

Full Length Research Paper

Occupant feedback on indoor environmental quality in refurbished historic buildings

S. N. Kamaruzzaman^{1*}, M. A. Emma Zawawi², Michael Pitt³ and Zuraidah Mohd Don⁴

¹Building and Real Estate Research Centre, Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia.

²Centre of Research and Graduate Studies, Faculty of Architecture, Planning and Surveying, University Technology MARA, 40450 Shah Alam, Malaysia.

³Facilities Management Research Group, Liverpool John Moores University, Liverpool, UK.

⁴Department of English Language, Faculty of Languages and Linguistics Building, University of Malaya, 50603 Kuala Lumpur, Malaysia.

Accepted 28 January, 2010

Since the year 2005, Malaysia has been moving away from constructing new buildings in favour of refurbishing historic and old ones. This is due to a number of reasons, including the economic crisis, land limitation and sustainable issues. However, when a historic building is refurbished, there is seldom any methodical study made of the occupants' opinions concerning indoor environmental quality. There are few studies on refurbished buildings on indoor environmental quality (IEQ) which should serve as a key building performance indicator. This study uses a questionnaire to document the occupant's perception towards the indoor environmental condition of six refurbished historic buildings in Malaysia. Analysis was carried out by normalising the data producing a fingerprint for preference as well as the level of importance. A correlation between preferences of the individual occupant score towards the overall building condition was also conducted. The paper shows that the questionnaire can be used effectively to survey all of indoor environment aspects as it has the advantage of looking at both negative and positive aspects of the environment. It is believed that this study would assist in the identification of any particular aspect of the environment that requires adjustment and improvement to provide a better internal environment for the occupants.

Key words: Environmental science, survey, refurbishment, historical buildings, Malaysia.

INTRODUCTION

The Malaysian property market is currently in the early stages of a promising spurt of growth. Due to a strong economic climate and new government policies to encourage foreign investment in real estate in Malaysia, many worldwide property purchasers are currently looking to Malaysia as a lucrative property market in which to invest. According to US-AEP (2001), this fast economic growth has resulted in the need for more buildings, especially in large cities. For this reason, many of the historical buildings have been refurbished and converted to cater for the national needs, especially in the large cities such Kuala Lumpur, Johor Bahru, and

Penang. In fulfilling these needs, most of these buildings were treated improperly. For instance, due to lack of technical knowledge, most of the renovation and refurbishment work was carried out using unsuitable and inconsistent techniques, which gives bad results and outcomes in the interior of the building as well as exterior (Kamaruzzaman et al., 2007).

In addition, when a historic building is refurbished, there is seldom any methodical study made of the occupants' opinions of the environment. Previous studies have tended to consider environmental comfort as a function of air temperature, air velocity, radiant temperature and humidity but not have considered lighting, noise and smell. All these factors can affect the occupants' perceptions of their indoor environment. Nor is there much advice available on the relative importance of the

*Corresponding author. E-mail: syahrulnizam@um.edu.my.

of the various factors in the occupants, perceptions of the environment.

Although there are standards and calculations for the design of environments in terms of temperatures, humidity, draughts, noise and lighting etc, engineers rarely measure what has been designed in any depth or ask the occupants how satisfied they are with their building and its services. This is for a variety of reasons including cost and possible legal implications. However, with the increasing awareness of the role of the interior environment in occupant productivity and efficiency, there is more interest in eliciting feedback from the occupants. When feedback is obtained, it is often by means of a questionnaire survey (Levermore, 1994; Vischer, 1989; Probe 1, 1995). This study presents the results of occupants' assessment carried out in four refurbished historic buildings in Malaysia.

INDOOR ENVIRONMENT DESIGN

It is a known fact that the occupant's well-being and performance are affected by various aspects of the building, included but not limited to, exposure to daylight and access to views, air quality, temperature, odours, noise, ergonomics, the design of the built environment, and opportunities for social gatherings and relaxation (Heschong Mahone Group, 1999; Kolleeny, 2003; Madhavi and Unzeitig, 2005; Leather et al., 1998; Smith and Pitt, 2009). In addition, since people spend most of their time indoors and the IEQ has an impact on the occupants (EPA and the U. S. Consumer Product Safety Commission, 1995), it is beneficial to get feedback from the users themselves (Zagreus et al., 2004).

