METHODOLOGIES IN ARCHITECTURAL RESEARCH

EDITORS
NOOR AZIAH MOHD ARIFFIN
MD MIZANUR RASHID
NURUL HAMIRUDDIN SALLEH

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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PREFACE

There is a general lacking of scholarly writings in the field of research methods in Architecture and Built Environment especially from the professionals' point of view, albeit some efforts from different individuals. It has been observed that there is a need to put these individual works in a common platform so that their views can be shared. This book is intended to appeal to people interested in doing research in architecture and the built environment. Being both comprehensive and could also act as an entry point into the world of research in architecture, this book targets primarily, final year undergraduates and postgraduate students and anybody interested in doing research in these fields. Through the topics covered in the book varied methods of researches were introduced to, perhaps, whet the interests of budding researchers as to how to conduct their impending issues and questions yet unanswered. Although the topics covered are not as varied but it would serve as a guide to construct and undertake a research project as offered by the authors in answering their research questions. The research process is by no means an easy one – it takes patience, diligence and requires a systematic inquiry into a subject to uncover the truths we are searching for. It is the hope and wishes of the editors and authors of this book that this will serve as a guide, albeit the non-variety, to help budding researchers undertake their research projects methodically, scientifically and satisfactorily.

This book project taken by the Department of Architecture, Kulliyyah of Architecture and Environmental Design (KAED) of International Islamic University Malaysia (IIUM) opens up an avenue to address this need. This book is an attempt to collate the individual ideas and thinking within KAED academic members about research in built environment. For this publication we are indebted to Research Management Centre (RMC) of IIUM for their continuous support and most importantly taking the active role for the realization of the book. Our gratitude also goes to the Kulliyyah for its continuous support and encouragement in making this publication a success. Along with the contributors we would like to thank the reviewers who have provided us with constructive feedbacks in such a short time. It is our pleasure to present this book to all the readers.

Thank you.

Editors

CONTRIBUTORS

FADZIDAH ABDULLAH is an academician at the Department of Architecture, International Islamic University Malaysia and holds a Ph.D. (Architectural Education) from University of Strathclyde, United Kingdom (2006), M.Sc. in Computer Aided Environmental Design from University of Sheffield, United Kingdom (2000) and Bachelor of Architecture from Texas Tech University, USA (1992). Her research interest in architectural education and problem based learning.

MIZANUR RASHID is a professional architect and an academician. He is currently working as an Associate Professor at the Department of Architecture, International Islamic University Malaysia. He was conferred his PhD in 2008 from the National University of Singapore. Mizanur started his teaching career just after the graduation in 1997 and was involved in the profession, as well as, studio teaching in Bangladesh for four years. During this time he completed his Master of Architecture in Human Settlement (1999) from the Catholic University of Leuven. As an academician, he has a particular interest in history of architecture, tradition and sustainability. His current research focuses on the emergence of monumental architecture in a vernacular environment. His studies are mainly on the elements and design principles that have been long in practice in traditional buildings that has gradually been adopted in a more formal mode of architecture. As a researcher, he believes that this is how the traditional practices can be sustainable and be re-interpreted in the vocabulary of contemporary architecture.

NURUL HAMIRUDDIN BIN SALLEH is the Head of Department, Department of Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Kuala Lumpur. He achieved his Diploma in Architecture and Bachelor in Architecture (Hons) degree in 1996 and 2000 respectively from Universiti Teknologi Malaysia, Johor, Malaysia. He was awarded the M.A. in Conservation Studies (Historic Buildings and Places) from the University of York, York, United Kingdom in 2003. Consequently he pursued his studies and was conferred the Ph.D in Architecture (Building Conservation) in 2011 from Universiti Sains Malaysia in Penang, Malaysia. His research interest includes conservation of heritage buildings, building fire safety, building technology and architectural documentation and recording. He is a member of the International Council on Monuments and Sites (ICOMOS), the Board of Architects Malaysia (LAM) and the Malaysian Institute of Architects (PAM). Nurul Hamiruddin is active in publication, research, supervision and consultancy. He also has won two bronze medals in research and innovation (IRIIE) exhibitions. He has co-authored 2 books and presented more than 10 papers on heritage fire safety and building conservation in national and international conferences.

ZEENAT BEGAM BT YUSOF is a lecturer in the Department of Architecture at the Kulliyyah of Architecture and Environmental Design, IIUM. She obtained her Bachelor of Science in Architectural studies and Bachelor of Architecture (Hons) from the International Islamic University Malaysia (IIUM) and her Master Degree in Environment from University Putra Malaysia (UPM). She received the Distinction Award for Master

Degree in 2008. In 2005 she did her Post-Graduate Diploma in Islamic Revealed Knowledge at IIUM. Currently she is undertaking her Ph.D in Architecture at the Universiti Teknologi Mara (UITM). She is a registered member of Lembaga Arkitek Malaysia (LAM) and a registered member of Pertubuhan Arkitek Malaysia (PAM). Her specialization and interest is on Island development guidelines, sustainable architecture, green approaches and techniques, tourism, development in Marine Parks and Environmental Management. She has participated in many conferences and seminars. She had conducted few researches on Islamic Principles, Marine Park guidelines and architectural elements, green hotel approaches and challenges and comparative study of material. She won the Bronze Medal at the IRIIE (IIUM) 2012 Research Award.

MAISARAH ALI is an Associate Professor in the Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur. She is a professional engineer and her specialist research field is in the area of Rehabilitation and Maintenance Structures, Bridge Inspection, Facilities Maintenance, Sustainable Building, Concrete, Traffic and Highway Planning, Renewal Energy, Water Environmental Planning, Occupational, Safety and Health in the construction and engineering sectors.

ZURAINI DENAN is an academician with a degree in Bachelor of Architecture from Texas Tech University, Texas, USA. She continued her Master in Architecture by research in University Teknologi Malaysia specializing on daylighting. In 2004, she completed her PhD in the area of Daylighting Application in Office Building from Cardiff University, Wales, United Kingdom. Besides daylighting studies, she also has great interests in visual comfort and cultural and heritage studies. She had worked as an assistant architect in private practice and a lecturer at LimKokWing Institute of Creative Technology College previously. She joined the International Islamic University Malaysia in 1998 has been a lecturer until today. She has taken the responsibilities as Head of Department of Architecture, Deputy Dean Academic Affairs and Deputy Dean Student Affairs. Her most previous appointment was as the course coordinator for Heritage Studies where she has assumed the post for 4 years.

NOOR AZIAH MOHD ARIFFIN works as a faculty member at the Dept. of Architecture, IIUM and holds a PhD in Architecture from the Curtin University of Technology in Western Australia. She specializes in energy efficient design particularly in housing design in Malaysia. Utilising passive design strategies learnt from the climatic designs of traditional Malay houses, discerning orientation and insulation potentials, she found that energy consumption in contemporary terraced houses can be reduced by about twenty percent than a business as usual scenario. She has written many papers and articles on the subject in many national and international conferences and won a Bronze Medal at IIRIE in 2010. Her interests also include sustainable design and development, ecological sustainable issues and climatic and comfort studies of heritage buildings especially of the Muslim world. She is also passionate about the education of the young on environmental issues and sustainable lifestyle.

1 Introduction

A building as a physical entity functions in different independent and interactive ways: it is a structural entity, it works as an environmental modifier, it acts as a cultural and social space, when design and construct fittingly it can perform economically, and effortlessly. Hence the discipline of architectural research practically stretches into separate areas of knowledge that do not only address the architectural knowledge in its epistemological sense but also in the applied logic as well. This resulted into a wide array of scopes, methods and strategies of research germane to the wide spectrum of issues that affect architectural studies and practices in different ways.

Prof. Bryan Lawson[1] of Sheffield University has categorised three stages of research to provide some clarity on architectural studies. According to him, the first stage is the process - referring to the process of designing and constructing buildings. Thus it might address the issues of the learning and teaching of history and theories of architecture and design; knowledge of construction and technology and the modulation of the environment. The second is the product, where he refers to researches that consider buildings as projected and completed objects and might include for example the issues of aesthetics, materials, and construction techniques and so on. The third stage is the building performance - referring to the buildings once completed and included issues like social occupation, cultural assimilation and environmental performance. It is evident from this model that architectural research avoids the science/arts and qualitative/quantitative splits and allows interdisciplinary innovative methods for researching into any of these three stages of a building. Hence it is possible for scientists, historians, academics and practitioners to work together and contribute to the field of architectural research at any of these three stages.

From this perspective, this publication is an attempt to compile and combine some of the works of the members of the Department of Architecture, at the Kulliyyah of Architecture and Environmental Design (KAED) of International Islamic University Malaysia (IIUM) in undertaking their varied research works. The papers included in this book are focused mainly to demonstrate the varieties of methods the architectural academics and professionals adopt to address the different research issues. Each of these papers is unique in its own way: hence it is difficult to categorize them thematically based on the methods adopted. Thus for convenience, we grouped the papers according to the sequences or stages after the model of Bryan Lawson's. This would portray how different methods (quantitative, qualitative or mixed methods) have

[1] Lawson, Bryan. How Designers Think: The Design Process Demystified. London: Architectural, 1980

been applied to address different issues and problems in architecture. The book starts with the works that address issues of buildings as a process; gradually proceeding with issues related to buildings as a product and finally concluding with works that evaluate the buildings' performances.

In the second chapter of the book Fadzidah Abdullah advocates a phenomenological approach to critically analyze the Problem Based Learning (PBL) approach for tertiary education of architecture. She took a single case study of the Technical University Delft (TU Delft), and argues that a phenomenological approach is the most appropriate for a single case study research in multidisciplinary field of architectural education. In her paper she elaborated how this particular method suited best to cater the issues of knowledge based on personal experience and the subjectivity of drawing conclusion from inferences.

While Fadzidah has adopted the phenomenological approach of drawing inferences to address the issues of architectural education, Mizanur Rashid in the third chapter used a similar approach, but catering to a totally different historical problem. Although broadly categorized as historical research using qualitative methods, Mizanur's research problem was so unique in nature that the investigation demands combination of different methods that the research resulted as a continuous process than a product. This archaeological investigative method is devised to cater the problem of limited and apparently blurred nature of the discourse that gradually exposes one layer after another.

Nurul Hamiruddin Salleh and Zeenat Yusof in the next two chapters consider buildings as objects although serving two different objectives. Nurul Hamiruddin is more concerned about the issues of fire safety in a heritage building and adopted a mixed method to provide a comprehensive analysis of the museum buildings in Malaysia for the purpose of providing fire safety guidelines. Zeenat on the other hand, chose the case study of one particular building, the Geodesic Dome Visitors' Centre of Pulau Payar Marine Park, to determine the impact of development on the island and its environment using the existing Island Development Guidelines. She adopted the qualitative evaluation research method as she has a focused objective. Her research is further substantiated with the observation method in getting a more binding result.

On the other hand, Maisarah Ali delved to enquire on how the quality of a completed building can be measured to ensure whether the building has met the approved standards. Comparing the quality between a conventionally-built building and one which uses the Integrated Building System or IBS method, she conducted a fieldwork assessing the qualities of the structural works, architectural works, mechanical and electrical (M&E) works and external works of buildings using a standard method for quality measurement for construction in Malaysia. She further substantiated results from the fieldwork with a questionnaire survey to statistically validate her findings.

In the last two chapters, Zuraini Denan and Noor Aziah Mohd Ariffin, both assessed and evaluated the performances of two well debated environmental issues in the buildings in Malaysia. These two papers using methods best described as the 'Applied Research' are archetypal examples of empirical research in architecture using the triangulation method. They start with assessing the existing conditions through observation and questionnaire survey. Secondly, subjective assessments were done under controlled environment using data loggers and related equipment, where finally a computer simulation model was undertaken to predict an applicable solution.

Zuraini addressed the issues of visual comfort in the office buildings utilising different tools of data collection to confirm the problem and justify the possibilities of the visual comfort of daylighting in office buildings in Malaysia. Noor Aziah, on the other hand, focused on thermal comfort in the residential buildings in Malaysia, where she delved on passive design strategies to conserve energy where several research tools were considered to amalgamate her hypothesis.

As mentioned earlier, it is difficult to define the scope of architecture within the latitude of one paper and research only; it is even more so to draw a line between the groupings based on the earlier discussion. There are always some overlapping of themes, ideas, methods and scopes of a particular research. Likewise, it is also difficult to provide a clear picture of the full spectrum of architectural research scenario only with seven papers. Hence the book is not intended to fill the lacunae in the field of architectural research method rather it is designed more to capture a glimpse on how different academics respond to his/her own unique research problem.

2 Phenomenological Approach for Evaluating Problem Based Learning in Architectural Education

Fadzidah Abdullah

2.1 Introduction

This paper explains the step-by-step research approaches adopted while undertaking research thesis titled "An Evaluation of Problem Based Learning in Architectural Education." This research was designed using the phenomenological approach of case study research. This research is organised around six major topics; the study region, the paradigm and methodology, research method and procedures, analysis of interview data, some ethical considerations and conclusion. This type of interpretative single case study research was selected because it allowed the use of a deduction mode of using the knowledge and information to understand something and form an opinion. Designing research methodology for the thesis requires prior identification of research aim, and objectives. Therefore, careful consideration should be undertaken so that strategies could be designed to achieve the objectives of research. For understanding of this research design, it is important to have context of the research background.

