Evaluation on Sustainability and Occupants' Perceived Health in Malaysian Terraced Houses

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ABSTRACT

Terraced houses account for 44% of the existing urban residential buildings in Malaysia. However, these houses have very constrained use of natural ventilation and lighting due to small window-to-floor ratio openings and deep planning which cause gloomy indoor spaces, low air change rate and poor indoor air quality. Hence, the sustainability of these terraced houses in tropical climate needs to be further investigated. Studies showed that indoor environments have major impact on occupants' well-being. Thereby this paper looks into indoor thermal and visual performances as the mean of sustainability and its impact on occupants' perceived comfort and health in Malaysian typical terraced houses. Survey of various terraced houses in Johor Bahru, Malaysia was conducted using questionnaire. Total of 31 houses were studied to identify the critical comfort and health issues in terraced housing. The relationships between occupants' perceived comfort, behaviour and health were studied. The variance among types of terraced house was also analysed. The findings demonstrated significant linear relationships among thermal comfort, visual comfort and health. However, occupants' behaviour did not give significant impact on comfort and health. This paper concludes that it is very essential to improve indoor thermal and visual comfort in Malaysian typical terraced houses through sustainable design to enhance occupants' health.

KEYWORDS: Indoor environment; occupants' comfort; occupants' health; tropical climate

1. INTRODUCTION

Terraced houses have been rapidly constructed in Malaysia since 1960's due to the increasing demands for housing. It accounts for 44% of the existing housing stocks in urban areas in Malaysia as of year 2000 (Malaysia Department of Statistic, 2000). This housing typology is adopted from the British terraced house design which is also known as "row house" (Omar et al., 2010). This type of house has relatively narrow and deep plan with limited fenestration at the front and rear facades. The housing layout is planned repetitively and monotonously in rows of rectangular lots with clear boundaries (Hashim and Rahim, 2008). The typical spatial characteristics of the terraced house in Malaysia have been remained the same for decades (Figure 1). Hence, the sustainability of these terraced houses in tropical climate needs to be further investigated.

In Malaysia, the annual maximum intensities of solar radiation falling on horizontal and vertical surfaces are about 1000 W/m^2 and 850 W/m^2 respectively for east and west facing surfaces (Ossen, 2005). The major building envelopes of terraced houses that are exposed directly to solar radiation are the roofs. The openings at the façades are the very limited sources for natural lighting although the external illuminance in tropical climate is as high as 130 klx (Lim et al., 2012). Besides, natural ventilation is also constrained by the small window-to-floor ratio (WFR). Tropical climate has very low wind speeds, thus the range of indoor air velocity in low rise buildings in Malaysia is only between 0.04m/s and 0.47m/s, which is inadequate for indoor air movement (Hui, 1998).

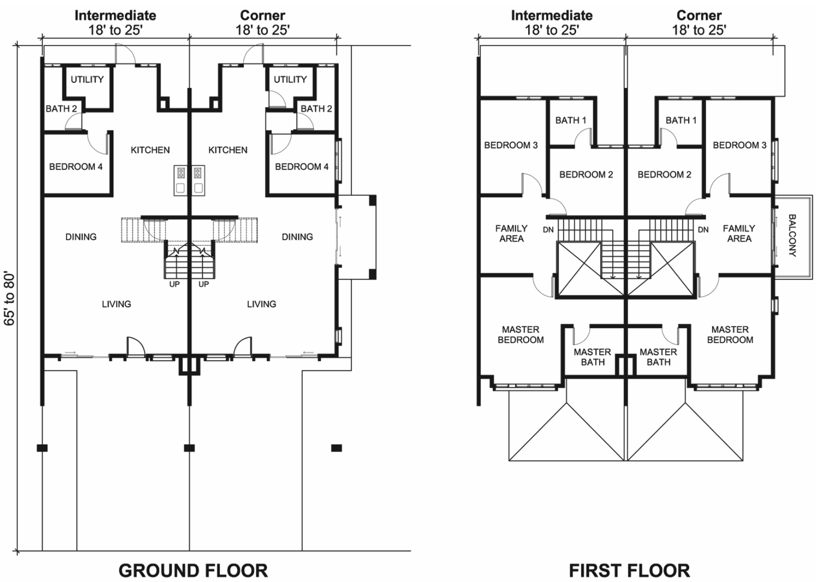

Figure 1. Layout of typical Malaysian terraced house for intermediate and corner units

Sadafi et al. (2011) had evaluated the thermal effects of internal courtyard in a tropical terrace house in Malaysia. Internal courtyard allows better natural ventilation but increases the radiation heat gain. Therefore, efficient openings and shading devices are needed. Kubota et al. (2009) investigated the effects of night ventilation technique on indoor thermal environment for terrace houses in Malaysia. The findings concluded that indoor humidity control during the daytime such as by dehumidification would be needed when the night ventilation technique is applied to Malaysian terraced houses. Otherwise, full-day ventilation would be a better option compared with night ventilation.