It is a known fact that the quality of office space can affect the productivity, health and comfort of workers. Gary and Rachel (2004) found that both severe and constant exposure to uncontrollable environmental stressors, such as noise, crowding, traffic congestion, or air pollution, can produce "learned helplessness" in adults as well as in children.

Clinical psychologists have documented the role of positive or negative emotions in various individual outcomes including productivity (Wright et al., 2002). They feel that "sad" or "depressed" individuals have low self-esteem, and exhibit reduced motivation and slowed thought processes. A study conducted by Wright et al. (2002), on worker productivity, found that psychological well-being (PWB) was positively related to job performance. In their field study, they defined PWB as that which measures the "pleasantness dimension" of individual feelings. Positive feelings were measured by terms, such as, "active", "alert", "enthusiastic", and "interested" and negative feelings were measured by, "afraid", "hostile", "irritable", and "upset" (Wright et al., 2002).

It can therefore be said without doubt that there are several factors that affect occupant performance and

well-being. These include, but are not limited to, indoor air quality (IAQ), ergonomics, noise, daylight, thermal comfort, and ventilation effectiveness. The American Industrial Hygiene Association Ergonomics Committee defines Ergonomics as "...a multidisciplinary science that applies principles based on the physical and psychological capabilities of people to the design or modifications of the jobs, equipment, products and work places." They go on to say that, the purpose of ergonomics is to decrease worker discomfort and improve worker performance (DiNardi, 1998).

In the United States people spend about 90% of their time indoors and so the indoor environmental quality is critical (EPA and the US Consumer Product Safety Commission, 1995). According to Fisk (2000), the U S can save \$6 to 14 billion from reduced respiratory illness, \$1 to 4 billion from reduced allergies and asthma, \$10 to 30 billion from reduced SBS and \$20 to 160 billion from worker performance and productivity gains. Under the category of Indoor environmental quality in the LEED checklist, IEQ includes indoor air quality (IAQ), including, environmental tobacco smoke, carbon dioxide monitoring, indoor chemical and pollutant sources, thermal comfort, daylight and views. However, IEQ consists of many more complex factors that may have an effect on the occupants, for example, noise, ergonomics, the quality of the artificial lighting and the spectrum of paints used etc. This factor makes the study of IEQ a lot more complex and during the review of the literature, it was found that most studies concentrated on one aspect of IEQ or another, while none included more than three conditions for their study. For the purpose of this study, the respondents are asked questions on most aspects of IEQ but the study does not deal with any one aspect in details. The main purpose is to inform rather than to find the cause and effect which an IEQ variable has the occupants.

MATERIALS AND METHODS

Occupants' questionnaires can help to assess peoples' perceptions of their indoor environment. In order to determine these perceptions, a questionnaire developed at UMIST (now part of the University of Manchester) was adopted for this study (Leventis and Levermore, 1996; Levermore et al., 1999). The questionnaire was seen to be considered the best method to gather data because many of the possible subjects move around the building during the course of their work, which makes other methods problematic (Mahmud, 2008).

The survey was carried out in six historic buildings in Peninsular Malaysia including offices, hotels and public buildings, three in the capital in the capital Kuala Lumpur and three in Penang. Each building is selected according to size and types ranging from air-conditioned standard (2000 – 8000 m²) to, naturally ventilated open plan (500 – 4000 m²), mixed mode cellular (100 – 3000 m²) and air-conditioned prestige (4000 – 20,000 m²). In addition, these were all British Colonial buildings in a Mogul architectural style (also known as a Moorish or Indian Muslim style), with Tudor, neo-Classical and neo-Gothic influences.

The questionnaires contains three sections, A, B and C. Section

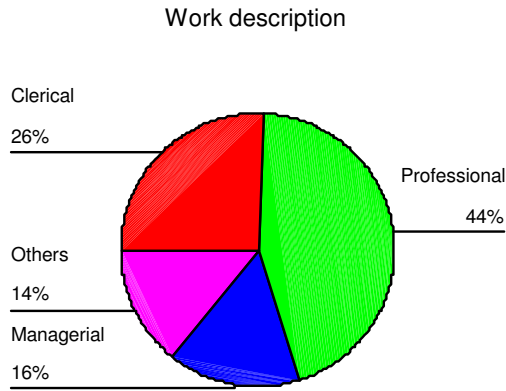


Figure 1. Work description total.

