiency in houses	Correlation Coefficient	.091
	Sig. (1-tailed)	.164
	N	119
5. Human behaviour influences energy efficiency practices	Correlation Coefficient	.028
	Sig. (1-tailed)	.382
	N	119
6. Passive architectural consideration in house design	Correlation Coeficient	-.027
	Sig. (1-tail ed)	.084
	N	119
7. Rain water harvesting,grey water treatment,solar panel,etc. are essential energy efficiency system to be included in the contemporary house design.	Correlation Coefficient	-.042
	Sig. (1-tailed)	.328
	N	117

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

Correlation is significant at 0.05 level (one-tailed); Spearman's rho correlation test statistics is 0.205 for question No 3 describing that preferences for energy efficiency has a significant relationship to the level of education of the respondents. Occupant behaviour and energy efficiency is the highest score in factors influential in house design that indicated the awareness of the respondents that have tertiary education (90.8%).

As discussed earlier, the respondents showed an inclination towards energy efficiency in houses. The survey on preference of comfort showed that thermal comfort is the primary concern. The cross tabulation performed on preference for comfort and the method used to regulate comfort shows correlation coefficient at 0.152 where correlation is significant at 0.05 level (one-tailed). On the other hand, the cross tabulation performed on the preference for comfort and daylighting regulation in houses showed weak correlation coefficient at 0.048.

Table 5. Correlations Results Importance of Comfort and Method for Regulation of Thermal Comfort

			Important aspect of comfort in house design	Method used to regulate thermal comfort
Spearman's rho	Important aspect of comfort in house design	Correlation Coefficient	1.000	.152*
		Sig. (1-tailed)	.	.045
		N	125	125
	Method used to regulate thermal comfort	Correlation Coefficient	.152*	1.000
		Sig. (1-tailed)	.045	.
		N	125	125

*. Correlation is significant at the 0.05 level (1-tailed).

Table 6: Correlations Results on Importance of Comfort and Method for Regulation of Daylighting

			Important aspect of comfort in house design	Method you used to regulate daylighting
Spearman's rho	Important aspect of comfort in house design	Correlation Coefficient	1.000	.048
		Sig. (1-tailed)	.	.299
		N	125	125
	Method you used to regulate daylighting	Correlation Coefficient	.048	1.000
		Sig. (1-tailed)	.299	.
		N	125	125

6. Conclusion

The research proved that comfort is the main consideration in choosing and building new houses. Thermal comfort appears to be a major factor among all comfort considerations. Eventhough previous studies highlighted the balance of privacy and thermal comfort, this study have attested that thermal comfort is valued over other forms of comfort. The research results verified that age and level of education have a significant relationship to attitude and behaviour of the inhabitants. The results are in line with similar researches that found a close relationship between behaviour and energy efficiency. The attitude and behaviour relationship to indoor environmental regulation supports energy efficiency practices. Opting for energy efficient concept in achieving comfort shows the respondents' awareness in regulating the indoor environment of their houses.

Since thermal comfort is the main issue in regulating the indoor environment, the research can be furthered in a scientific collection of environmental parameters that effects thermal comfort; air temperature, mean radiant temperature, humidity and air speed at the interior environment. The study should also record parsonal parameters of comfort for the occupants including factors such as clothing types and activity level of the inhabitants.

Acknowledgements

The research is conducted as an exercise to gauge the current expectations in choosing or building new houses. The authors would like to thank all parties involved in the data collection for this research.

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