UNIVERSITY OF LIVERPOOL

AN EVALUATION OF BIOCLIMATIC HIGH RISE OFFICE BUILDINGS IN A TROPICAL CLIMATE: ENERGY CONSUMPTION AND USERS' SATISFACTION IN SELECTED OFFICE BUILDINGS IN MALAYSIA

By

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ABSTRACT

This research has been carried out with the aim to investigate how high rise office building design in tropical climate can contribute in reducing energy consumption while maintaining comfort. The main objective of this study is to compare the performance of a sample of bioclimatic high rise office blocks with that of conventional ones when situated in a tropical climate such as that in Malaysia. The research firstly reviewed all the characteristics of bioclimatic buildings in the Malaysian Peninsula particularly the traditional Malay house and the transformation through time. Secondly, the research studied some design planning and architecture of several high-rise office buildings principally the bioclimatic approaches. Thirdly, the claimed benefits of bioclimatic design approach for high rise office buildings were examined in the results of previously conducted research projects, dealing with energy consumption and design approaches which compares the bioclimatic and conventional high rise. The performance was measured according to a combination of technical and social criteria: direct observation on various architectural aspects, environmental measurement and users' perception of comfort and satisfaction with their working environment via questionnaires. The energy consumptions were compared based on the electricity bills recorded for at least a year period. The local building energy index is used as the benchmark to check whether there were real energy savings in the bioclimatic high rise office blocks or otherwise. The major finding of this work is that the occupants in bioclimatic high rise office buildings have a higher level of satisfaction with their working environment than those in conventional office blocks. There is evidence that bioclimatic high rise office buildings are energy efficient as the most recent bioclimatic high rise office building (Menara UMNO), has a lower energy index than the ASEAN standard and within the latest Malaysian Standard related to energy efficiency. In the past, high rise buildings have been perceived as inefficient users of energy, with the new bioclimatic design concept and technologies, there is no doubt that high rise office buildings in the future would be much better in design that provide better environment to the users and consume less energy.

Keywords:
Bioclimatic, High rise, Energy, Sustainable Architecture, Tropical Climate, Comfort.

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LIST OF ABBREVIATIONS

ASEAN	=	The Association of Southeast Asia Nations.
ASHRAE	=	American Society of Heating Refrigerating and Air Conditioning Engineer Atlanta.
ATCP	=	ASHRAE Thermal Comfort Program.
BNL	=	Background Noise Level.
CIBSE	=	The Chartered Institution of Building Services Engineer London.
CIMB	=	Commerce International Merchant Bankers Tower.
CO_2	=	Carbon Dioxide.
CPZ	=	Control Potential Zone.
DISC	=	Predicted Thermal Discomfort.
EPU	=	Economic Planning Unit of Malaysia.
ET*	=	New Effective Temperature
EW	=	East – West.
HVAC	=	Heating, Ventilation and Air-Conditioning.
IBM	=	*Menara IBM* (IBM Cooperation Tower).
ISO	=	International Standards Organisation.
KOMTAR	=	*Menara Kompleks Tun Abdul Razak* (Tun Abdul Razak Complex Tower).
LEO	=	Low Energy Office.
LUTH	=	*Menara Lembaga Urusan Tabung Haji* (Pilgrim Management and Fund Board Tower).
MECM	=	Ministry of Energy, Communications and Multimedia, Malaysia.
MESINIAGA	=	*Menara Mesiniaga* (Mesiniaga Tower).
MMS	=	Malaysian Meteorological Service of Malaysia.
MRT	=	Mean Radiant Temperature.
MS	=	Malaysian Standards.
NS	=	North – South.
PC	=	Personal Computer.
PD	=	Predicted percent dissatisfied due to Draft.
PMD	=	Prime Minister Department of Malaysia.
PMV	=	Predicted Mean Vote.
PNB	=	Permodalan Nasional Berhad Tower.
POE	=	Post Occupancy Evaluation.
PPD	=	Predicted Percent Dissatisfied.
PSPS	=	Cumulative Percent of People Choosing a Particular Air Velocity at the Specific Temperatures Tested.
RH	=	Relative Humidity.
SPSS	=	Statistical Package for the Social Sciences computer software.
T_a	=	Air Temperature.
TIMA	=	*Menara Tun Ismail Mohd Ali* (Tun Ismail Mohd Ali Tower).
T_n/TN	=	Neutral Temperature
TS	=	Thermal Sensation Vote
TSENS	=	Predicted Thermal Sensation.
UMNO	=	United Malay Nation Organisation Tower.
UTHM	=	University Tun Hussein Onn of Malaysia.
V_a	=	Air Velocity.