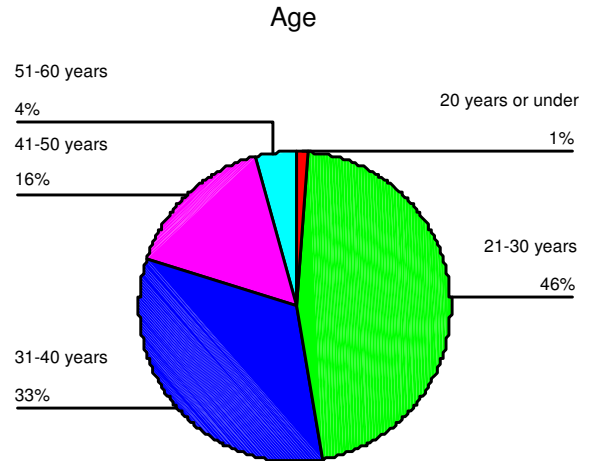


Figure 2. Age total.

A is concerned with personal information, while section B deals with issues relating to the internal environment, which affects the occupants' comfort. Section C explores questions involving noise, lighting, temperature, humidity, ventilation, management, colleagues and the internal and external appearance of the building. Using likert scale (Table 1), the occupants were asked to rate items according to their likes and dislikes and on how important they thought these issues were.

Each section of the questionnaire was analyzed using different methods, as will become clear in the discussion below.

The method of analysis

Section A

Section A consists mainly of personal information. For each question the equivalent answers are totalled and represented on a graph.

Section B

The questions in this section are designed to find out, for instance, whether, there is a relationship between a person's liking or disliking the temperature and a perception of a degree of hotness or coldness. The mean was found for each answer and then represented on a bar chart.

Section C

Section C is about the occupants' ratings of their likes and dislikes with regard to the internal environment and of how important they consider these environmental conditions. The first part of the analysis is to find the overall likeness score (OLS). The likeness score of a building (an overall rating for a building's indoor environment) can be determined from the equation overleaf: (Levermore, 1994, 1994a, 1998; Levermore and Meyers, 1996)

$$OLS = \left[\frac{\sum_{k=1}^n \sum_{j=1}^m i_{j,k} I_{j,k}}{m n i_{\max} I_{\max}} \right] 100 \tag{1}$$

Where;

j = questionnaire number, k = question number, i = importance rating $1 \leq i \leq 7$
 i_{\max} = maximum value of i, (7), I_{\max} = maximum liking rating (+3), I = liking rating $-3 \leq I \leq +3$, m = number of filled in questionnaires, n = number of questions in the score.

The score is normalised between +100 and -100%. The higher the score, the more the building is liked. The lower the score, the more the building is disliked. Zero indicates a neutral position. Multiplying the liking rating by the importance rating allows a degree of freedom in the questions asked. The score is expressed as a percentage and most occupants' scores range between +20 and -20%. A positive score indicates a degree of liking and a negative score the degree of disliking.

Correlation calculations

Finally, to see if there is any correlation between the individual's liking and subjective experience, linear regression was used. It was used in particular to find any correlation between the individual's liking score and their answer to question twenty-one, which appertains to the building in general.

RESULTS AND DISCUSSIONS

Audit section A

From the results presented in Figure 1 below, it can be seen that less than 50% of the respondents in all buildings, class themselves as professional, while 26% class themselves as clerical and 16% as managerial. Figure 2 shows that all the people questioned were aged between 21 and 60, with 46% being between 21 and 30. Figure 3 shows that 51% of the respondents were male. As per Figure 4, most people in the building spend either more than 4 h or less than 1 h working a VDU. As presented in Figure 5, it can be seen that there is a big difference in the time the occupants spend at their desks. However as per Figure 6, it is understood that the people

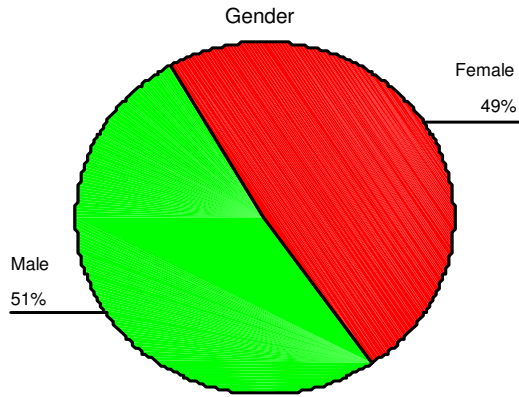


Figure 3. Gender total.