Previous research on Malaysian terraced houses had been focusing on thermal comfort in tropical climate. However, studies have shown that indoor environments, including work and living spaces, have major impact on occupants' well-being (Bluyssen, 2010; Choi et al., 2012; Todorovic and Kim, 2012). Environmental stressor such as discomfort air temperature, poor air quality and inadequate lighting produce negative stress which can cause short-term illness and long-term health problems both physical and mental (Bluyssen et al., 2011). According to the Rio Declaration, the Principle 1 stated, “Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature”. Thereby, this paper studies the impacts of natural ventilation and lighting on occupants’ thermal comfort, visual comfort and perceived health in existing Malaysian typical terraced houses.

2. METHOD

This paper presents a preliminary study of occupants’ perceived comfort and health in Malaysian terraced houses. Drop-off and pick-up questionnaire method was employed to conduct survey in twelve terraced housing estates in Johor Bahru, Malaysia on 23-30 May 2013. Random purposeful sampling method was employed in order to cover various types of terraced houses including intermediate, corner and end units (Table 1). Due to the limited time and manpower to collect the data, the total number of samples collected was only 31 houses among the housing estates. However, it fulfilled the minimum need of 30 samples for statistical analysis (Roscoe, 1975).

Table 1. Summary of respondents according to types of terraced house

No.	Type	No. of House(s)	Percentage (%)
1	Intermediate Unit	20	64.5%
2	Corner Unit	6	19.4%
3	End Unit	5	16.1%
	Total	**31**	**100.0%**

The questionnaire is divided into 4 major sections. Section 1 is intended to evaluate the occupants’ comfort in relation to natural ventilation, indoor temperature and air quality. Section 2 is to obtain feedbacks from occupants regarding to the use of natural lighting for task performance and visual comfort. Section 3 investigates the behaviour of the occupants to use and control natural ventilation and lighting. Section 4 aims to evaluate the occupants’ psychological and physical health. All the questions are using 1 (lowest) to 5 (highest) scales.

The data collected were analysed using statistic methods. First of all, the means of each question in Section 1, 2 and 4 were computed in order to identify the most critical comfort and health issues. Then, the correlations between sections were analysed. Spearman’s rho correlation was employed for this analysis since the data was qualitative in nature thus fall under the category of non-parametric test. This correlation tests were important to understand the significant relationships among the variables.

The variance between types of terraced house (intermediate, corner and end units) and comfort, behaviour and health were also studied using Mann-Whitney U test. It was a non-parametric test as well as data were qualitative in nature. It was to find out the effect of different types of terraced house on occupants’ perceived comfort and health. Since the designs of corner unit and end unit are identical with similar openings at the sides, these 2 types of terraced house were combined as ‘corner unit’ for the statistical analysis. All the tests were analysed at a default confidence level of 95%.

3. RESULT AND ANALYSIS

With the total of 22 questions regarding to thermal comfort and visual comfort, there were 7 questions scored mean below 3.00 (average) as shown in Table 2. This evidenced majority of the respondents agreed that these issues are critical in terraced houses. The lowest score was Air movement in Toilet with mean 2.58. This indicated that most of the respondents were unsatisfied with the natural ventilation in toilet which is very essential to assure fresh air and hygiene. Meanwhile, second and third lowest scores were yielded by indoor temperature comfort during afternoon and noon times. Among all the 7 lowest scores, only 1 of them is related to visual discomfort, thus thermal comfort issues are more significant than visual comfort issues in the terraced houses.