CHAPTER 1: INTRODUCTION AND RESEARCH BACKGROUND

1.0 Introduction

It is generally accepted that traditional or vernacular architecture is well adapted to the dominant climate of its surroundings by means of the method of trial and error. Passive environmental strategies in Malaysia have been widely adopted in vernacular buildings for many centuries before the colonial era. These strategies are evident in the traditional Malay houses and their various components. However, during the colonial era, with the influence of western styles, many of these strategies were abandoned particularly with the introduction of new building typologies.

Since independence in 1957, Malaysian architecture has experienced significant transformation, as many colonial towns have turned into the new state capitals. Symbols of nationhood were expressed in new and daring form of buildings, houses and structures designed by overseas trained Malaysian architects (Ruby and Christ, 1998). Creative and innovative techniques which were applied in the construction industry have changed the scale of commercial and residential buildings and have also enabled the erection of tall buildings in the capital city of Kuala Lumpur and other major cities such as Penang and Shah Alam.

In the 1990s, the drastic increase in economic growth has also increased the rate of building construction of numerous mega projects. This trend has extended to major cities in the country as shop houses have been replaced by shopping arcades, then by mega malls. Large scale housing estates have created suburban centres and townships with repetitive single and double storey terraced houses. Bungalows and apartments have been replaced by condominiums with centralized facilities and more high-rise tower buildings have been created all over the cities.

The low cost of electricity and domestic air-conditioning systems associated with higher expectations of social lifestyle and levels, have contributed to the high popularity of artificial cooling equipment in buildings (Ismail, 2000). Persistent economic growth encouraged a high rate of building construction in a number of Malaysian cities and the proliferation of high-rise office towers and shopping complexes (see figure 1.1). These towers are symbolically associated with a fast growing economy and a sign of progress, aimed at placing Malaysia at the forefront of the developing countries in the region (Chen, 1998).

As the global and national economy has become continuously stable, the construction industry has also increased drastically. New design concepts have been introduced, with most of them disregarding the lessons from the local tropical vernacular architecture. The new and "progressive" architecture is generally allied with the architecture of immaculate steel and glass panels. Problems of energy usage, air quality and amenities provided by the building to its users have then become an issue (Radzi, 1998).