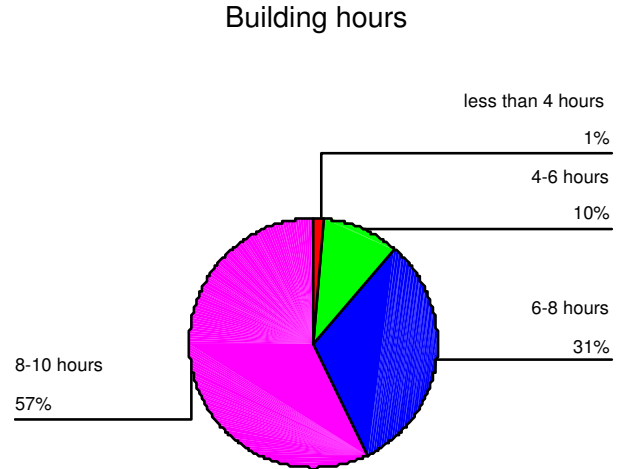


Figure 6. Building hours total.

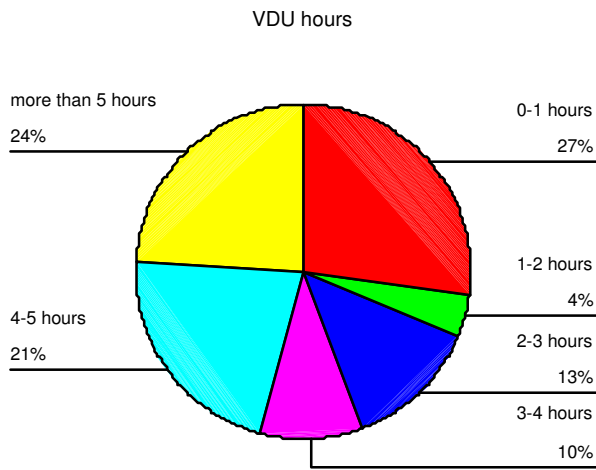


Figure 4. VDU hours total.

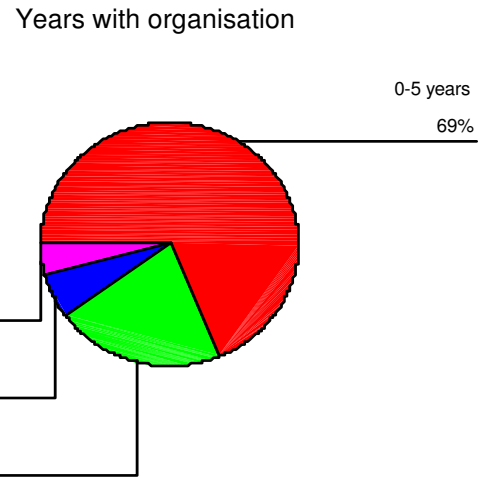


Figure 7. Years with organisation.

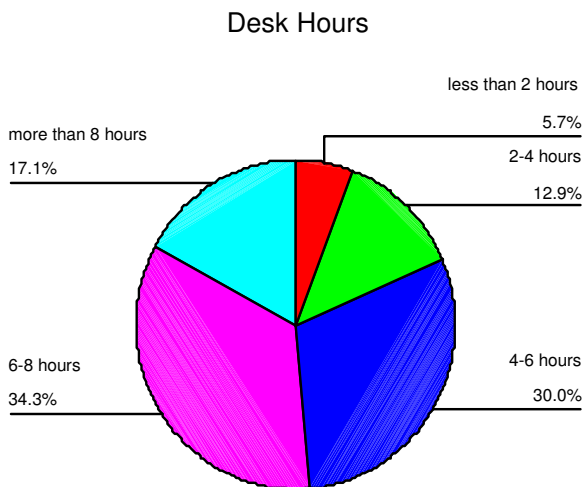


Figure 5. Desk hours total.

remain in the building with 88% spending over 6 h per day. Figure 7 indicate that most of the respondents have been working in the organisation between 0 - 10 years. However, Figure 8 shows that over half of them have spent less than 2 year at their current desks. As per Figure 9, most people said that there are more than ten people in the office. The others probably had their own offices elsewhere.