The research has the aim of understanding the phenomena influencing the termination of Problem Based Learning (PBL) implementation in the Faculty of Architecture at Technical University of Delft, Netherland (TUDelft). An evaluation was carried out using the followings research objectives; to investigate if the PBL pedagogical approach gave a workable theoretical framework to architectural education; to examine the process of adaptation and implementation of PBL in the Faculty, as compared to other architectural institutions and other disciplines of studies; to identify the changes influenced by the introduction of PBL in the Faculty of Architecture at TUDelft; to investigate the acceptance of PBL among people involved in the implementation; and to suggest appropriate ways to improve the implementation of PBL in architectural education.

The aim and the objectives formulated for the research show how they resulted in the selection of the qualitative research format, which was the interpretive case study. The procedures focused on three issues: identifying the research strategies, selecting data collection methods, and choosing data analysis methods. Research strategies were identified to meet the research objectives. Data was sought from documentation of the PBL implementation, and first-hand accounts were sought from educational and architectural specialists, with experience of PBL implementation in the

Faculty of Architecture at TUDelft. Since the former was carried out as part of the literature review to form the framework of the analysis, the latter was conducted using focused face-to-face interviews to fill the gaps found in the earlier investigation. The interviewees were chosen based on their involvement in the PBL implementation at TUDelft. Consequently, analysis of interview data was carried out by using content analysis method.

These identified research strategies were known as “archival” and “opinion” (Buckley at. al., 1975), where techniques of content analysis and interviews were vigorously applied. These identified research strategies led to the decision to select the research format to be undertaken in order to achieve the strategies. Applying a “deduction” mode of using the knowledge and information to understand something and form an opinion, the research was designed using a phenomenological approach of Case Study. Data would be collected, based on the formatted research design, and displayed so that analysis and discussion of the findings would be made possible.

2.2 Paradigm and Methodology of Case Study

This section outlines the overall structure of the research framework and justifies the use of a phenomenological approach applied in the research. Description of the research design is substantiated with an underlying theoretical explanation of the chosen method.

A phenomenological approach was chosen as the main methodology in undertaking the research of case studies. Generally, this so-called qualitative research design is often done intensively, and yet offers great flexibility in term of application of research methods. In addition, the analytical method of a phenomenological approach might be quite systematic although the result would not be treated as representative (One Plus One, 2004). Instead, an understanding of the significance of different representations allows interpretative judgment of the research synthesis to be done in the areas where less is known.

In accord with the phenomenological approach of case study research, this research of PBL in architectural education represented a singular event that would never be replicated because the analysis of data focused on specific themes of content. The “singular event” referred to an explanatory case study of the PBL Implementation in the Faculty of Architecture at TUDelft. However, comparison to the same set of events was considered crucial to “pose competing explanation” (Yin, 1994) that might strengthen understanding of the research synthesis. In this instance, the description of PBL implementation in the Faculty of Architecture at University of New Castle, Australia (UniNC) was used as the comparison to allow understanding of the significance of different representations.

Although there are various research methods in the phenomenological approach, case study was selected over survey, observation, and experiment because it enabled the writer to focus on subjects under investigation; the reason behind the discontinuity of PBL implementation in the Faculty of Architecture, TUDelft. Case study is an associated methodology under qualitative research design that correlates research with "developing an in-depth analysis of a single case or small number of cases" (Creswell, 1998). In the instance of the paper, research project mainly focused on studying one particular case study, the Implementation of Problem Based Learning in the Faculty of Architecture at TUDelft. This case study was considered to be an "explanatory case study" because it described "causal inquiries" of how and why (Yin, 1994; Tellis, 1997). Yin (1994) notes that case study method is normally used because researchers want to deliberately cover "contextual conditions" of why and how certain "decisions" are made, either in "individuals, organisations, processes, programmes, neighbourhoods, institutions, or events."

The Faculty of Architecture at TUDelft was chosen as the main case study because it was the first architectural faculty in Europe to implement PBL as an educational approach to learning architecture. Based on the research questions identified in the research, the study sought to determine how and why PBL was implemented in the Faculty of Architectural at TUDelft, and why the implementation was discontinued whilst claiming its success. Subsequently, the findings of the research determined whether PBL was an appropriate pedagogical approach to be introduced in Architectural Education throughout the globe, or not.

2.3 Justification for the Methodology Used

Case study research methodology was the most appropriate methodology to approach the subject studied, because it enabled the writer to look in depth at issues related to the implementation of PBL, although the writer did not have control over the event. It also enabled the research to "focus on meanings, try to understand what is happening, look at the totality of each situation, and develop ideas through induction from data" (Creswell, 1998). In this way, a single case study could be seen to satisfy the three tenets of qualitative research methods: describing, understanding, and explaining, providing it met the established objective (Tellis, 1997). In this instance, an evaluative application of describing, understanding, and explaining the PBL implementation in the faculty of Architecture at TUDelft was carried out to assess the effectiveness of educational initiatives. This type of investigation could not be done by merely quantitative techniques, due to the nature of empirical research that tends "to obscure some of the important information" to be uncovered (Tellis, 1997).

The main data collection methods used in this research study was documentation review and interview survey. For practical reason, other types of data collection methods also sometimes used in the case study research approach, such as survey, observation, and experiment, would not be used in this research. The exclusion of observation and experiment was due to the nature of this research, which required investigation of a PBL implementation in the Faculty of Architecture, TUDelft that had been discontinued. In this instance, the PBL implementation in the faculty was considered as history. Therefore, observation and experiment methods, which usually require the subject investigated to be present, could not be done because the researchers could not play the major roles in the event to be observed and experimented. Something that had happened in the past could not be available to the researcher to participate in the subject of research directly.

Moreover, this research also did not use survey as part of its research design, simply because this research did not aim to produce "laws" or generalization in the same way as quantitative methods. The use of a small number of interviewees could not provide an adequate basis for inferential statistics (Creswell, 1998). Instead, this research aimed to provide awareness of the crucial roles of pattern and context via a non-laboratory setting, in which research was facilitated by the "most hard to specify stimulus, the human face" (Yin, 1994).

Hence, the data collection methods of documentation review and interview were left as the strategic options to carry out the research. Document review was useful for making inferences about events, whilst focused interview was used to confirm data collected from the documentation review. In order to get first-hand accounts from educational and architectural specialists on the experience of PBL implementation in the Faculty of Architecture at TUDelft, the research demanded face-to-face interviews in the case study research. Besides, this focused face-to-face interview provided "a humanistic validity" (Yin, 1994), whilst the review of documentation provided substantial information to scientifically and iteratively corroborate the evidence from the former source, thus ultimately provided the research synthesis in the case study. This combination of interview and documentation review as research strategies provided comparative explanations to satisfy the "ethical need" of confirming the validity of the processes (Tellis, 1997).

2.3.1 Research Method and Procedures

In this case study research, data collection methods were done through document review and interviews. Document review of the PBL Implementation in the Faculty of Architecture, TUDelft, provided the framework of this research study that had been generated by the research questions. Meanwhile, face-to-face interview was chosen as one of the data collection methods to explore individuals' opinion in depth about the PBL implementation subject studied.

2.3.2 Unit of Analysis

Choosing unit of analysis for case study research is very important to ensure accuracy of the information gathered. For this research, three main people who had different and specific roles in the implementation of PBL in the Faculty of Architecture, TUDelft, were chosen as units of analysis in this case study research because of their direct involvement in the PBL implementation process. They were expected to give their individual perceptions in detailed accounts of PBL implementation. The first interviewee was chosen was responsible for the enforcement of the implementation. He was expected to give personal accounts on the implementation of PBL in the faculty based on management point of view. The second interviewee was because as a specialist in education, he was responsible for providing training for the architecture faculty members. He was expected to provide viewpoints based on pedagogical perspectives. The third interviewee was one of the faculty members, who taught Computer Aided Design during the implementation of PBL. He was expected to give comment on architectural and practical aspects of PBL implementation in the Faculty of Architecture at TUDelft.

2.3.3 Instruments and Procedures of Data Collection

Prior to the interview session, relevant documentation about the implementation of Problem Based Learning in School of Architecture, TUDelft, was examined. This review of documentation provided the basis framework for the studies, and led to the finding of several gaps in the implementation, which ultimately helped formulate the research questions.

Questions were formulated in order to fully understand the constructs of the implementation. Semi-structured questions were prepared prior to the interview to ensure the focus of information collected. The questions mainly functioned as the instruments in the effort to obtain answers to the research questions. The questions were divided into seven (7) main categories, as follows:

- Conceptual Framework- to further clarify the concept and philosophy of the implementation
- Implementation - to provide in-depth information about the implementation.
- Comparison with Other Approach – to examine the model of Problem Based Learning in architectural schools as compared to other professional disciplines of education.
- Changes in Curricula, and Management – to examine the changes and transformation involved during the implementation of Problem based Learning.

- Staff Commitment – to understand the overall involvement of staff, in terms of commitment, acceptance, understanding and perceptions.
- Students' involvement – to check the students involvement
- Conclusion – summary of the implementation account.

Semi-structured questions in face-to-face interview session "allowed the respondent freedom of expression, yet still produced data that the researcher considered essential" (Simister, 1995). Besides, the flexibility of semi-structured questions in face-to-face interview provided an opportunity to have the interview sessions appear informal, thus giving an opportunity to the interviewees to deliver data which are not usually expressed in written documentation. This type of interview was known to be relatively easy to control as the interviewer had the opportunity to lead and guide the conversation within the subject discussed (Denscombe, 2003). In addition, applying the data collection method of face-to-face interview allowed the interviewer to address "further inquiry" whenever necessary (Yin, 1994).

However, there was also a limitation to the method chosen. It was noticed that, although semi-structured questions were addressed to the interviewees, most of the time the answers received were not focused on the subject asked. It was difficult to control the conversation specifically around the subject asked, rather the conversation always diverted from the topic. Interrupting the experts might be considered rude, while letting them get carried away was not preferable because the researcher needed to optimise the time available for the interview sessions. More effective control of the interviews might have been possible with stronger preparatory communication skills training for the interviewer.

Interview was the best option as tool of data collection when looking at individuals' perception because it provided good interaction via eye contact and tone of voice, and presented emotion of verbal communication. Interview had "an element of personal interaction between the researcher and the respondent not present in other forms of data collection" (Simister, 1995). Through personal interaction, interviewees might give personal opinion about the issues discussed which had not been exposed in written format anywhere else.

The interviewees were contacted via email, some months prior to the preparation of research questions. This correspondence was to get their personal agreement to be interviewed, as subjects of research analysis. The programme of the interview sessions, with suggested times, dates and venues of the interview sessions, was sent to the interviewees via emails. This correspondence also helped in the preparation of questions, based on the interviewees' possible experience and involvement. The interview session could be carried out only once the agreements from the interviewees had been secured, and the semi-structured questions were satisfactorily prepared.

With permission from the interviewees, note taking and tape recorder were used as aids to the interview sessions. The purpose of using tape recordings to record the conversation in the interviews sessions was to avoid missing out on data. In this research, neither the interviewer nor interviewees were native English speakers. As such, it was expected that the conversation in the interview sessions might not go smoothly because of communication problems. However, the tape recording of the conversation would ensure all subjects discussed were captured for future transcribing of data into verbatim form.

Besides that, data from the interview session was also recorded in textual format by means of note taking. During the interviews, the interviewer might catch some of the essence of the conversation and have reflective remarks on some of the subjects discussed. Hence, note taking was used to ensure these reflective responses would not be forgotten after the conversation ended. The process of note taking was essential because it functioned as the collection of reflective ideas obtained while listening to the conversation, as the textual capture of emotions involved in the expression of interviewees, and as a reference during the analysis of data.

2.3.4 Limitation of Data Collection Method

Case study research did not have uniform protocols (Tellis, 1997), perhaps partly because the literature available on case study research was "primitive and limited" (Yin, 1994). Although this might be considered as providing freedom for a researcher to formulate a personal method of research, yet it does create difficulty in avoiding criticism of its primacy.

During the interview sessions, note taking was carried out as an aid for analysis to be done later. Nevertheless, note taking during conversation might result in limitation of the interaction between interviewer and interviewees, especially eye contact. Eye contact was known to be essential to see the emotion involved during discussion. The lack of eye contact might lead to an over-formalised conversation. Regarding this, one of the interviewee questioned the attempt to take notes, suggesting that he preferred an interviewer to listen to him attentively.

2.4 Analysis of Interview Data

2.4.1 Content Analysis

Choosing unit of analysis Data collected during the interview sessions would not have any meaning without analysing them. In order to make the data obtained during the interview sessions useful, several processes of content analysis were done. In its simplest format, content analysis was the "extraction and categorization of information from text" (Simister, 1995). In this instance, content analysis was done on the interview transcripts to extract meaning and categorise sets of information regarding the implementation of PBL in the Faculty of Architecture at TUDelft. By doing content analysis, the process of "describing, understanding, and explaining" (Tellis, 1997) the findings of the case study research would be made easier, as compared to trying to find information from the whole interview transcripts.

There were 9 main activities involved in the process of content analysis: transcribing the recorded data into verbatim format, coding of the collected data, adding reflective remarks to the data, adding marginal remarks to the transcribed and coded data, categorizing of data, data reduction, data displays, analysing meaning of the data, and drawing conclusions.

2.4.2 Transcribing the Interview Transcripts

Transcribing was the first step in content analysis after the collection of data via the interviews. It involved the process of transferring the tape-recorded data into textual format for ease of analysis. The recorded data was transcribed into verbatim format, as closed as possible to the original conversation taking place during the interviews. Some limitations appeared during this process of transcribing.