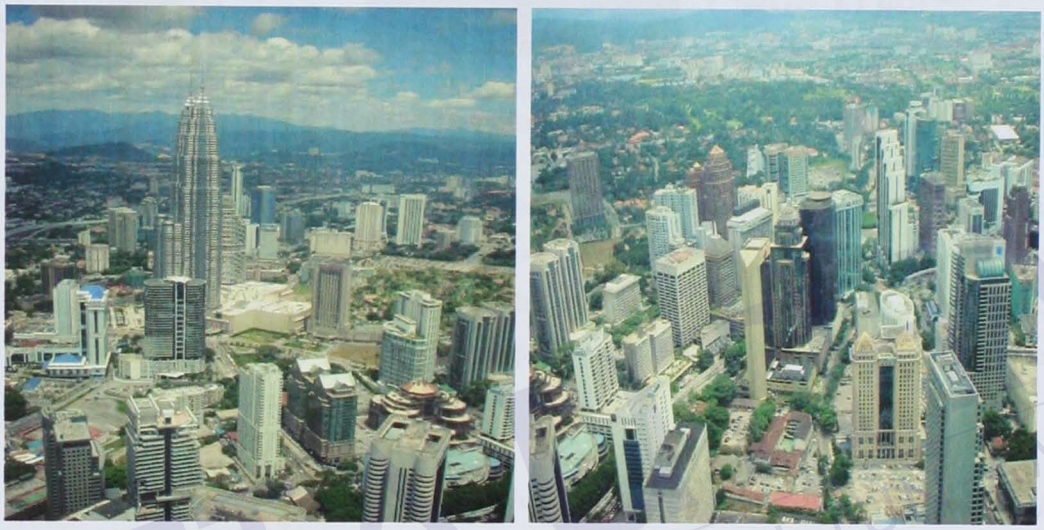

Figure 1.1: Kuala Lumpur city towers and development

1.1 Background

In the new millennium, greater urbanization demands more environmentally responsive solutions to the way Malaysians live and work. Passive environmental response is becoming popular in modern building design. The basic principles of vernacular tropical architecture are being re-interpreted in the new "green architecture" with the adoption of more natural ventilation, lighting as well as sun shading devices as evident in the local vernacular architecture.

These strategies are found working in the architecture of the traditional Malay house (see figure 1.2). It is fully shaded by vegetation and trees surrounding its area and providing a buffer zone to the indoor environment. Height is increased in the roof architecture in order to capture winds at a higher velocity, and openings incorporated in the walls encourage airflow through the buildings. Building orientation towards the direction of the prevailing wind is also an important factor in maintaining good cross ventilation (Davidson, 1998).

Figure 1.2: Tropical architecture in traditional Malay house
(Source: Davidson, 1988:86-88)

Many of these strategies developed in the vernacular architecture are fully applicable to the architecture of contemporary buildings. However, we are today dealing with different building typologies, new building materials and building and planning regulations. Furthermore, lack of interest to learn from the past has led the local traditional architecture to develop further. According to Wan Abidin;

'From the understanding of the construction and design rules, the transformation of Malay houses through the ages can be traced. However, lack of interest in these traditional design and construction principles has inhibited the formal development of the Malay house and will further lead to its demise. Learning from tradition in Malaysia is hindered by law, policy, education curriculum, research and practice which not only discourage but also present obstacles to the development of traditional buildings' (Wan Abidin, 1984:28).

There is no doubt that urbanization in Malaysia is growing drastically especially in Kuala Lumpur and Penang. Resources of urban land for high density urban development have led to the proliferation of high-rise buildings. Many buildings are built up high to create more space and maximize the use of land, enabling developers to create more usable floor space. Many newly built hotels; condominiums, apartments, commercial centres as well as offices are built in this style.

Because of the high energy consumption of high-rise buildings, it is important to integrate clear adequate environmental strategies in the design. Energy efficiency of a building based on bioclimatic principles is determined by a set of environmental, technical and usage factors. The location of a building is a major determinant of bioclimatic strategies (Coch, 1998). Specific requirements for every single building type in terms of energy efficiency

should be defined. It is important to renew and update existing building regulations which have been inherited from the colonial period. Building standards should reflect the local people's socio-economic needs and local cultural and ecological conditions.

1.2 Problem Statement

Malaysia is located in the tropical climates region and has economic growth predicted to be continuously stable for the next three decades. The construction industry growth anticipated that the Malaysian architect would be able to promote new design concepts that represent the national identity, provide comfort and energy efficiency. Unfortunately most have left behind the traditional approaches of tropical architecture and adopted the international style which is generally associated with the architecture of immaculate glass boxes.

The cooling device which plays a significant role in providing a comfortable environment has been over exploited and contributes to energy waste (Ismail, 2000). Office workers suffer discomfort and this contributes to deterioration in their work performance. This reflects that natural ventilation and sun shading are still important features to be considered in building design in the tropics.

In the early 80's, the styles of the Malay vernacular architecture inspired many young architects and engineers in designing Malaysia's contemporary architecture. The Malay vernacular architecture has modified its style in order to adapt to modern society. According to Ahmad:

'*Many modern buildings have focused their design concepts on the Malay vernacular architecture, particularly the Malay houses and palaces. Various roof shapes have derived from the Malay houses such as the states of Negeri Sembilan, Kelantan and Terengganu'* (Ahmad *et al.*, 2002:4).