Audit section B

Section B contains questions on the internal environment to identify the occupants' level of satisfaction in terms of comfort. In Figure 10 below, one can see whether, for instance, the perception of a degree of hotness or coldness

Table 1. A seven-point scale of likes and dislikes and important and unimportant (Levermore et al., 1999).

Do you like the...	dislike							like							How important is this in the design of your ideal office?						
	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
1. noise level	----- ----- ----- ----- ----- ----- -----							----- ----- ----- ----- ----- ----- -----							----- ----- ----- ----- ----- ----- -----						
Comments :	_____																				

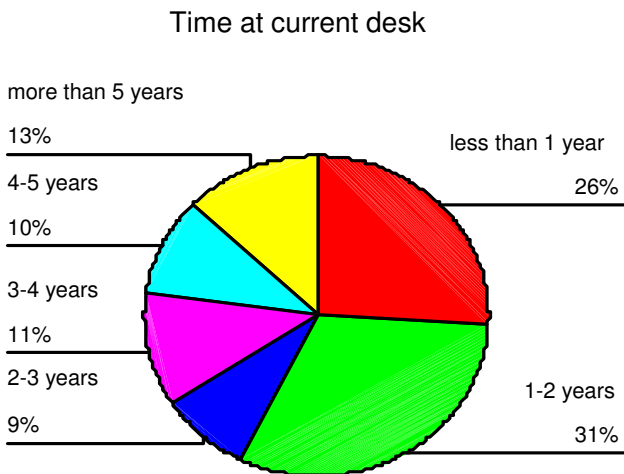


Figure 8. Time at current desk.



Figure 9. Number of people in office.

relates to a liking, or disliking of the temperature. Most of the results were close to the neutral axis. There were

only two results that were slightly away from the neutral axis. They were the question about brightness, which had a score of 3.47 and the question on draught levels, which had a score of 4.61. From this it can be seen that, if anything, the lights were too dim (and not bright enough) and the building was too draughty.

Audit section C

The liking score for this building was 13.38. The people working in this office showed a slight liking for their indoor environment. Out of the seventy people questioned, respondent 63 showed the most satisfaction with the environment, with an individual score of +84. It was found that this person is female manager aged between 21 and 30, spending more than 5 h per day working at a VDU and 6 h per day at her desk. She spends 10 h per day in the building and has worked for the organisation for two years. She has spent about one year at her current desk and there are more than ten people in her office. Respondent 11 had the lowest score of -58. The eleventh person was a female manager aged between 31 and 40, spending more than four or five hours per day working at a VDU and all eight hours (out of eight hours a day) at her desk. She has worked for the organisation for 7 years and remains at her current desk. There are more than ten people in her office.

Figure 11 shows the Overall Liking Score. Surprisingly, it can be seen that most of the bars are on the right hand side of the graph. Eventually, this shows a liking for the indoor environment even though with a very small figures. The main questions that elicited positive responses are listed in Table 2.

The largest scores concerned the immediate colleagues. This is due to an open plan concept that allows immediate interaction with other occupants. Since Malaysia enjoys an abundance of sunshine through out the day, blinds are usually drawn, but the sun can still penetrate into the building through other openings such as ventilation shafts. This has the effect of brightening the room and creating an interesting atmosphere in the building, which results in high positive scores. As expected, people like the building in general, with a score of +17.89.

Table 2. Audit main likeness.

Question Nr	Question subject	Score
14	Colours of the room	17.68
17	Amount of Space	17.14
19	Colleagues	18.09
20	Management	17.00
21	Building in general	17.89