Since both parties, the interviewer and interviewees, were not native English speakers, the recorded format appeared to have many grammatical errors, unclear pronunciation, and too many pauses taken to find the correct choices of words. As a result, this already lengthy and tedious process was made worse because it was so time-consuming. However, it was essential that this process be done properly because the transcripts produced were the basis for analysis.

To reduce the burden of having the tedious task of transcribing, notes taken during the interview sessions offered a great help to the transcribing process, especially if the taped words were inaudible. With the completed transcript at hand, data retrieval was made easier as compared to listening to tape recorder for analysis.

In interview session, it was hard to control the conversation around the subject questioned. Some of the information needed for certain questions was answered at different times, while a different question was being addressed. As such, information appeared scattered all over the transcripts, which were difficult to comprehend in the original conversational sequence. Therefore, before beginning the analysis, the textual data needed to be coded and categorised in the sequence of the prepared semi-structured questions.

2.4.3 *Coding the Collected Data*

Coding was generally used for the purpose of "systematically searching data to identify and to categorise specific observable actions or characteristic" (Tellis, 1997a). In this instance, coding was used to label sections of text that related to a certain topic, or to a certain question. The coding system was formulated in the same sequence as the prepared list of semi-structured questions. However, the nature of a semi-structured interview with open responses provided ample opportunity to interviewees to give additional information that was not asked by the interviewer. This additional information might be important to the research. As such, additional codes were provided to label this extra information. For example, there were only two questions in the category of conceptual framework: both were regarding architectural educational approach in architectural education. However, information gathered about the subject included the definition of Problem Based Learning. Therefore, additional codes were needed to label the extra information.

In the coding process, a printed version of the transcripts was read several times to retrieve information, and consequently be labelled with the appropriate codes. Besides labelling the text in the transcript with codes, marginal and reflective remarks were added to the transcript hard copy. These informal forms of notes were used later in the analysis process. The coded transcript would then be categorised and arranged in a new format of information displays for easier analysis.

2.4.4 *Adding Reflective Remarks*

Besides taking notes on important information during the interview sessions, the remarks on responses and reflections were noted upon the interviewees' answers and statements. These notes might be highlighted later when embarking on data analysis process. Research specialists recognised the practice of jotting down reflective remarks as an important activity during interviewing. Miles and Huberman (1997) defined reflective remark as raw field notes about the field-worker's reflections, and commentary on issues that emerged during the process. It added substantial meaning to the write-up, not least to other readers. It usually strengthened coding, in pointing to deeper or underlying issues that deserve analytic attention (Miles and Huberman, 1997).

2.4.5 *Adding Marginal Remarks*

Similarly, some reflective ideas and reactions were noted whilst in the process of data analysis. In research, these textual ideas are known as marginal remarks. However, although marginal remarks are analogous to reflective remarks, they were not done during data collection process. Instead, the process of adding marginal remarks was intensively carried out during the data analysis process when some more new ideas were continuously added throughout the analysis process. Capturing the emerging ideas in textual format was important as they suggested "new interpretation, leads, connections with other part of the data," and they usually pointed towards questions and issues to look into during the next wave of data collection, if applicable (Miles and Huberman, 1997). In addition, those captured ideas would also give direction on ways of elaborating some of the research findings.

2.4.6 Categorization of Data

As mentioned previously, the textual data was categorised and arranged in the same sequence as the prepared semi-structured questions. Based on the codes labelled to sections of text earlier, text from the three different transcripts was broken down into discrete sections (Simister, 1995), and transferred into categories in new documents. In this process, text excerpts from three different interviewees were combined together according to similar categorisations. As such, there were seven documents produced for the seven categories of the codes. The combination of excerpts from the three different transcripts would later ease the process of comparing interviewees' ideas.

Some of the content of the transcriptions appeared unnecessary for the research project. Therefore, the data were intensively reduced, in order to format the text into useful categories.

2.4.7 Data Reduction

During the categorisation process, data was organised in such a way that final conclusions could be drawn and verified. Besides, intensive data reduction was done to some of the insignificant pieces of information in the transcripts. This process was described by Miles and Huberman (1997) as the process of selecting, focusing, simplifying, abstracting, and transforming the data that appeared in written-up or transcriptions. The process of data reduction occurred continuously throughout the content analysis of this research.

2.4.8 Data Displays

Displaying the data obtained from the interview session was the most important process to ensure the data could be easily understood by readers. Different types of data displays, such as matrices, charts, and networks, were used to show the relationships between information presented. Good data displays were a major avenue to valid qualitative analysis. In this research, intensive analytic activities were required to display data, which had appeared in a dispersed and poorly structured textual format. Only with organised and well-structured displays of data could conclusions be drawn.

Accordingly, Miles and Huberman (1997) described a display as an organised, compressed assembly of information that permits conclusion drawing and action. It functions to reduce complex information into selective and simplified gestalts or easily understood configurations. These “analytic activities” were designed to assemble organised information into an immediately accessible, compact form so that the analyst could see what was happening, and draw justified conclusions.

2.4.9 Analytical Analysis of Meaning

The whole process of data analysis was iterative and cyclical, rather than sequential. As such, well-documented processes of this overall content analysis were necessary. Having well-documented processes would eventually help to understand clearly just what was going on during the analysis process, in order to reflect and refine the methods undertaken, and probably make them usable to others.

Although this case study research produced a massive amount of data in textual format, no computer-assisted data analysis program was used. No doubt computer assisted data analysis program would have made the process of retrieval of data much easier, but the nature of this case study research required a high amount of cross-references which could be comfortably done with word processing software and hard copy format. In addition, most of the data should be analysed in context, which was lacking in available computer-assisted data analysis coding systems. The theory-generating features in many of the computer programs were limited to producing a basic format of networks, whilst this research required the use of several forms of matrices for data displays. The whole process of intense analytical handling made it difficult and complicated to embark on becoming familiar with so many options of computer assisted data analysis software. Furthermore, the nature of this research was not intended to produce any law of generalisation in which examination of repetition of words was important. Therefore, the use of a computer-assisted program to perform content analysis in this study was not necessary.

2.5 Drawing Conclusions

The discussion on data displays and its meaning led to the drawing of conclusions. According to Miles and Huberman (1997), conclusion drawing is the practice of “noting regularities, patterns, explanations, possible configuration, causal flows, and proposition” of information. Such conclusions from the data analysis helped to answer the research questions of the thesis, and provide an understanding of the research phenomena.

Nevertheless, the meanings emerging from the data have to be tested for their validity. In this instance, the design of a single explanatory case study research required the construction of an “internal validity”, in which multiple sources of evidence were used as the way to ensure construct validity (Tellis, 1997b). Since this research had data collected from documentation review and interview, cross-referencing was cyclically done between both materials to construct a “corroborating mode” of validity (Tellis, 1997a).

2.6 Ethical Consideration

During the data collection process of interviews, there were three obvious ethical considerations. Permission was sought from the interviewees on instruments to be used during the interview, respected the time allocation for the duration of the interview sessions, and managed the interviews in ways most convenient to the interviewees.

Permission was sought from the interviewees about the use of tape recorder and note taking prior to the commencement of interviews. As expected, all the three interviewees granted their permission on the use of tape recorder, but one interviewee seemed to prefer the interviewer to listen to him attentively without taking notes. Moreover, another interviewee requested that he should be notified if any of the content of the interviews was to be published.

In addition, the time allocation given by the interviewees was respected. Although it was suggested that the interview session would take two hour of each interviewee’s time, only two of them agreed with the proposal. One of the interviewee said he could only spare one hour for the interview to take place. Lastly, the date, time and venue of interview sessions proposed also took into consideration whatever was the most convenient for interviewees.

As suggested by research specialists, a set of rules of conduct was also observed during the data analysis process. The importance of observing the ethical issues in doing research was raised by Denscombe (2003), stating that researchers should produce truthful and transparent research; should not do any harm while doing research; should conduct randomised controlled experiments; should observe privacy and confidentiality; and should observe legality and professionalism. Although the process of doing this case study research did not deal with controlled experiments, every effort was made to observe the other issues listed.

2.7 Summary

This research was an example of a single case study research in multi-disciplinary fields of architectural education and Problem Based Learning. Specifically, this research would provide a critical analysis of the implementation of Problem Based Learning educational approach in architectural tertiary education. It was hoped that this research would encourage educational specialists and architectural professionals to have a greater enthusiasm for improving architectural education by appropriately applying formal pedagogical innovation in architectural curriculum structure.

Using a phenomenological research approach as its paradigm, this research employed the use of interviews as the main data collection method, and content analysis as the main analysis method. Unfortunately, guidance on the how to employ manual content analysis in a phenomenological approach of a single case study within educational research was severely limited. As such, the method of manual content analysis of interview data obtained from specific participants, or in this case the interviewees were called units of analysis, needed to be explored further. Having made the attempt to explore this type of research, it was hoped to expand the horizon of phenomenological qualitative approach of single case study research.

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3 Theoretical Reconstruction of Sompur Mahaviahara at Paharpur, Bengal through a Buddhist Religious Architectural Process

Md Mizanur Rashid

3.1 Introduction

The 8th century Buddhist monastery of Paharpur in Bengal drew the attention of architectural historians of the South Asia as the earliest evidence of monumental architecture in the Bengal delta (Majumder 1946, De Leeuw 1957, Ashraf 1997). Its strategic geo-temporal location demonstrated its instrumental role in the development of Buddhist monastic architecture in South Asia. Its layout, gigantic scale and the unique architectural features became the centre of the research question. Several attempts have been made so far to recover the memories of this medieval Buddhist Monastery after the amnesia of a millennium. However, the limited amount of archaeological resource, literary evidences and epigraphic records at the disposal of the architectural historians appears as the main thicket. Filling up this lacuna based on these scantily documented and apparently inconspicuous resources is the main research problem today. As an architectural historian how can we approach to a problem like this from a telescopic distance? Is it possible to retrieve the lost architectural features of the monument as well as discern the overlapping layers of different ideas, meanings and values that shape this architecture within a particular context, in a limited resource situation?

There are several attempts by different scholars (Myer 1969, Naqi 1999,) to propose a superstructure for ruins of the central structure of the monastery. However, none of them was able to portray a complete narrative of the structure from its conception to completion because of certain limitations, which would be discussed later.

In this regard this article is an attempt to search for an appropriate method to alter these constraints into opportunities and to offer much accommodating grounds for different contesting narratives regarding this architecture. It potentially looks into the history in a more dynamic way and uses virtual reconstruction as a flexible tool to reconstruct the lost form of the building.

3.2 The Problem

Since its discovery in the early twentieth century, the ruins of Sompur Buddhist monastery became the focus of the scholars of the architectural history of Bengal. This mega-structure is considered as a landmark in the history of architecture of Bengal mainly for two reasons. Firstly it marks an important transition from the subconscious and vernacular mode architecture to the most conscious, symbolic and metaphoric mode. Secondly, it represents a particular era when Buddhism had its last stronghold in India under the royal patronage of the Pala kings and gradually transforming into a more ritualistic practice than the philosophical doctrine as preached by Buddha, which is known as neo-Buddhism or *'Tantric'* Buddhism. Considering its cultural and historical significance, UNESCO has inscribed it as a World's Cultural Heritage Site in 1985.

The most striking architectural feature that distinguished Sompur Mahavihara from the other Buddhist monasteries found in South Asia is the central cruciform structure (Figure 3.1).

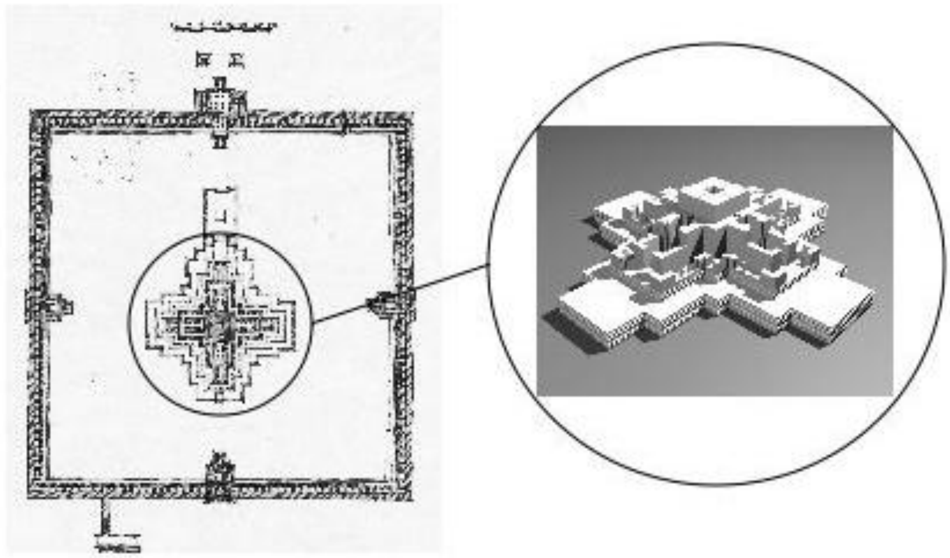

Figure 3.1: Plan of Sompur Mahavihara and the reconstructed model of the central structure

Hence most of the debates generated hitherto on the architecture of Sompur Mahavihara are centred on the missing superstructure as well as its layout, configuration and architectural details. The ruin of the structure rises upward in a tapering mass of three receding terraces, which reaches a height of 23 meters. Each of these terraces has a circum-ambulatory passage around the monument. At the topmost terrace (of the existing ruin) there were four antechambers on the projecting arms of the cross. The overall design of this complicated architecture is centred on a square hollow shaft, which runs down from the present top of the mound to the level of second terrace.