In Kuala Lumpur there are buildings which are identified as following the same steps, such as Commerce International Merchant Bankers Berhad (CIMB) Tower, Permodalan Nasional Berhad (PNB) Tower, Maybank Tower, the National Museum and the National Library building. However, these types of buildings are only representations of the so called 'identity' and thus do not carry a deeper meaning of the vernacular tradition. The passive strategies approaches applied in the traditional house have not been properly implemented in

these buildings. This is still happening in the new millennium although Wan Abidin first talked about it more than 25 years ago.

'Most of these works and studies are merely descriptive and almost all romanticise the beauty of a dying tradition attempts to 'create a national identity' have led to the borrowed use of indigenous architecture not only in residential buildings but also in the design of commercial and recreational buildings' (Wan Abidin, 1984:28).

One of the main characteristics of traditional Malay Houses is that they were designed with a deep understanding and respect for nature. This design with nature approach found in the traditional Malay house is best reflected in the climatic design of the house. According to Lim;

'To appreciate the climatic adaptations of the traditional Malay house, one must first understand the climatic and environmental conditions that the house is set in' (Lim, 1987:77).

1.3 Research Questions

The bioclimatic design approach design for high rise buildings was introduced and implemented by a few architects who learnt from their mistakes. The Malay vernacular architecture has modified their styles in order to adapt to the new building typologies without disregarding the local climatic and environmental conditions. The approach was later presumed to be the corrective strategies of the early high rise. However, the rationale for adapting the bioclimatic approach to high-rise design is that it can address many of the problems which conventional high-rise design does not. But to what extend does bioclimatic approach contribute to resolving these problems?

- Does the bioclimatic approach create a better environment for the building users?
- How do building users perceive the bioclimatic design?
- How does it affect their behaviours within the building?
- Does it really reduce energy consumption and by how much?
- What are the bioclimatic features that contribute in low energy building design?
- How does a bioclimatic approach reduce energy use in existing building?

These are the challenges that are needed to be countered not only by the architects promoting this approach but also those who are really involved in this industry.

1.4 Hypothesis

Environmental factors are the basic elements of bioclimatic principles. The principles have been developed and being used at design stages of bioclimatic high rise office as part of low energy strategies. Therefore, the following assumptions have to be substantiated through a series of building design evaluations.

Hypothesis 1:

"High rise office buildings in Malaysia incorporating bioclimatic design have better environmental performance and consume less energy than conventional ones"

- The transformation of bioclimatic approach from traditional into modern high rise office building in Malaysia can be seen in several component of the design.
- The bioclimatic approach provides natural ventilation and consequently will reduce energy consumption for cooling strategies especially from air- conditioning systems in high rise office building.
- The bioclimatic building must finally benefit from the natural light or day lighting strategies that will significantly reduce energy consumption for artificial lighting in high rise office building.

Hypothesis 2:

"Bioclimatic high rise office buildings create a better working environment for the users and provide higher level of satisfaction than conventional ones".

- The bioclimatic approach for high rise office building creates a better environment for the building users and they do perceive the benefits of the bioclimatic approach.

1.5 Aim and Objectives of the Research

It is frequently argued that bio-climatic design strategies result in substantial energy savings in buildings and higher levels of user's satisfaction. However, such claims have not been fully substantiated by systematic research particularly when dealing with building types such as high rise office blocks.

"The aim of the research is to investigate how high rise office building design in tropical climate can contribute in reducing energy consumption while maintaining comfort. The main objective of this study is to compare the performance of a sample of Bioclimatic high rise office blocks with that of conventional ones in two Malaysian cities".

Such performance was measured according to a combination of technical and social criteria: direct observation on various architectural aspects, environmental measurement and users' perception of comfort and satisfaction with their working environment. In this study, the processes were divided into two parts and the specific objectives can be described as follows:

Part I: Literature Review - The Basic Concept of Building Design and Environment, Low Energy Strategies in Buildings and Energy Systems.

- Perform a critical literature review on energy consumption in office building in order to identify problems and research area, and to develop hypotheses, research question as well as research methodology.
- Review the design of high rise buildings, the evolution and the invention of the bioclimatic high rise.
- Review previous research work on bioclimatic design in tropical climates.
- Learn from vernacular architecture and environment in a tropical climate with regard to ventilation strategy, optimization of natural lighting and protection against heavy rain and glare.
- Understand building performance evaluation method and approach in the scope of users' perception, energy consumption and comfort condition.
- Determine and identify a suitable method and approach for the case studies and design an appropriate working program.