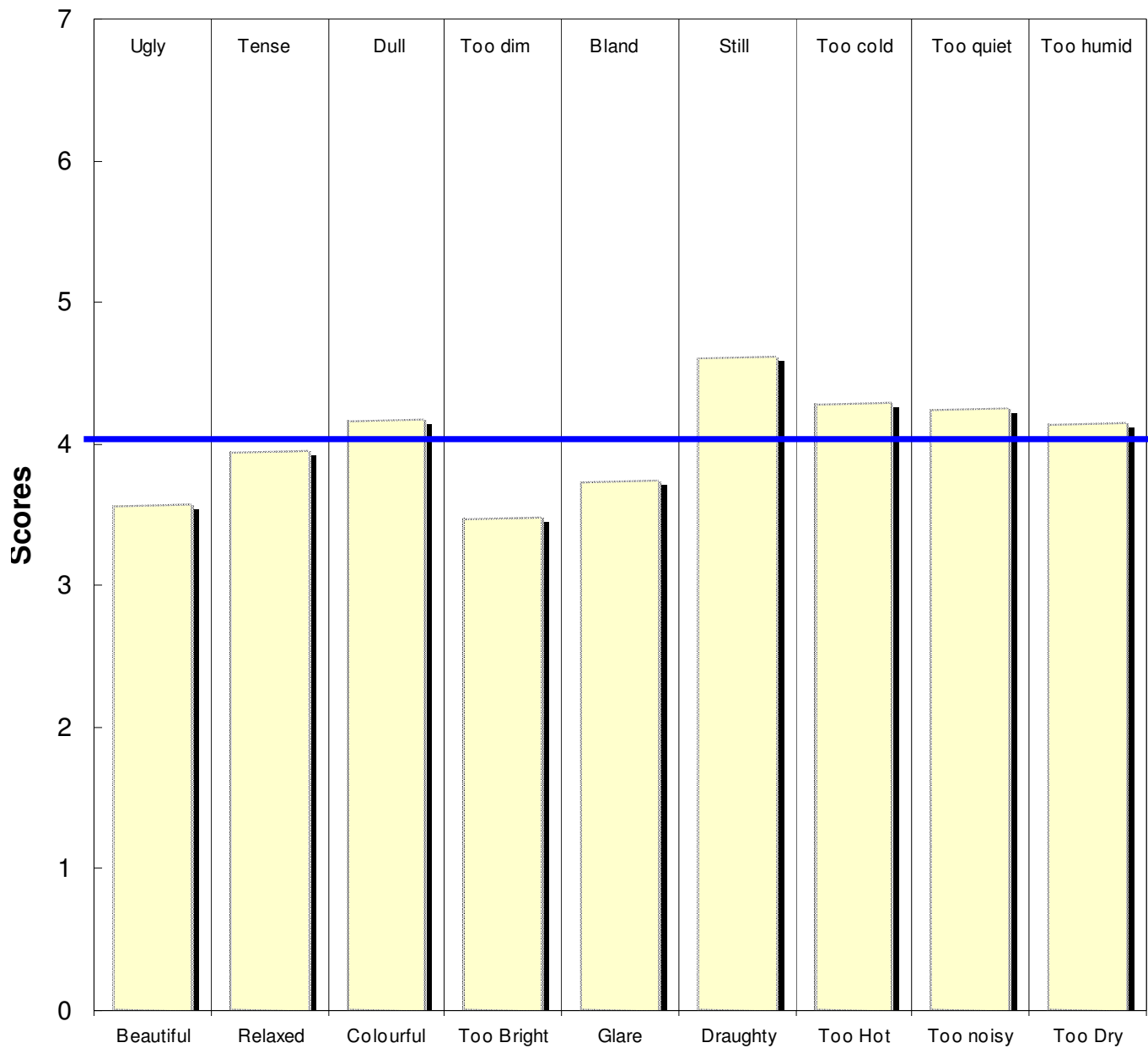


Figure 10. Average result of section B audit.

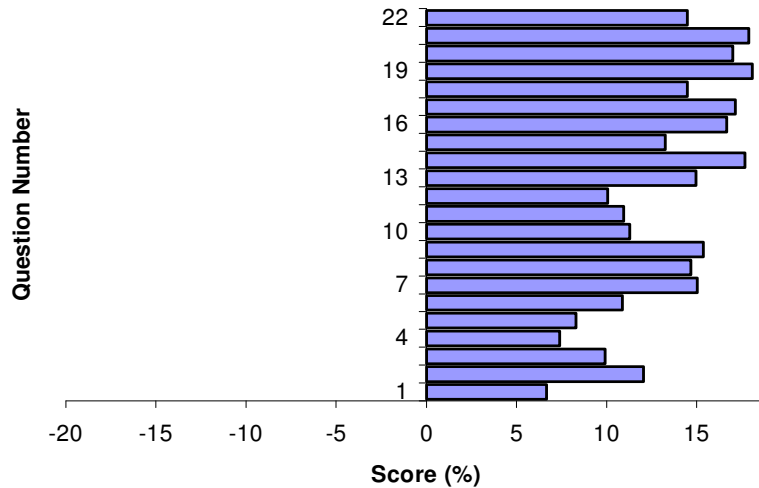


Figure 11. Overall liking score.