Sompur Mahavihara is definitely the mostly studied historical monument in Bengal. The three-dimensional articulation of the missing superstructure of the central edifice remains at the centre of the debate that led to several attempts of theoretical reconstruction by different scholars. However, the nature and the extent of the earlier studies are not sufficient enough to substantiate the historical discourse. The reason could be manifold, but the most important one is the non-availability of substantial amount of resource including a comprehensive architectural documentation at the disposal of the researchers. Tacit historical records coupled by the fragmented archaeological remains that are mostly at foundation level have perplexed the situation. Consequently, most of the works done so far are mainly limited on the findings of the archaeological excavation and studying the artifacts from the archaeological perspective. Hence the history of Buddhist architecture in Bengal is yet to be recovered from the amnesia of a millennium.

3.3 The Amnesia

Buddhism was almost declining in South Asia after the fall of the Pala Kings in the eastern region i.e. Bengal. The withdrawal of the royal patronage from the monasteries endangered the fate of the religion. For Buddhist the 'Sangha' (community of Monks) and the monastic life was the foundation of the religious practice. The declining state of monasteries expedited the waning of the religion. However, in the eleventh century the Afghan invaders gave the final blow by destroying the religious edifices of Hindu and Buddhist's either to fulfill their missionary zeal or for the requirement of building material for the construction of mosques. Such an obliteration of the monasteries ultimately wiped up the root of the Buddhist 'Sangha' and forced the monks to flee away. Consequently, Buddha and Buddhism were totally forgotten from the land of their birth.

The rediscovery of the history of Buddhism began with the attempts of some British colonial officers, who were informed about Buddha and his birthplace from the officials from Myanmar and Sri Lanka, where Buddhism was alive at that time. In particular Sir Alexander Cunnigham (1871) made some excavations in the places like Sarnath and Bodhagaya, which were mentioned in the Srilankan texts, for some archaeological evidence. Eventually these attempts took a much concrete shape when the travelogues of two Chinese travelers, Fa Xian's '*Records of the Buddhist Countries*' and the Xuanzang's '*Records of the Western Regions*' were translated into English (Giles 1877, Beal 1906). The later one gave a vivid description of the Buddhist religious edifices with every detail including its location, size and shape. Cunningham (1871) used these two records as guide to rediscover the Buddhist past of India. These Chinese records not only helped to map out the Buddhist religious sites but also helped to delve the history of these monuments. However, the absence of any other records than the Chinese travelers (later came other Chinese travelers like, I- Tsing and Sheng Chi, who also recorded different Buddhist architecture), has resulted into the discovery the Buddhist India, seen only by them (Takakusu 1966). The amnesia has been recovered but partially.

The places that were not travelled and recorded by anybody remained forgotten. Recent archaeological discovery has revealed their physical existence but cannot retrieve the memories (Dikhshit 1938). Sompur Mahavihara is one of them. Although being a significant monument in terms of its size, shape, location and most importantly it's mentioning in the historical records, it has failed to offer us a continuous narrative of its architecture.

As mentioned earlier reconstructing the past with limited resources in hand, which are fragmentary and inconspicuous in nature, is the major problem today. Whether we take the challenge and delve deeper to shape architectural history, or we leave it out as a forgotten chapter, is a vital question. If we opt for the later, we need to develop a pragmatic method of confronting this situation.

3.4 From Constraints to Opportunity

The earlier attempts of understanding the architecture of this monastery through theoretical reconstruction have failed to offer a cogent resolution. The reason seems to be the over reliance on the lack of and fragmented resources in hand. However, it was felt that the main problem is not the scarcity of resources rather it is the absence of a scientific framework to collate all the resources in hand. There is no doubt that it is seemingly difficult to depend solely on materials that are available at first hand to demonstrate a continuous narrative of the architecture of this monument but not impossible. This lack of physical resources could be transformed into opportunities than constraints for followings reasons:

- The lack of sufficient physical resources may be a hindrance to demonstrate a lucid description of architecture. Nevertheless, it at the same time offers a 'Tabula Rasa' by deconstructing any preconceived notion. The apparent amnesia could be seen as a great opportunity to understand the building process of the monument from a very neutral point of view. It may not give us a very accurate understanding of the individual architecture but it would lessen the risk of deviation because of the wrong interpretation of the archaeological ruins. Especially for the case of Sompur Mahavihara, where most of the architecture is missing we could use this situation to too look at the problem from a broader perspective and in a much flexible way. The focus of the study should be turned from the product to the process to use the fullest extent of this scope.
- It further opens up a ground for accommodating the earlier studies and contesting hypotheses. The apparent discrete nature of the approaches of these earlier works does not necessarily indicate a disjunction. Rather it demonstrates the array of possibilities of looking at the problem. Putting them together in a common platform through a critical analysis may give us much elucidating picture of the problem. The idea is not to debunk them or the assumptions upon

which they are based, but to develop an integrated approach that includes all the possibilities and scopes. Eventually it may establish a theoretical framework for further study by accepting, criticizing and refuting some of these earlier assumptions. This study can be considered as an addition to the existing body of knowledge. The terrain will not only be much richer once all the ideas and hypothesis will be put together but also offer a much wider scope to fill up the lacuna.

- As architecture this building is a part of the material culture of this region. The determinants of the material culture of a particular location include the tradition and world view of the people, the custom of reverence, symbol and rituals of expressing status, gender relationship, the sepulchral tradition etc. exist in a layered manner. These layers are not only overlapped with each other but also maintain an osmotic relationship of continuous transformation of ideas and themes in between them. Hence, the religious architecture is a result of a contestation of multiple themes, ideas and authorship (Bandarnayake 1974). Because of the amorphous nature of the religion, Buddhist religious architecture is much susceptible to changes due the cultural paradigm both in terms of form and meaning (Rashid 2006). This is not as simple as borrowing some elements from the other or adopting some style of expression. It is deeply rooted at the very conception of architecture or piece of art. Hence once we could understand the process and discern the layers that acted we would be able to understand the architecture as well. That means we have to look into the history in a more dynamic way and use all the available tools. We need to use information from different sources and to evaluate the problem of architecture from a much broader perspective.
- Virtual modeling can be used as a useful tool for multiple verification and criticism. It is not directed towards the end product as photographic realization of the original structure of *Sompur Mahavihara*. On the contrary, it concentrates more on developing a method of evaluation and synthesis to conceptualize the formal expression of the structure. Virtual reconstruction is to be applied in two levels for doing so. At one level it should be used to develop an exact visualization of the existing remains of the structure to be used as the basis for further study. The next level of modeling involves a comprehensive process of evaluation and verification. Main objective of this level is to generate a process of theoretical reconstruction of the structure by using all the available information. It is difficult from the presentably available material to come up with a single model of the central structure. Hence the present study may end up with several theoretical models of the Sompur Mahavihara based on different contesting hypotheses. This process of theoretical restoration and interpreting available information is a continuous one. What would not be found today can be kept for the future to comprehend, provided that the present information is

> not destroyed. Even the correction and criticism and debate can be accommodated by the successive reconstruction. It is perhaps the most flexible means using all the available resources that are apparently inconspicuous in nature (Forte and Silliotti 1997).

In this situation it was felt that the priority is to understand the process through which architecture is conceived and materialized. The study started from a much broader perspective to portray a broader picture of the development Buddhist religious buildings through time and space and tried to locate the case within this. Then it gradually zoomed down by discerning each of the layer one after another. It tried to develop a framework where the threads of all the available resources will be put 5thread was kept open for inflow of the future resources so that the model or the proposal can be modified when newer resources would be available.

3.5 The Study

At the beginning of such study, it was difficult to propose a definite course of the research. The reason was the limited amount of resources in hand as well as the blurred nature of the field. Hence our initial framework was more flexible and tentative. The strategy was to proceed in stages. It has adopted a method that initially started from a broader framework and then gradually descends to the next levels one after another. The inference deduced in one level actually determined what type of information should be looked for and what type of resources should be delved in at the next level. Hence with the progress of the research, the overall frame-work was getting more concrete. In the schematic diagram described in Figure 3.2, a comparison was done between the tentative framework and the actual course of the study. It would give us a clear idea about different levels of the actual study, their objective, findings and interrelationships.

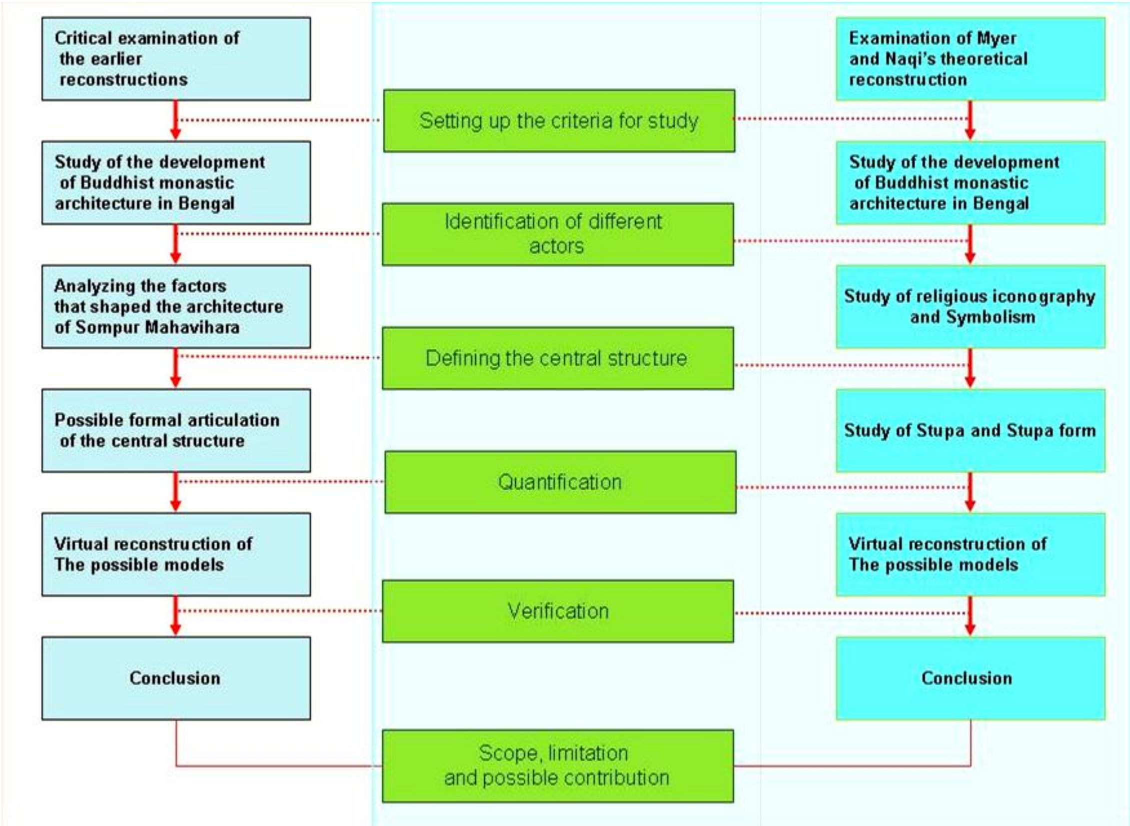

Figure 3.2: A comparison between the initial research outline and actual course of study

In a nutshell the gradual research progression could be broadly divided into two major phases. In the first phase we were more concerned about the historical study to define the structure itself in terms of its purpose and use, and in the second phase it concentrated more on the technicalities of the theoretical reconstruction of the monument.

3.5.1 Historical Study: Defining the Structure

The historical study focused mainly on the process of resilience and assimilation through which the design of the monastery was conceived and materialized in this particular context of Bengal. We started with unraveling and discerning the historical layers that assimilated to shape this particular architecture. Hybridized forms and shared architectural narratives that arose during the Pala period in Bengal were unique to the material culture of that place. The study identified the historical processes of hybridization of the major layers and their diverse morphological outcomes. It further revealed that two things worked together to shape the architecture of this great monastery or Mahavihara. On one hand, there was the conscious attempt of creating a particular place with religious and symbolic meaning, which is reflected at the most explicit level. On the other hand, at the core exists the realm of the vernacular that centered on the world view of the particular culture, its values and attitudes towards space.

Thus while the theme of the religious consciousness shapes the ‘visible’ superstructure; the underlying idea of the vernacular defines the ‘true’ nature of the space. Hence the earlier monastic architecture (Vihara) of Bengal that took the morphology of traditional courtyard house as vehicle, was gradually transformed into a more symbolic and metaphoric building. In one hand the highly esoteric and ritualistic nature of Tantric Buddhism inculcated the principles of Mandala for planning and organizing spaces as well as the determining hierarchic interrelationship between different spaces (Snodgrass 1985, Gail 1999). On the other the political zeal of the Pala ruler provided the gigantic scale of the building as part of the grand scheme to demonstrate their power and hegemony. After analyzing and synthesizing these layers it was deduced that the central structure of the monastic complex must be a manifestation of the Stupa - the most venerated of Buddhist religious edifices. However to conform the archaeological remains with the architectural characteristics of a Stupa, the study needed to go through another rigorous study of the different types of Stupa, its transformation through time and possible manifestation due to social and cultural impact. At the end it was presumed that the central Stupa is not only a Stupa but it is new type of Buddhist religious structure that evolved during this period and known as ‘Stupa-Shrine’ a combination of shrine with a super structure of a Stupa (Rashid 2008) .

It is clear now that this ‘unique’ architectural type of ‘Stupa-Shrine’ was conceived to cater the religious, social and political aspiration of that time. Yet, in a vernacular nature of building industry where the use of model or variations of models was the main practice for the construction of building, it is difficult to imagine that some artisan(s) had come up with a unique cruciform design solely out of his/their creativity. Rather it is more rational to think that the repeated use, alteration and modification of certain model to meet the newer demand, either religious or political, helped them to come out with the final version of the design.