Table 2. Critical comfort issues with mean < 3.00

	Comfort Issues	*N*		*Mean*	*Std. Deviation*
		Valid	Missing		
1	Air movement in Toilet	31	0	2.58	1.089
2	Indoor temperature comfort in afternoon	31	0	2.65	1.279
3	Indoor temperature comfort at noon.	31	0	2.84	1.267
4	Air movement in Other Bedrooms	30	1	2.87	.937
5	Air movement in Kitchen	31	0	2.90	1.165
6	Glare / contrast from the window	31	0	2.94	1.124
7	Air movement in Dining Hall	31	0	2.97	1.110

Table 3. Critical health issues with lowest mean scores

	Health Issues	*N*		*Mean*	*Std. Deviation*
		Valid	Missing		
1	Quality of sleep without air-conditioning	31	0	3.23	1.175
2	Having blocked / runny nose symptom	31	0	3.52	1.122
3	Concentration in performing work	31	0	3.52	.890
4	Influence of indoor environment on health	31	0	3.61	.761
5	Having lethargy / tiredness symptom	30	1	3.70	1.022

Table 3 indicates 5 health issues with lowest mean scores. The mean scores for health issues ranged higher than the mean scores for comfort issues. Even the lowest score for health issue which is related to quality of sleep without air-conditioning yielded 3.23 (slightly above average). Therefore, most of the respondents were satisfied with their health condition. Among the 5 lowest scores, 3 of them are related to psychological health which influences their minds and emotions. Among all the physical health issues, blocked or runny nose symptom obtained the lowest score. This issue can be related to poor ventilation and air quality as well as discomfort indoor temperature. Meanwhile, the physical health issue with second lowest score (lethargy and tiredness) can be caused by poor ventilation, insufficient indoor lighting level and lack of natural lighting.

Table 4 shows the correlation between Natural Ventilation & Thermal Comfort (Section 1) and Occupants' Health (Section 4). There is a positive linear relationship between these 2 variables. The value of 'sig. (2-tailed)' (.005) is less than the predetermined alpha value (.05/2 = .025), thus the stated null hypothesis is rejected. There exists adequate evidence to show that there is significant positives linear relationship between Natural Ventilation & Thermal Comfort and Occupants' Health. The better the Natural Ventilation & Thermal Comfort in the household, the healthier they would become.

This conclusion is made at the significance level of 0.5.

Table 4. Correlation between Natural Ventilation & Thermal Comfort (Section 1) and Occupants' Health (Section 4)

			SECTION 1	SECTION 4
Spearman's rho	**SECTION 1**	Correlation Coefficient	1.000	.488**
		Sig. (2-tailed)	.	.005
		N	31	31
	SECTION 4	Correlation Coefficient	.488**	1.000
		Sig. (2-tailed)	.005	.
		N	31	31
**. Correlation is significant at the 0.01 level (2-tailed).				

Table 5 indicates the correlation between Natural Lighting & Visual Comfort (Section 2) and Occupants' Health (Section 4). There is a positive linear relationship between these 2 variables. The value of 'sig. (2-tailed)' (.011) is less than the predetermined alpha value (.05/2 = .025), thus the stated null hypothesis is rejected. Hence, there is adequate evidence to show significant positives linear relationship between Natural Lighting & Visual Comfort and Occupants' Health. The better the Natural Lighting & Visual Comfort in the terraced houses, the healthier the occupants would become. This conclusion is made at the significance level of 0.5.

Table 5. Correlation between Natural Lighting & Visual Comfort (Section 2) and Health (Section 4)

			SECTION 4	SECTION 2
Spearman's rho	**SECTION 4**	Correlation Coefficient	1.000	.452*
		Sig. (2-tailed)	.	.011
		N	31	31
	SECTION 2	Correlation Coefficient	.452*	1.000
		Sig. (2-tailed)	.011	.
		N	31	31
*. Correlation is significant at the 0.05 level (2-tailed).				

Table 6. Correlation between Natural Ventilation & Thermal Comfort (Section 1) and Occupants' Behaviour (Section 3)

			SECTION 1	SECTION 3
Spearman's rho	**SECTION 1**	Correlation Coefficient	**1.000**	**.315**
		Sig. (2-tailed)	.	.084
		N	31	31
	SECTION 3	Correlation Coefficient	.315	1.000
		Sig. (2-tailed)	.084	.
		N	31	31

Table 7. Correlation between Natural Lighting & Visual Comfort (Section 2) and Occupants' Behaviour (Section 3)

			SECTION 2	SECTION 3
Spearman's rho	**SECTION 2**	Correlation Coefficient	1.000	.392*
		Sig. (2-tailed)	.	.029
		N	31	31

	SECTION 3	Correlation Coefficient	.392*	1.000
		Sig. (2-tailed)	.029	.
		N	31	31

Table 8. Correlation between Occupants' Behaviour (Section 3) and Occupants' Health (Section 4)

			SECTION 3	SECTION 4
Spearman's rho	SECTION 3	Correlation Coefficient	1.000	.256
		Sig. (2-tailed)	.	.164
		N	31	31
	SECTION 4	Correlation Coefficient	.256	1.000
		Sig. (2-tailed)	.164	.
		N	31	31

The correlations between behaviour and comfort as well as behaviour and health were analysed as shown in Table 6, 7 and 8. The results show that there are positive linear relationships between these variables however there exists not adequate evidence to show that they are significant. The value of 'sig. (2-tailed)' is more than the predetermined alpha value (.05/2 = 0.025), thus the stated null hypothesis is accepted.