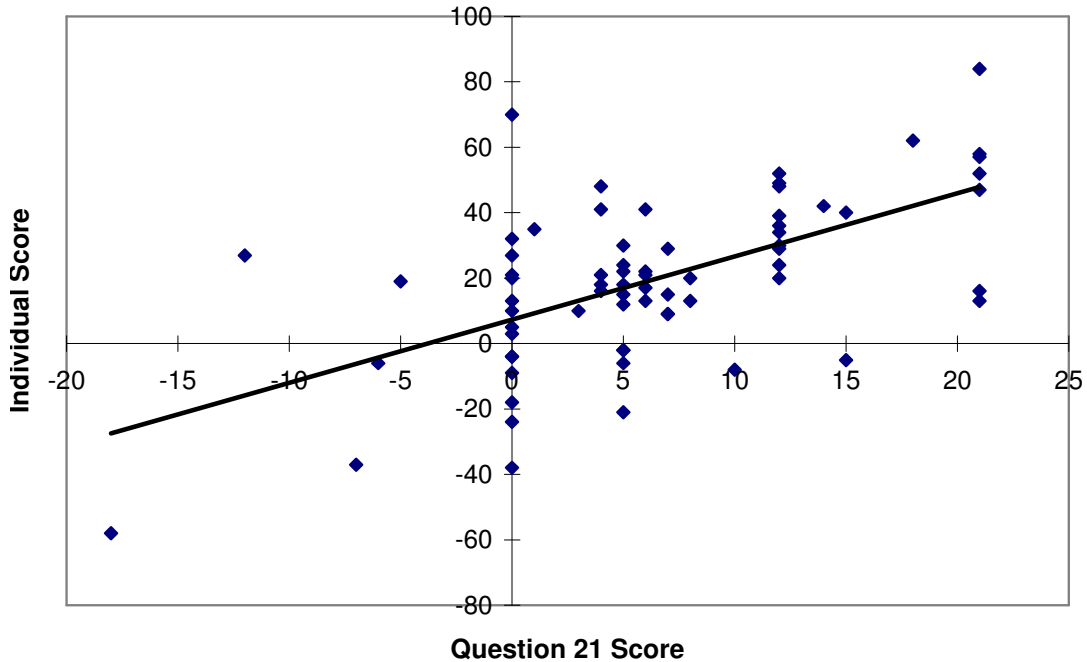


Figure 12. Regression analysis of question 21 with individual score.

Correlation

Linear regression was used to find any correlation between an individual's liking score and their answer to question twenty-one. Question 21 refers to the office in general. If someone likes the office in general, they can be expected to have a positive individual score. This regression calculation is worked out to see if there is any correlation between the two.

Figure 12 shows a scatter diagram and regression calculation. With 70 observations, this gives an R^2 value

of 0.36 with a standard error of 20.53 (Table 3). This shows some regression between the individual score and the respondent answer to question 21.

Conclusion

This study has attempted to study the internal environment of six historic buildings in Malaysia using a set of questionnaires developed at UMIST. A total of 120 questionnaires were distributed and 70 completed ques-

Table 3. Summary of regression output.

Regression statistics	
Multiple R	0.60
R Square	0.36
Standard Error	20.53
Observations	70.00

tionnaires was used for the analysis. The findings of section B are particularly interesting. It was found that the occupants feel the buildings are too dim with the score of 3.47 and that they are not satisfied with the level of lighting. This is what might be expected, because during the site visits and surveys, it was found that the blinds were drawn most of the time. This did not cause any serious glare problems either around the desk or in the room, leading to the results of 16 and 20%, respectively. On the other hand, electric lighting was used almost all the time the buildings are occupied. In view of the availability of sunlight in Malaysia, it is recommended that proper measures be taken to use sunlight to replace electric lighting in the buildings. A study of the energy consumption would be a first step towards identifying any waste of energy scope for improvement.