How the vernacular designers actually came with this complicated design is a big question. However after rigorously studying the available resources in hand the study posited two possible schemes. The first one is based on typical late Mahayana Stupa with elongated drum, bulbous dome and elaborated finials with four Buddha statue seated on four cardinal directions, which is described in Figure 3.3, as Scheme A.

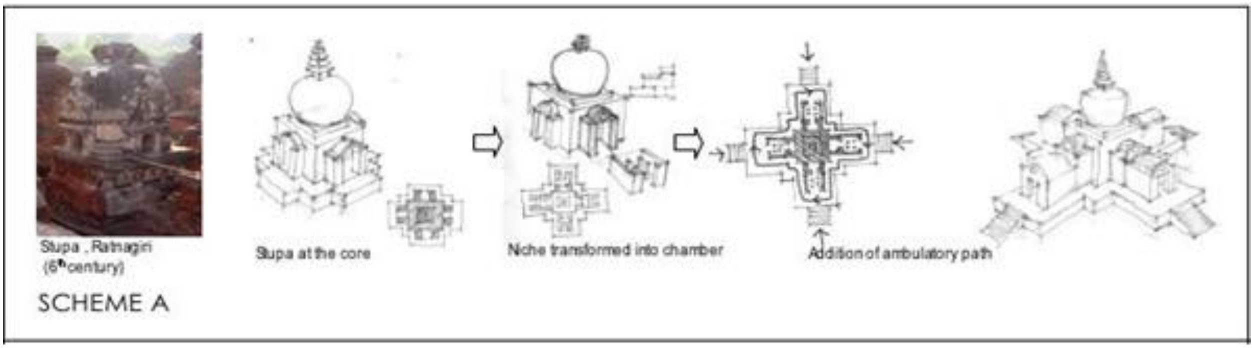

Figure 3.3: *Probable schemes for conceptualization of the design of the central structure –SCHEME A*

The second one is based on the archaeological discovery of certain structure, where conscious attempts of combining 'Stupa' and a shrine chamber is discernible. This is described as Scheme B and shown in Figure 3.4. Based on this it was concluded that the central structure, the 'Stupa Shrine' and the archaeological ruin in the site was actually crowned by the Stupa super structure.

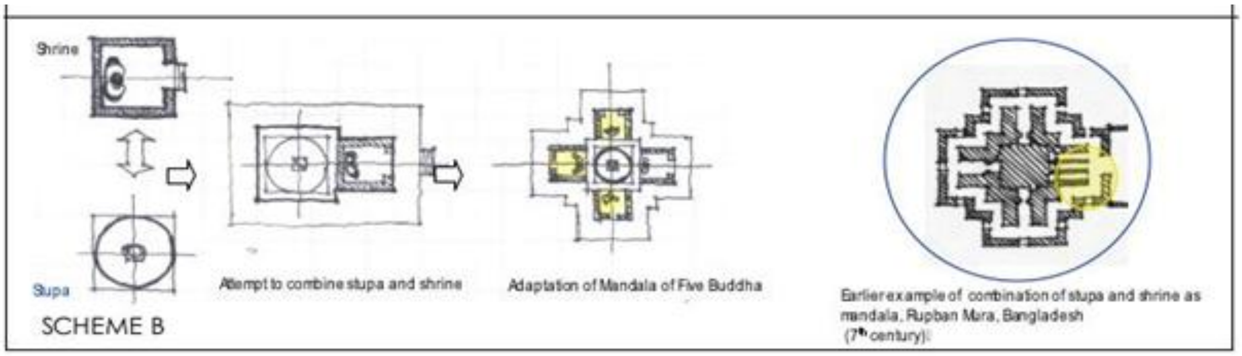

Figure 3.4: *Probable schemes for conceptualization of the design of the central structure* – SCHEME B

3.5.2 Quantification and virtual reconstruction

As the primary objective was to reconstruct the structure virtually, the study was in need of some quantifiable data to turn it into reality. From the ruins of the central structure the two dimensional lay out is discerned with the dimensions. Its precise geometry suggests the presence of a relationship between the two-dimensional layout and three-dimensional manifestation. Hence once this relation can be revealed it would help to do a possible reconstruction of the structure. The study attempted to resolve this problem by two ways. First, step was to do a metrological study of the Stupas that have formal affinity to understand the proportioning system. And secondly it (the study) looked for some contemporaneous records that demonstrate the metrology and proportion of the Stupa. The 9th century manual of '*Kriya Samgraha'* of Kuladutta (Skoeupski 2000) that described vividly the dimensions, forms and proportion of the four types of Stupa to be built for worship was very helpful in this regard.

The study tried to combine both of these sources to come up with possible three-dimensional reconstruction of this monument. Virtual reconstruction was adopted as the most flexible means to use all the available resources that were apparently inconspicuous in nature. The idea of using this tool was to keep the research open for further verification. It did not propose or argue for a certain three-dimensional model for Sompur Mahavihara, rather it tried to examine all the possibilities based on the resources in hand. These models were verified and checked with the archaeological ruins to identify the closest possible match. However, this process remains continuous and has enough room for accommodating future criticism, evaluation and correction when more resources will be available.

3.5.3 Comparison with Earlier Studies

The study was considered as continuation of the earlier works on Sompur Mahavihara. It certainly criticized the earlier theoretical reconstructions but never refute them totally. It used their contribution to developed further refined methods to approach this problem. Hence it could be considered as an addition in the existing body of knowledge, with respect to the earlier reconstructions of Myer (1969) and Naqi (1999), in terms of approaches and methods adopted. We could see that Myer was more concerned about the central structure than the whole complex and assumed the central structure to be a 'Stupa'. Although not dominant, her approach hints a bias to the colonial construct of linear progression of Buddhist architecture from South to South East Asia. As a result she identified the architecture of this central structure as 'Stupa' that was either related with the South East Asian or the Nalanda type.

Naqi has started with studying the Vihara 'archetype' but he suddenly focused into the central structure without verifying any connection between the Vihara with this cruciform structure. He assumed it as a 'Shikhara' type 'Stupa' mainly drawing inference from the Ananda temple at Pagan and contemporaneous Hindu temples. Like Myer, Naqi's assumptions were also affected by the colonial construct of the development of Buddhist religious architecture. Our study was attempted to cater two levels. In the first level, it started from much broader aspects of In Vihara architecture by putting emphasis in the regional varieties and the influence of internal conditions of a region. In this level, we tried to define the central structure with respect to the Vihara complex and understand the preconditions that made it as an integral part of the monastic architecture. The second level of the study focused on 'Stupa' and its architecture and was based on the deduction made on the first level. In conclusion, it combined these two at the end to make proposition regarding the formal expression of the central structure, shown in Figure 3.5.

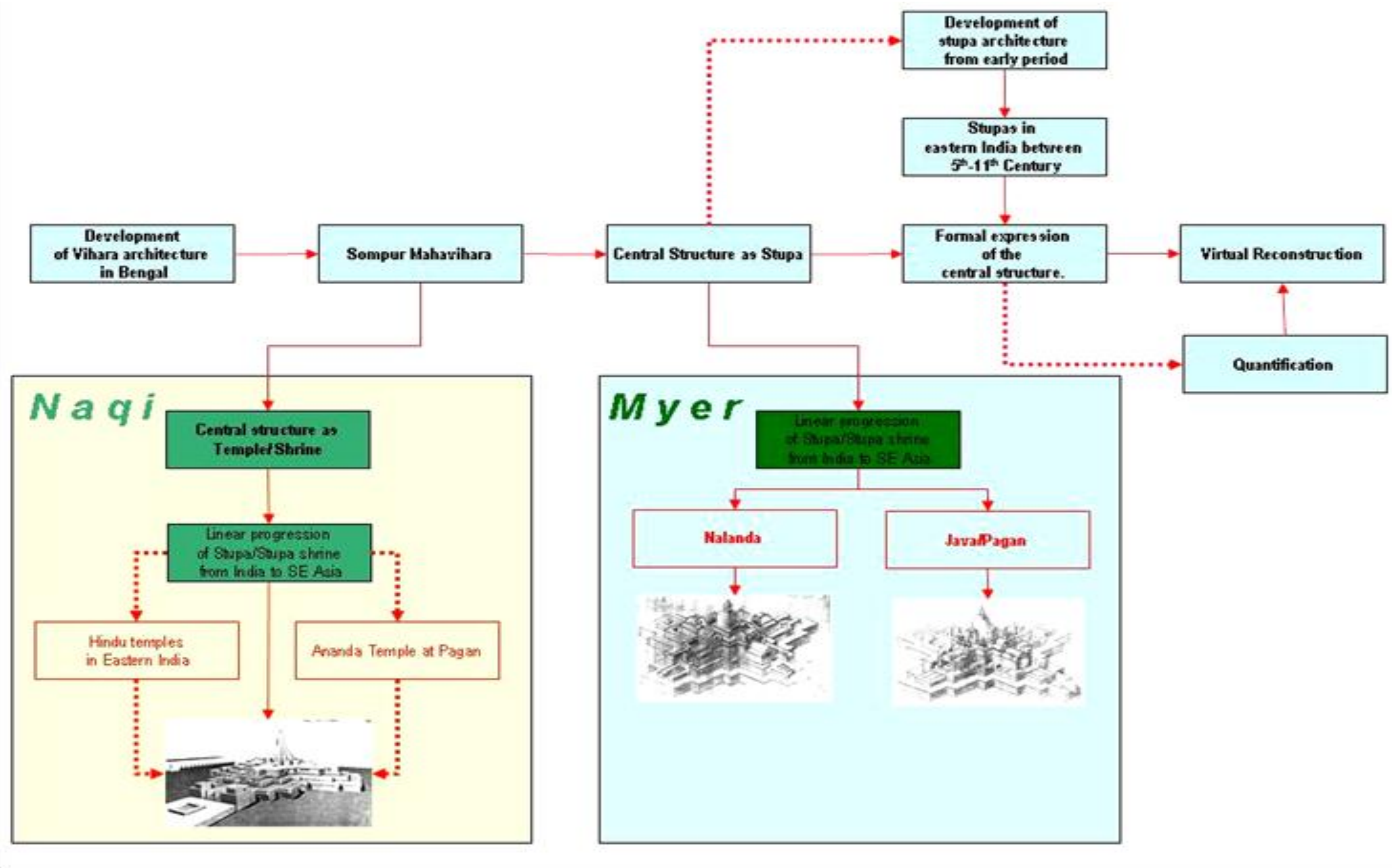

Figure 3.5: A comparison of the present study with Naqi's (1999) and Myer's (1969) works.

3.6 Summary

The study was an effort to collect all the available information regarding this monastery from different sources and then deduce logical inference by using this information. Because of the fragmentary nature of the information there were some grey patches in the study. However it did not hamper the objective of the research. It tried to look into the problem in a more architectural way and fill up the gaps using architectonic reasoning. This might not give a definite solution but it shaped the discourse, which was earlier amorphous. Now it is clear that what type of information should be looked at, and how it may change the form of the building. The study collates all the available information and organized them in a systematic manner. The main contribution of the study is the development of interactive framework of information that is open for necessary feedback in the future and refinement of the virtual model. This framework is described in the Figure 3.6.

It tries to compile all the available information and interlink them in a systematic way for the virtual reconstruction. The most important aspect of the framework is that it not only relies on architectural or archaeological sources, rather it adopted a cross disciplinary approach. Hence any small discovery at any discipline can be used in this framework to observed how it will affect the three dimensional expression of this structure. It also helped the future researcher to be aware of the type of information to be looked for and how this should be used to understand the architecture of Sompur Mahavihara. This framework also demonstrates the possible scope for future extension of the research that would engender further refinement the virtual model. These areas were not covered in this study due to the limitation of time and scope of this dissertation. For this reason the ends are kept open to accommodate the outcome of the future studies in these areas within this framework to verify the model at more detailed level. The most interesting part is that the framework itself is flexible and can be modified in future if necessary. This is a continuous process and would go on, as more resources are made available.