Part II: Case Studies Data Analysis - Environmental Design Condition and Users Perception in Malaysia, Recommendations and Conclusion

- Document case studies characteristics
- Conduct direct measurement using specific equipment to provide quantitative data for air temperatures, air flow rates, light levels and noise levels.
- Conduct personal observation on the use of space.
- Accomplish an energy consumption for case study buildings using available utility bills (electricity) provided by the building's manager.
- Conduct a survey on users' perception and behaviour within the building using questionnaires to provide qualitative data.

1.6 Significance of the Study

At the start of the new millennium, Malaysian architecture faces great challenges in the technological world. Greater urbanization will demand more environmentally responsive solutions to the way Malaysians live and work and also to fit with the world wide environmental agenda in reducing CO_2 emissions and global warming. People are becoming more sensitive to the environment and becoming less favourable to accepting an architecture which does not deal well with the relationship between the indoor and outdoor climate. The climate and the occupants are the key elements in shaping a building that provides comfort (Roaf *et al.*, 2002). To this end, it is very important to conserve Malaysia's early buildings and to draw from them valuable lessons on the scale and usage for a better quality of life in the future.

1.7 Scope of the Study

The scope of this study focused on both engineering and architectural strategies in reducing energy consumption in buildings particularly on elements related to lighting, ventilation and thermal comfort condition in the buildings. From the case studies, energy audits and studies using a mathematical model, energy performance in a certain climate depending on three factors can be identified: (1) building design, (2) services design and performance (systems) and (3) occupant behaviour (Baker and Steemer, 2000).

Therefore, this research includes the assessment of the environmental design aspects mentioned above. These also include building design strategies and services. To further illustrate the relationship between building attributes and climate, the user's satisfaction data was gathered via questionnaires which were distributed to the building occupiers, mainly in the open plan office spaces. This will show the comfort requirements desired by the office workers and will indicate the kind of design criteria which are needed to achieve these comfort requirements in the tropical climate.

At the end of the research, comparisons between two types of buildings by using the same method and approach of analysis were done and conclusions of the findings were produced. The findings from the research which was based on the hypotheses mentioned earlier are explained in the summary and conclusion chapter.

1.8 Thesis Outline

The framework of the study is divided into two main parts. The first part presents the literature review of the basic concept of energy and environment in building. This section begins with Chapter 1 which describes the introduction and research background. The second chapter defines the detail of the environmental strategies in tropical climate and describes the environmental design condition. Comfort condition of the occupants in building and high rise architecture in Malaysia is also described in this chapter. The methodology adopted in the present study and the criteria used for the evaluation which include post occupancy evaluation (POE) and environmental measurement are described in Chapter 3.

The second part concentrated on the analysis of several case studies. This section begins in Chapter 4 in which the selection and characteristics of the bioclimatic sample building are discussed. The control buildings (conventional) are also described briefly in this chapter. Observations of various architectural elements related to bioclimatic approaches and energy used through electrical bills provided by the building managers are also presented in this chapter. Chapter 5 discussed the occupants' perception on several architectural features specific in the office areas whereas in chapter 6, the occupants' perception on several architectural features in communal areas and services are presented. Chapter 7 presents the general results of the environmental measurements conducted by the researcher himself. The occupants' perception on the indoor environment conditions are presented in Chapter 8. Performances between the two types of buildings are compared in these four chapters (5, 6, 7 and 8) with tables and figures. Most of the investigated aspects in relation to users' satisfaction are re-evaluated in Chapter 9. Further analysis on the relationship between user's satisfactions and their location in the building is also described in this chapter. Chapter 10 discusses the whole findings of the research and several recommendations are provided for consideration in future high-rise office building design. Potential research related to this study (in the Malaysian context) is also suggested and the overall conclusion is summarised at the end of this chapter. Finally, the appendices that might be useful for further references are provided at the end of the thesis.

The thesis is divided into two distinct parts; Part 1 and Part 2. The illustration of the specific objectives together with the structure of the study is shown in Figure 1.3.

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