Variance between 'intermediate' units and 'corner' units (including end units) was studied using Mann-Whitney U test. Table 9 summarises 12 items which showed significant difference between types 'intermediate' and 'corner' units. All these items have values of 'Asymp.Sig (2-tailed)' which are smaller than the predetermined alpha value (.05/2 = .025), thus the stated null hypothesis is rejected. Among the 12 items, 4 of them are related to natural lighting and visual comfort. Thus, the effect of different house types is more significant on natural lighting in comparison with natural ventilation.

Table 9. Summary of items which showed significant difference between house types

Section	Question	Item	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)	Exact Sig. [2*(1-tailed Sig.)]
1	4	Annoyed by bad smell	48.000	258.000	-2.649	.008	.009[b]
2	1a	Sufficient natural lighting brightness in Living Hall	48.500	258.500	-2.623	.009	.009[b]
	1c	Sufficient natural lighting brightness in Kitchen	51.000	261.000	-2.638	.008	.014[b]
	1f	Sufficient natural lighting brightness in Toilet	49.000	259.000	-2.607	.009	.011[b]
	3b	Using natural lighting to perform work with computer	56.500	266.500	-2.317	.021	.025[b]
3	7	Frequency to look at view through window	57.000	267.000	-2.246	.025	.029[b]
4	1	Influence of indoor environment on health	54.000	264.000	-2.520	.012	.020[b]
	5a	Having Dry / Watering Eyes symptom	47.000	257.000	-2.817	.005	.008[b]
	5b	Having Blocked / Runny Nose symptom	53.500	263.500	-2.430	.015	.018[b]
	5c	Having Dry / Irritated Nose symptom	56.000	266.000	-2.347	.019	.025[b]
	5d	Having Chest Tightness symptom	52.500	262.500	-2.544	.011	.016[b]
	5g	Having Lethargy / Tiredness symptom	42.000	232.000	-2.817	.005	.006[b]

a. Grouping Variable: TYPE

b. Not corrected for ties.

4. DISCUSSION

From the analysis of critical comfort issues, it showed that thermal discomfort is more serious than visual discomfort in terraced houses. This can be due to most of the activities or tasks performed in terraced houses do not demand high level of brightness such as leisure, cooking and sleeping. Apart from that, most terraced houses are natural ventilated; hence the issues of air movement and indoor temperature are very essential.

Despite the low mean scores for thermal and visual comfort issues; the mean scores for health problems are relatively high (above 3.00 – average). The analysis of health issues demonstrated that indoor living environment in terraced houses affected the physiological health issues more than physical health. Therefore, occupants may feel unhealthy due to dissatisfaction with the indoor environment. Nevertheless, this scenario can be affected by other factors and needs to be further investigated.

By employing Spearman's rho correlation tests, the findings evidenced significant linear relationship between occupants' comfort and health. The better the comfort level in the terraced houses, the healthier the occupants feel. Thus, thermal and visual comfort gives significant impact to occupants' perceived health. However, the correlation tests proved that the relationships between behaviour and comfort as well as behaviour and health are less significant. This suggests that to achieve comfortable and healthy indoor environment, the design of the house itself is more important than how the occupants behave and manage the indoor environment.

The findings also demonstrated that different types of terraced houses give impacts to the occupants' comfort and health. The variance between intermediate and corner units proved that larger WFR with the existence of openings on the side walls (for the corner or end units) affects the natural lighting and visual comfort as well as occupants' health significantly. Nevertheless, it requires further analysis to determine which type of terraced house actually gives better comfort and health.

6. CONCLUSION

This paper presents a preliminary study of the occupants' perceived comfort and health in Malaysian terraced houses by using questionnaire. Critical comfort and health issues in terraced houses were identified. Besides, the findings signify linear relationships among thermal comfort, visual comfort and health in terraced houses. Subsequently, more efforts are needed to look into more specific variables that influence the occupants' perceived comfort and health. For further research, detailed questionnaire and more samples are needed to draw a concrete conclusion on this matter.

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