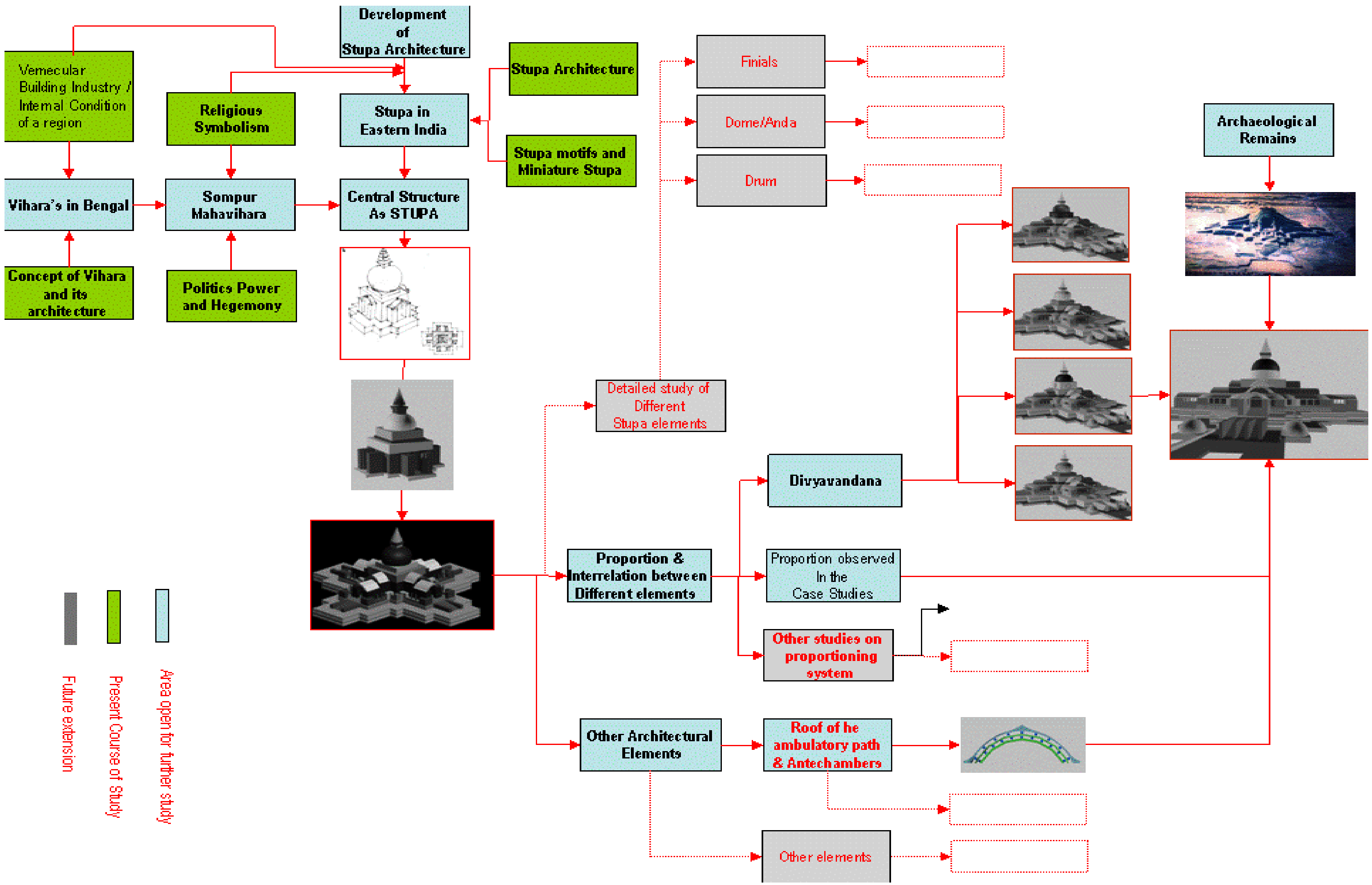

Figure 3.6: Scheme showing the theoretical framework adopted for the study with scope for future research.

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4 Mixed Methods Approach for the Study of Fire Safety Management in Malaysian Heritage Building

Nurul Hamiruddin Salleh

4.1 Introduction

This chapter presents the methodologies selected in the study of fire safety management in heritage buildings that are divided into three main methods. The first method involves literature review, where both heritage building and fire safety literatures were reviewed in order to identify key issues and recent research that relate or has significance to the research topic. The second method involves the collection of primary data through onsite observations, interviews and questionnaires. Finally, three case studies were selected as an approach to audit and to examine directly the fire safety management in the heritage buildings.

4.2 Background

In Malaysia, there are a number of valuable heritage buildings which have been classified into several categories, namely traditional timber Malay houses, pre-world war shop houses, colonial office buildings, and religious buildings. Some of them have been listed as Heritage Buildings or National Heritage Buildings under the National Heritage Act 2005 (Act 645). However, mostly due to inappropriate management and poor fire protection measures; several irreplaceable heritage buildings in Malaysia were destroyed or burnt down by fire. Examples of such incidents were the burning down of Pak Ali's House (Rumah Pak Ali) (Figure 4.1), the former High Court of Kuala Lumpur (Figure 4.2) and the Sarawak Club. In fact in the last decade, at least one heritage building was destroyed or damaged by fire almost every year in Malaysia. The worst fire incident occurred in 2008, where a total of 59 heritage buildings were involved in five different fire incidents. These tragedies emphasised the vulnerability of heritage buildings and their contents to fire and its aftermath. Therefore, this study is an analysis of the current practice of fire safety management in Malaysian heritage buildings, specifically heritage buildings that are used as museums either originally or through adaptive re-use processes.

Figure 4.1: Traditional timber house 'Rumah Pak Ali' built in 1876 was destroyed by fire in October 2003. (Source: Surainie Mohd Hanif)

Figure 4.2: The former High Court of Kuala Lumpur (1896) was twice destroyed by fire in 1992. The first fire occurred in 16 March 1992 when the building was undergoing renovation works (left) and later in December (right). (Source: http://www.beritaharian.com.my, 23 March 2008)

4.3 Objective of the Study

The objectives of this study are to:

a) audit the fire safety measures in Malaysian heritage buildings,
b) examine the management of fire safety by the employees of Malaysian heritage buildings, and to
c) formulate fire safety guidelines for relevant organisations or those involved (directly or indirectly) in heritage building conservation in order to prevent and protect occupants, fabric and contents of the heritage buildings from the risk of fire.

4.4 Research Method

The study conducted was based on a mixed methods approach using concurrent procedures. According to Creswell (2003), there are three general strategies in a mixed methods approach: sequential procedures, concurrent procedures, and transformative procedures. Concurrent procedures are a strategy in which the researcher combines quantitative and qualitative data in order to provide a comprehensive analysis of the research problem. In this method, the researcher collects both quantitative and qualitative data at the same time during the study and then integrates the information in the interpretation of the overall results (Creswell, 2003).

The study was conducted in stages until the conclusion of the overall research was completed. The first stage involved literature review, where both conservation and general fire safety literatures were reviewed in order to identify key issues and recent research that relate or were significant to the research topic. The second stage involved the collection of primary data through interviews, questionnaires and observations. The interview sessions specifically involved the museum managers or administrator officers who were responsible for fire safety management in their respective museums. Meanwhile a questionnaire survey was also conducted on the staff of the museums. In this respect, questionnaires were designed according to the objectives of this study as well as based on the expected output for analysis purposes. The interviews and questionnaires were conducted mainly to gather information on the current level of fire safety management in the selected buildings and the level of fire safety awareness among the staff. In the observation stage, with the permission of the building managers, the existing fire safety and protection measures in the buildings were briefly audited and manually recorded in a Fire Safety Checklist Form, a modified version of Form I (Reg.2) of the Fire Services Act 1988, as well as taking photos for research purposes.

In the third stage, three case studies were selected as an approach to audit directly the practice of fire safety management in the selected buildings. In this stage, fire safety and protection measures in the buildings have been audited and examined with reference to the requirements of the Uniform Building By-laws 1984 (UBBL 1984), the Fire Services Act 1988 (Act 341), the Occupational Safety and Health Act 1994 (Act 514) and the relevant Malaysian Standards.

In the last stage, recommendations and conclusions were made based on the analysis of the literature and the collected data. It is hoped that the recommendations will be a useful guidance to assist those involved in managing any heritage buildings particularly building managers in safeguarding their buildings' occupants, fabrics and contents from fire. Even though fire cannot be totally avoided in some cases, it could at least minimise damage to the buildings and contents from fire through the proposed recommendations. The research framework of this study is summarised in Figure 4.3.

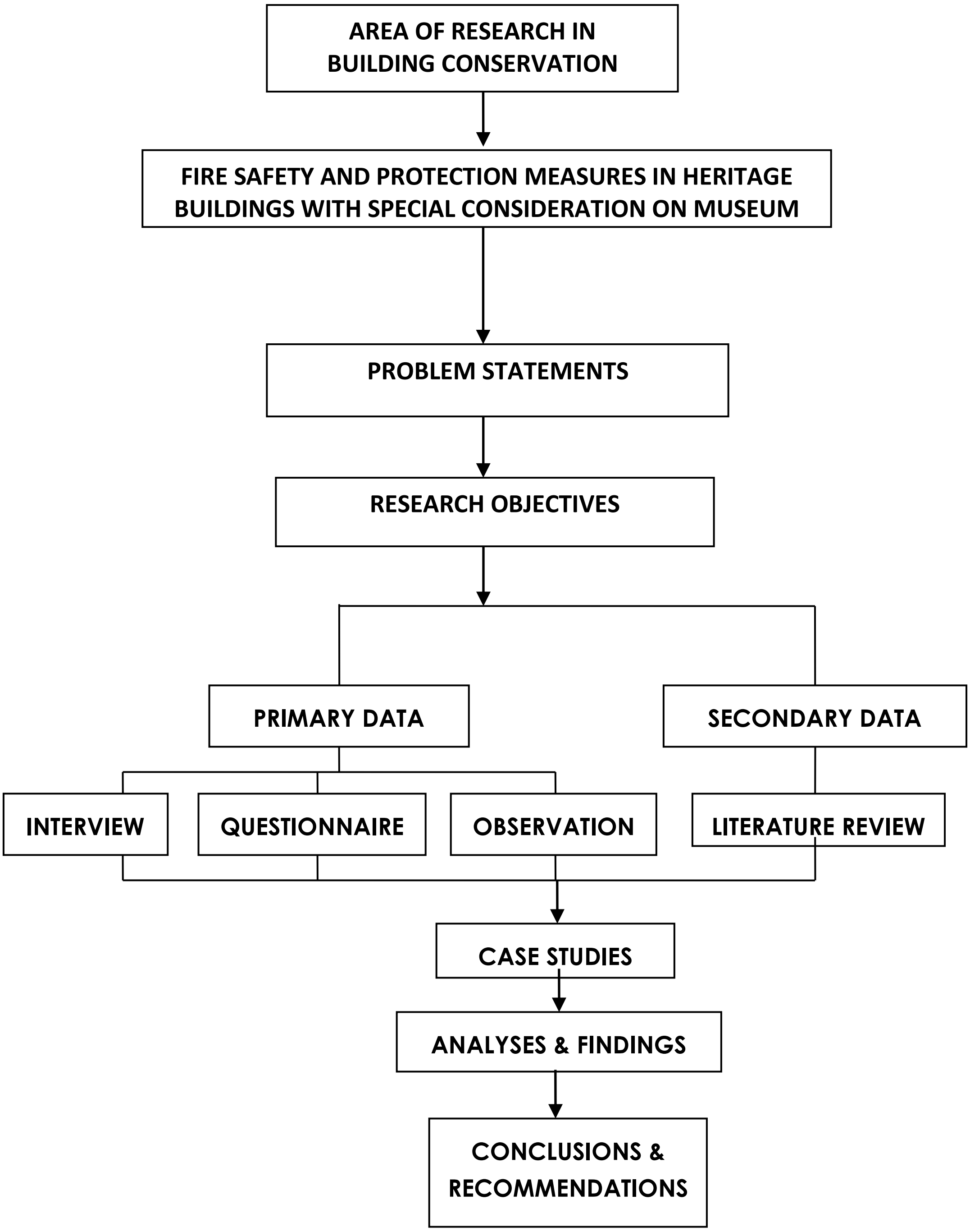

Figure 4.3: The research framework

4.5 Literature Review

A review of the literature aims to provide an overview of the nature and scope of prior research and provide the background of measurement used in the present research. As the scope and focus of previous studies are different in terms of users and context, some adjustments are needed to suit the undertaken research. This is particularly important in developing the questionnaires for the survey interview and issues focused for the in-depth interview which will be discussed further in the subsequent sections on the survey interview. For the purpose of this process, the data and information were derived from relevant sources such as books, theses, journals, conference proceedings, reports, internet websites, and some information obtained from the Department of Museums Malaysia, the Fire and Rescue Department of Malaysia (FDRM) and the Department of National Heritage, Malaysia.

4.6 Observations

This study focuses on museum buildings as sample buildings of heritage buildings. Museum buildings were selected because the buildings are not only heritage buildings but also contain priceless historical collections. In the context of museums or gallery collections, the loss of the building's contents and the building's significance in fire can be considered as a great loss to the country. In addition, based on the background study conducted, most of the buildings lacked fire prevention and protection systems as well as having weak fire resistant structures. This was what happened to the Pak Ali's house fire tragedy in 2003 where the building and its contents were totally destroyed with a total loss of more than RM1 million. Before the tragedy the building was one of the main attraction places for local and international tourists in Kuala Lumpur.

Historically, the institution of museums in Malaysia began in 1883 with the establishment of the first museum, the Perak Museum in Taiping. At present, there are about 132 museums in Malaysia (Table 4.1) with Kuala Lumpur as the leading state with 25 museums (19%), followed by Melaka with 23 museums (17.4%). Each one plays a significant role in collecting and preserving the cultural and historical heritage of the country. Their contribution depends on the resources and capabilities of each museum. The administration of museums in Malaysia can be categorised into five categories, which are the Federal Government with 22 museums (17%), State Governments with 65 museums (49%), Government Agencies with 31 museums (23%), Government Linked Companies with 2 museums (2%) and Private ownership with 12 museums (9%).

Table 4.1: The total number of museums in Malaysia. (Source: Personal survey, 2009)

No	State	Total	%
1	Kuala Lumpur	25	19.0
2	Melaka	23	17.4
3	Sarawak	13	9.9
4	Kedah	12	9.1
5	Perak	11	8.3
6	Selangor	11	8.3
7	Johor	8	6.1
8	Kelantan	6	4.5
9	Pulau Pinang	6	4.5
10	Negeri Sembilan	5	3.8
11	Pahang	4	3.0
12	Labuan	3	2.3
13	Sabah	2	1.5
14	Terengganu	1	0.8
15	Perlis	2	1.5
GRAND TOTAL		**132**	**100**

From a total number of 132 museums in Malaysia, 56 museums (42%) are currently using buildings that are 50 years old or more and could indeed be called heritage buildings. Most of them were built during the colonial period or before Malaysian independence in 1957. In fact, some of them are more than 100 years old such as the History and Ethnography Museums (Stadhuys) of Melaka, the Perak Museum, the Sarawak State Museum, the Penang Islamic Museum and the Kelantan Royal Customs Museum. In this study, 37 museums in nine different states were surveyed, where 32 of the museums are more than 50-years old (Table 4.2).