A great deal of information was found out about the occupants' perceptions of their environment. The results from the liking fingerprint showed all the problems and good points of the internal environment. The building liking questionnaire analysis table showed all the occupants' individual scores and also gave the overall building likeness score. This study has shown that the liking questionnaire can be used effectively to survey all indoor environment. It has the advantage of looking at both positive and negative aspects of the environment. This survey has indicated that the best buildings are those that not only keep the majority of people comfortable but also support their work tasks efficiently and inconspicuously for most of the time, but which also respond rapidly when people need to make a change in their environment.

REFERENCES

- DiNardi SR (1998). Ergonomics. In DiNardi, S. R. (Eds.), *The Occupational Environment-Its Evaluation and Control* Fairfax, Virginia: American Industrial Hygiene Association. Pp.726-775.
- Environmental Protection Agency and the U. S. Consumer Product Safety Commission (1995). *The Inside Story: A Guide to Indoor Air Quality*. Retrieved August 2005 from <http://www.epa.gov/iaq/pubs/insidest.html>.
- Fisk WJ (2000). Health and Productivity Gains from Better Indoor Environments and Their Implications for the U.S. Department of Energy. In *Proceedings of E-Vision Conference*. Washington, DC: Indoor Environment Department.
- Gary EW, Rachel S (2004). Motivational Consequences of Environmental stress. *J. Environ. Psychol.* 24(2): 143-165.
- Heschong Mahone Group (1999). *Daylighting in Schools*. An investigation into the relationship between daylight and human performance. Fair Oaks, CA: Heschong Mahone Group.
- Kamaruzzaman SN, Edwards RE, Zawawi EMA (2007). *Energy Consumption of Electricity End Uses in Malaysian Historic Buildings, Energy and Environment, Multi-Science Publishing Co Limited, United Kingdom*, 18 (3+4): 393-402.
- Kolleeny FJ (2003). Designing for Well-Being: Environments That Enhance The Quality of Life, *Architectural Record* 191(11): 90-118.
- Leather P, Pyrgas M, Di B, Lawrence C (1998). Windows in the Workplace: Sunlight, View, and Occupational Stress. *Environ. Behav.* 30(6): 739-763.
- Leventis M, Levermore GJ (1996). Occupant Feedback - Important Factors for Occupants in Office Design. CIBSE/ASHRAE Conference, Harrogate.
- Levermore GJ (1994). A questionnaire and rating score method for occupants' assessment of indoor environment, University of Manchester.
- Levermore GJ (1994a). Occupants' assessments on of indoor environments. Questionnaire and rating, CIBSE Res. J. BSERT. 15(2): 113-118.
- Levermore GJ, Leventis M (1998). Occupant feedback using a questionnaire rating liking and importance of up to 24 factors, CLIMA 2000 Brussels.
- Levermore GJ, Lowe D, Ure J (1999). Occupant feedback questionnaire producing a fingerprint and a score, ASHRAE Transactions 105(2): 661-670.
- Levermore GJ, Meyers D (1996). Occupant questionnaire on interior environmental conditions: Initial results. CIBSE Res. J. BSERT Vol. 17(1): 29-36.
- Madhavi A, Unzeitig U (2005). Occupancy Implications of Spatial, Indoor Environmental, and Organizational Features of Office Spaces. *Build. Environ.* 40(1): 113-123.
- Mahmud Z (2008). *Handbook of Research Methodology: A Simplified Version*. University Publication Centre (UPENA): Shah Alam.
- Probe I (1995). Tanfield House Building Services the CIBSE Journal Sept. 17-9.
- Smith A, Pitt M (2009). "Sustainable workplaces: improving staff health and well being using plants" *J. of Corporate Real Estate*, ISSN 1463-001X. 11(1): 52-63.
- US-AEP (2001). US-AEP Country Assessment: Malaysia, Unites States- Asia Environmental Partnership, <http://apocalypse.usaep.org/country/malaysia.htm> (accessed 01 September 2007).
- Vischer JC (1989). *Environmental quality in offices*. Van Nostrand Reinhold, New York.
- Wright TA, Cropanzano R, Denney PJ, Moline GL, Park R (2002). When a Happy Worker is a Productive Worker: A Preliminary Examination of Three Models. *Can. J. Behav. Sci.* 34(3): 146-150.
- Zagreus L, Huizenga C, Arens E, Lehrer D (2004). Listening to the Occupants: A Web-Based Indoor Environmental Quality Survey. *Indoor Air* 14(s8): 65-75.