Table 4.2: List of museums surveyed in this study

No	Name of Museum	Year Built	Building Material
1	The National Museum, Kuala Lumpur	1959	Concrete & Masonry
2	The History and Ethnography Museums (Stadhuys), Melaka	1650	Masonry & Timber
3	The Melaka Governor Museum, Melaka	Between 1641-1795	Masonry
4	The People Museum, Melaka	Mid-17th century	Masonry
5	The Literature Museum, Melaka	Mid-17th century	Masonry
6	The Architecture Museum, Melaka	Mid-17th century	Masonry & Timber
7	The Malay World Museum, Melaka	1910	Masonry
8	The Melaka Islamic Museum, Melaka	1850	Masonry & Timber
9	The Perak Museum, Taiping, Perak	1886	Masonry
10	The Tuanku Fauziah Museum and Gallery, USM, Pulau Pinang	1938	Masonry
11	The Sultan Azlan Shah Gallery, Kuala Kangsar, Perak	1903	Masonry & Timber
12	The Sultan Abdul Aziz Royal Gallery, Klang, Selangor	1909	Masonry & Timber
13	The Kelantan State Museum, Kota Bahru, Kelantan	1981	Masonry & Timber
14	The Kelantan Royal Customs Museum (Istana Jahar), Kota Bahru, Kelantan	1887	Masonry & Timber
15	The Istana Batu Royal Museum, Kota Bahru, Kelantan	1939	Masonry
16	The Second World War Memorial (Bank Kerapu), Kota Bahru, Kelantan	1912	Masonry
17	The Sarawak State Museum, Kuching, Sarawak	1891/1911	Masonry & Timber
18	The Sarawak Art Museum, Kuching, Sarawak	Early 19th century	Masonry & Timber
19	The Sarawak Islamic Museum, Kuching, Sarawak	1930	Masonry & Timber
20	The Sarawak Textile Museum, Kuching, Sarawak	1907	Masonry, Timber & Concrete
21	The Telecommunications Museum, Kuala Lumpur	1928	Masonry, Timber & Concrete
22	The Royal Malaysian Police Museum, Kuala Lumpur	1952	Concrete, Masonry & Steel
23	The Kedah Royal Museum, Alor Setar, Kedah	1735	Timber
24	The Kedah State Art Gallery, Alor Setar, Kedah	1912	Masonry & Timber
25	The Independence House *(Rumah Merdeka)*, Alor Setar, Kedah	1953	Masonry & Timber
26	The Penang State Museum, Penang	1817	Masonry & Timber
27	The Penang Islamic Museum, Penang	1860s	Masonry & Timber
28	The P.Ramlee House, Penang	1926	Timber

No	Name of Museum	Year Built	Building Material
29	The Perak Royal Museum, Kuala Kangsar, Perak	1926	Timber
30	The Darul Ridzuan Museum, Ipoh, Perak	1926	Masonry & Timber
31	The Pasir Salak Historical Complex, Pasir Salak, Perak	1990	Masonry, Timber & Concrete
32	The Sungai Lembing Museum, Pahang	1902	Timber
33	The Tun Abdul Razak Memorial, Kuala Lumpur	1962	Masonry, Timber & Concrete
34	The Tunku Abdul Rahman Memorial, Kuala Lumpur	1956	Masonry & Timber
35	The Tun Hussein Onn Memorial, Kuala Lumpur	1983	Concrete & Masonry
36	The Galeria Sri Perdana, Kuala Lumpur	1983	Masonry, Timber & Concrete
37	The Proclamation of Independence Memorial, Melaka	1911	Masonry & Timber

The museums were selected based on the following criteria:

i. The building with historical and architectural significance;
ii. The building exhibits importance objects of historical, scientific or cultural interest;
iii. The building under the management of different agencies such as the Federal government, state government, government agencies, government-linked companies and private.

Statistically, 59.4% (22) of the surveyed buildings are managed by state governments, 24.4% (9) managed by government agencies (e.g., the National Archives Malaysia, the Royal Malaysian Police and Universiti Sains Malaysia), 10.8% (4) by the Federal government under the Department of Museums, and 5.4% (2) under government linked company and private agency as shown in Table 4.3.

Table 4.3: Management of surveyed museums

No	Management Agency	Total nos of museums	%
1	The National Archives Malaysia (GA)	7	19
2	The Melaka Museum Corporation (PERZIM)-(SG)	6	16
3	The Department of Museum Malaysia (FG)	4	11
4	The Sarawak Museum Department (SG)	4	11
5	Lembaga Muzium Perak (SG)	4	11
6	The Kelantan Museum Corporation (SG)	4	11
7	Lembaga Muzium Kedah (SG)	2	5
8	Lembaga Muzium Pulau Pinang (SG)	1	3
9	Lembaga Muzium Selangor (SG)	1	3
10	Universiti Sains Malaysia, Penang (GA)	1	3
11	The Royal Malaysian Police (GA)	1	3
12	TM Berhad (GLC)	1	3
13	Dewan Perniagaan Melayu Malaysia Pulau Pinang (DPMMM)- (PI)	1	3
GRAND TOTAL		37	100
Note: FD: Federal Government, SG: State Governments, GA: Government Agencies, GLC: Government Linked Company, PI: Private / Individual			

The aim of this observation survey was to examine management of fire safety in the buildings by the different administrators. This survey also provided direct observation on the existing fire safety and protection measures in the buildings. As mentioned earlier, all information in this survey is recorded in a Fire Safety Checklist Form. In general, the surveyed museums represented 57% sampling of 56 total museums using historic buildings. Thus, the number is considered sufficient to provide the relevant information for the study.

4.6.1 General Background of the Surveyed Museums

From the survey, it is discovered that a majority from a total of 37 surveyed museums were 100 years old or more (43%, n=16) and 6 of the museums were built more than 200 years ago. The oldest museum is the History and Ethnography Museum of Melaka believed to have been built in 1650 (age: 359 years). However, 5 museums (14%) were found to be less than 50 years old. In terms of total staff, most of the museums (30%, n=10) have a total staff of around ten people or less. Whereby, 8 museums (24%) have a total staff of between 11 to 20 people and 3 other museums (9%) have a total staff of more than 30 people.

In terms of visitors, a majority of the museums have an average number of visitors between 10,000 or less in a month (73%, n=24). Nevertheless, 9 museums have an average number of visitors with more than 11,000 visitors per month (27%). In fact, 1 museum has an average number of between 51,000 to 60,000 visitors per month. The survey also found that the type of collections exhibited in the museums varies. Five of the museums (15%) displayed the most common collections, three-combination of collections comprising ethnological, archaeological and nature artefacts. Nevertheless, a majority of the surveyed museums (18%, n=6) exhibited special collections such as the Royal Malaysian Police Museum, the Architecture Museum, the Telecommunications Museum, the Proclamation Independence Memorial, the Darul Ridzuan Museum and the Sungai Lembing Museum. In terms of the total percentage of original collections compared to replica collections in the museum, the survey found that 16 museums (48%) housed more than 80% of original collections compared to replicas. In fact, seven of them housed between 91%-100% original collections. Therefore, even though the historical artefacts are commonly considered as priceless collections in terms of value, 14 museums (42%) claimed that the value of the collections in their museums is approximately RM3 million or more. Moreover, four of the museums claimed that the value of their collections is more than RM10 million (12%).

In terms of built-up area and building height, 9 museums (27%) with the built-up area of more than 3000 m/sq. while, 4 (12%) museums are made up of less than 1000 m/sq. built-up area. The height of the museums varied from 1-storey to 4-storey. However, 39% (n=13) of the museums are 2-storey and only one museum with 4-storey height which is the People Museum of Melaka.

4.7 Interviews

Interview is one of the prominent methods in qualitative research, where it allows researcher to understand the museum by listening to explanations from the participants of museum administrators (Creswell, 2003). In this study, data collected from the interviews used only as supporting material. This is because the objective of this study is to examine fire safety management in Malaysian heritage buildings, notably museums. Therefore, in this case, the museum administrators were interviewed such as managers/directors or officers who are responsible in managing fire safety in the museums. In general, a manager is a leading person who is responsible for managing an organisation and activity in the building that may include formulating fire safety policy in the building. It is widely accepted that the success or failure of an organisation depends on the credibility of its manager or leader. Museums in Malaysia usually have curators who are also normally appointed to be managers or directors.

The main respondent of this survey should have been a manager or director of the museums, but during the survey, it was discovered that some of the museums were only led by an assistant curator. In fact, two of the surveyed museums were supervised by an assistant administrative officer and one museum by a museum assistant. In addition, there were some cases where one manager was responsible for more than one museum or up to four museums. In this study, 24 respondents representing the 33 surveyed museums were interviewed and their respective positions are shown in Table 4.4.

Table 4.4: List of respondents and their positions

No	Museum	Respondent's Position	Date of Interview
1	The National Museum, Kuala Lumpur (The Department of Museums Malaysia)	Director	27/09/07
2	The Perak Museum, Taiping, Perak (The Department of Museums Malaysia)	Curator	31/10/07
3	The Sultan Azlan Shah Gallery, Kuala Kangsar, Perak (Lembaga Muzium Perak)	Manager	31/10/07
4	The History & Ethnography Museum, The Literature Museum, and The Governor Museum in Malacca (The Melaka Museum Corporation (PERZIM))	Curator	18/12/07
5	The Malay World Museum, Malacca (The Melaka Museum Corporation (PERZIM)	Museum Assistant (Representative)	18/12/07
6	The Tuanku Fauziah Museum and Gallery, USM, Penang (Universiti Sains Malaysia)	Assistant Curator (Representative)	08/01/08
7	The Architecture Museum, Melaka (The Department of Museums Malaysia)	Assistant Senior Curator	12/02/08
8	The Sarawak State Museum, The Sarawak Art Museum, The Sarawak Islamic Museum, and The Sarawak Textile Museum in Kuching, Sarawak (The Sarawak Museum Department)	Assistant Security Officer (Representative)	19/03/08
9	The Kelantan State Museum, The Kelantan Royal Traditions and Customs Museum (Istana Jahar), The Istana Batu Royal Museum, and The Second World War Memorial (Bank Kerapu) in Kota Bahru, Kelantan (The Kelantan Museum Corporation)	Assistant Curator	08/04/08
10	The Royal Malaysian Police Museum, Kuala Lumpur (The Royal Malaysian Police)	Curator	17/06/08
11	The Kedah Royal Museum, Alor Setar, Kedah (Lembaga Muzium Kedah)	Assistant Curator	30/06/08
12	The Kedah Art Gallery, Alor Setar, Kedah (Lembaga Muzium Kedah)	Assistant Curator	30/06/08

No	Museum	Respondent's Position	Date of Interview
13	The Penang Islamic Museum, Penang (Dewan Perniagaan Melayu Malaysia Pulau Pinang)	Manager	30/06/08 Via telephone
14	The Penang State Museum, Penang (Lembaga Muzium Pulau Pinang)	Assistant Curator	01/07/08
15	The Perak Royal Museum, Kuala Kangsar, Perak (Lembaga Muzium Perak)	Assistant Administrative Officer (Representative)	03/07/08
16	The Darul Ridzuan Museum, Ipoh, Perak (Lembaga Muzium Perak)	Assistant Administrative Officer (Representative)	03/07/08
17	The Pasir Salak Historical Complex, Perak (Lembaga Muzium Perak)	Assistant Curator (Representative)	04/07/08
18	The Sungai Lembing Museum, Pahang (The Department of Museums Malaysia)	Assistant Curator	07/07/08
19	The Telecommucations Museum, Kuala Lumpur (TM Berhad)	Technical Executive Operation	10/07/08
20	The Independence House, Alor Setar, Kedah (The National Archives Malaysia)	Assistant Director	18/07/08 Via telephone
21	The Tun Abdul Razak Memorial, Kuala Lumpur (The National Archives Malaysia)	Director	30/07/08
22	The Tunku Abdul Rahman Memorial, Kuala Lumpur (The National Archives Malaysia)	Assistant Director	31/07/08
23	The Proclamation of Independence Memorial, Melaka (The National Archives Malaysia)	Director	01/08/08
24	The Tun Hussein Onn Memorial, The Galeria Sri Perdana in Kuala Lumpur (The National Archives Malaysia)	Director	06/08/08

Nevertheless, a number of managers assigned their officers who were directly responsible for the fire safety management of the museums as their representatives. The managers of the People Museum of Melaka, the Melaka Islamic Museum and the P. Ramlee House of Penang were not available during the survey. Meanwhile, the manager of the Sultan Abdul Aziz Royal Gallery was reluctant to be interviewed because no consent was given by the Selangor Palace. In order to protect the identities of the respondents, their names are not disclosed.

4.8 Questionnaire Survey

In order to collect sufficient information, structured interviews were conducted with 31 questions in three sections. The first section focuses on demographic variables such as age, gender, position, year of service, educational background and professional qualification. The second is on the general information of the museums. The last section focuses on fire safety management in the museums. Personal calls were made by the author who introduced himself and the purpose of the call. Appointments were made for face-to-face interview according to the appropriate time and convenience of the respondents. 22 respondents were interviewed at their own offices through appointments and 2 respondents were interviewed by telephone with the author.

In order to obtain reliable information the questionnaire forms were also distributed to the supporting staffs that are monitoring the exhibition galleries in the surveyed museums during the on-site observations. The supporting staff are people who were employed by an organisation to support the manager in ensuring that all activities in the building run smoothly and that the building is safe at all times. Generally, the total number of staff in a museum depends on the size and status of the museum itself. In this study, a set of questionnaires was designed specifically to be answered by the staffs. As stated earlier, the questionnaires were distributed mainly to gather information on the current level of fire safety management in the selected buildings and the level of fire safety awareness among the staffs.

Questionnaire forms were distributed by hand to 238 staffs that were monitoring exhibition galleries in 35 museums. Unfortunately, the questionnaire forms were unable to be distributed at the Sarawak Textile Museum and the Sultan Abdul Aziz Royal Gallery of Selangor. Statistically, a response rate of 92% was obtained, with 219 staff returning the questionnaires. The total sample of respondents is 57% from the total population (n=381). The respondents were asked to complete a questionnaire of 34 variables in a two-page form. The questionnaires were collected by two methods of collections, namely self-collected and posted via mail.

4.9 Case Studies

The next method is a case study where Yin (2003) defines this method as, "… an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." The case study as a research strategy comprises an all-encompassing method covering the logic of design, data collection techniques, and specific approaches to data analysis. Furthermore, the case study:

i. Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result.
ii. Relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result.
iii. Benefits from the prior development of theoretical propositions to guide data collection and analysis.

4.9.1 The Selection Criteria for Case Study

The main aim of this case study is to provide important information which cannot be gathered by the surveys, and to support or complement findings from the surveys. This study focuses on museums as a sample building of heritage buildings. The museums are selected in this study for the following reasons:

i. Museum fires are the second highest fire cases involving historic buildings in Malaysia after historic shop houses.
ii. Both building and contents in the museums have a historical significance. Obviously, unlike other historic buildings, the loss of heritage contents and buildings in fire can be considered as a great loss to the country.
iii. A museum is an educational resource for the community; therefore, the building is normally open to public and receives a large amount of visitors that may increase fire risks to the building.

In order to gather various information and comparison as much as possible, the buildings have been selected in accordance to the following criteria:

i. Heritage buildings that are 100 years old or more. Based on the survey, the majority of museums in Malaysia are 100 years old or more. It is widely accepted that, when a building becomes older, it could be faced with higher fire risks.
ii. Heritage buildings that are made of timbers, masonry and a combination of both. The building material is the main factor to be considered in designing and selecting fire safety measures in any buildings. Different building materials may require different considerations.

iii. Heritage buildings that are managed by both federal and state governments. In practice, installing, commencing and maintaining fire safety measures in a building normally require large amounts of money. Unlike other museum managements, such as private sectors, federal and state governments are believed to have strong financial supports.

4.9.2 The Selected Case Studies

Based on the criteria above, three buildings have been selected as case studies. Firstly, the 276-year old Kedah Royal Museum in Alor Setar managed by the Kedah State Museum Board (State Government) to represent a timber heritage building. Secondly, the 125-year old Perak Museum in Taiping managed by the Department of Museum Malaysia (Federal Government) has been chosen to represent a masonry heritage building. Finally, the 124-year old Kelantan Royal Traditions and Customs Museum (Istana Jahar) in Kota Bahru, Kelantan managed by the Kelantan State Museum Corporation (State Government) has been selected to represent a combination of timber and masonry heritage building. The selection of the buildings is summarised in Table 4.5. In this study, fire safety measures and protection in the buildings have been audited and examined with reference to the requirements of the UBBL 1984, the Fire Services Act 1988, the Occupational Safety and Health Act 1994 and 4 relevant Malaysian Standards.

Table 4.5: List of case studies

No	Museum Name	Building Material	Management Agency	Year Built
1	The Kedah Royal Museum, Alor Setar, Kedah	Timber	The Kedah State Museum Board (State Government)	1735
2	The Perak Museum, Taiping, Perak	Masonry	The Department of Museums Malaysia (Federal Government)	1886
3	The Kelantan Royal Traditions and Customs Museum, Kota Bahru, Kelantan	Masonry and Timber	The Kelantan Museum Corporation (State Government)	1887

Case Study 1: The Kedah Royal Museum, Alor Setar, Kedah

The Kedah Royal Museum was formerly a palace for several former Kedah rulers (Figure 4.4). Before it became a museum, the building was known as the Kota Setar Palace, the Mak Wan Besar Palace and the Bridal Palace (Istana Pelamin). The building was built in 1726 and completed in 1735 during the reign of the late Sultan Muhammad

Jiwa Zainal Adilin Mu'adzam Shah II (1710-1778). The building was built when Alor Setar became the administrative centre for the state of Kedah. Originally, the building was built entirely of timber material (Muhammad Amin et al., 2007). However, it was renovated several times and that had influenced the architecture of the building. Most of the building renovations were conducted after several foreign invasions including the Bugis (1771), the Siamese (1821-1842) and the Japanese (1941). The building was totally burnt down during the Bugis invasion in 1771 but later was rebuilt to its original design. The building was also badly damaged during the invasion of the Siamese in 1821.

Figure 4.4: The front façade of the Kedah Royal Museum, Alor Setar, Kedah

In 1856, during the reign of the late Sultan Ahmad Tajudin Mukarram Shah (1854-1879), the building underwent a major renovation where most of the building materials were changed to brick, cement and marble. It became the first building that used those modern materials at that time (Muhammad Amin et al., 2007). Meanwhile, in 1903, during the reign of the late Sultan Abdul Hamid Halim Shah II (1882 – 1943), an extension to the old walls of the building was built to provide a hall for the Sitting-In-State of bridegrooms and brides in preparation of the Royal Weddings of the Sultan's five children in 1904. After the memorable wedding ceremony, the building was known as Istana Pelamin (the Bridal Palace).

During the Second World War, the Japanese army occupied the building. After the building was abandoned for several years, the Sultan then consented the building to be used by various voluntary organisations. According to the museum's supervisor, Rahimah Mat[2], among voluntary organisations that were used the building: the Sekolah Latihan Gadis, the Women's Institute, the St. John Ambulance, the Scouting Movement

[2] Personal communication, November 16, 2009.

and the Kedah Ex-Soldiers Movement. The building went interior renovations in order to suit the individual needs of each organisation that occupied the building.

In conjunction with the Silver Jubilee Celebration of the reign of Sultan Abdul Halim Muadzam Shah (the current Sultan of Kedah) in 1983, the building was restored to its original architecture before it was officially opened as the Kedah Royal Museum. The construction of new public toilets and roofed platform for a replica of vessel and royal hearses took place in 1990. Nevertheless, in 2000, the Royal Museum was temporary closed to the public for major building restorations including interior refurbishment, a project funded by the Federal Government of Malaysia under the supervision of the then Department of Museums and Antiquities. The works were completed in 2003 and the building was handed over to the Kedah State Museum Board (Lembaga Muzium Negeri Kedah). On the 1st of August 2008, five years after the restoration, the Kedah Royal Museum was re-opened to the public with its new interior layout and more collections. Since its opening, a total of 29,889 visitors visited the museum from August 2008 until December 2009.

Case Study 2: The Perak Museum, Taiping

The Perak Museum (Figure 4.5) is the first and the oldest museum in Malaysia. The first curator of the museum was Leonard Wray Jr. (1883-1903). In 2009, the Perak Museum was officially declared as a National Heritage under the National Heritage Act 2005 (Act 645). The Perak Museum is directly administrated by the Federal Government under the Department of Museums Malaysia (DMM).

Figure 4.5: The front façade of the Perak Museum, Taiping, Perak

Built in 1883, the Perak Museum was built in several phases. In the first phase (1883-1886), only the main building was completed. The building served as a centre for research as well as for exhibiting artefacts collected. It also housed the museum's office and library. Further construction was resumed in 1889 with the addition of two verandas to the front and rear of the museum. From 1891 to 1893, another wing was added to the west of the museum. In 1900, the British built an additional building two-storey high at the rear of the main building due to the increase of the museum collections. The annex building was completed in 1903. From November 2007 until January 2009, the Department of National Heritage was assigned to supervise major restoration works to the museum. The restoration of the museum was divided into 3 phases, at a cost of more than RM3 million (Farizah Idris[3], personal communication, April 10, 2009). According to the Department of Museums Malaysia, a total number of 3,112,217 visitors visited the museum from January 2000 until December 2007. In 2009, the museum was the second highest museum in the country that received the most visitors after the National Museum of Kuala Lumpur.

[3] A heritage officer of the Department of National Heritage Malaysia who supervised the restoration of the Perak Museum.

Case Study 3: The Kelantan Royal Traditions and Customs Museum (Istana Jahar), Kota Bharu, Kelantan

According to the Kelantan Museums Corporation, the erection of the palace was started at the end of the reign of Sultan Muhammad II (1837-1886) and completed in 1887 during the reign of Sultan Ahmad (1886-1889). The palace was built as a wedding gift for Sultan Ahmad's prince, Long Kundur, who later succeeded him as Sultan Muhammad III (1889-1890). During the reign of Sultan Muhammad III, the palace was used as an administrative centre for the state of Kelantan. Nevertheless, Sultan Muhammad III was on the throne for only one and a half years. Long Mansur, a brother of the late Sultan Muhammad III, was enthroned as the next Sultan. During the reign of Long Mansur, he used another palace as his official palace known as the Istana Balai Besar. Since then, an administrative centre of the state was moved to the Istana Balai Besar. The Istana Raja Bendahara became a palace for Long Senik, a prince of the late Sultan Muhammad III (Figure 4.6).

Figure 4.6: The front façade of the Kelantan Royal Traditions and Customs Museum, Kota Bharu, Kelantan

In 1911, Long Senik became a Sultan of Kelantan also known as Sultan Muhammad IV. During the reign of Sultan Muhammad IV, the Istana Raja Bendahara was renovated several times. He also directed a *Jahar* tree[4] to be planted on the ground of the palace. Since then the palace was famously known as the Istana Jahar. In 1980, Sultan Ismail Petra (1979 – 2010) agreed that the Istana Jahar be turned into the Kelantan State Museum. As a result, the palace was renovated after many years of neglect. On the 30th of March 1981, the Istana Jahar was officially opened as the Kelantan State Museum by Raja Perempuan Zainab II. Nevertheless, in 1990, the Kelantan State Museum was moved to a new building at Jalan Hospital. Since then, the

[4] A leaf of Jahar tree usually used by the Indian in curry dishes, whereby its flowers are used by the Malays in the traditional Kelantanese food called as '*kerabu*'.

Kelantan Museums Corporation adaptive re-used the Istana Jahar into the Kelantan Royal Traditions and Customs Museum to exhibit the regalia of the Kelantan sultanate. The building was again renovated to restore its original design. In order to preserve the historical value of the building, a few conservation experts were consulted in the restoration works including Mrs Waveney Jenkins, Prof. Wolf Killman, Mr. Ditier and Mr. Dingdari (Kelantan Museums Corporation, 1992). A new block of timber building was also added at the back of the museum to exhibit its weapon collections. On the 27th of July 1992, the Kelantan Royal Traditions and Customs Museum was officially opened to the public.

The museum was last renovated in 2008 under the supervision of the Department of National Heritage without sacrificing its original structure and design. According to the Department of National Heritage, the renovation cost was RM170,475.00 over a duration of 16 weeks (November 2007 – March 2008). In 2009, the museum received the highest visitors compared to other museums in the state where a total of 38,471 visitors visited the museum.

4.10 Summary

The selected methodologies have provided sufficient information needed for this study although some obstacles and problems occurred during the data collection processes. A combination of observations, interviews, questionnaires and case studies was employed to achieve the objectives of the study. The survey methods, namely observations, interviews and questionnaires were selected to provide primary data on the practice of fire safety management in the selected museums. Meanwhile, the case studies complement the findings of the surveys particularly in providing specific details and information on the management aspects of fire safety and its relation to the physical environment as a historic building. This is particularly useful as there are limited references and empirical studies on fire safety in Malaysia. Data from the surveys and data from the case studies were analysed and discussed to provide reliable information which complemented the recommendations.

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5 Mixed Methods Inquiries in the Assessment of Development Guidelines for the Geodesic Dome Visitors' Centre at Pulau Payar

Zeenat Begam Yusof

5.1 Introduction

This chapter describes the methodology used in the in the assessment of the Federal Department of Town and Country Planning (JPBD) Island Development Guidelines and the impacts of Pulau Payar Geodesic Dome Centre on the surrounding environment of the Marine Park. This research aim is to understand how far JPBD Island Development Guidelines were implemented in the physical planning of the Visitors' Centre and what the impacts of the development were on the surrounding environment. This chapter explained the various methods used to obtain data regarding the assessment and the impacts of the visitors centre. This research used the qualitative method utilising several data collection tools such as semi-structured interviews, structured observation using checklist method, visual method and document analysis.

5.2 Background

Malaysia is a developing country which has tourism sector ranks as a second generator of foreign exchange (Yeo, 1998). This industry is growing rapidly because it has wide range of natural asset such as marine parks, lakes, mangroves, limestone caves, waterfall, island and many others. Marine ecosystem is the most biologically diverse and productive ecosystem on earth is among the entire natural assets (Li Ching, 1998). Tourism throughout the Marine Park islands in Malaysia has been increasing rapidly over the last decade and is set to increase further in the coming decades (Dirhamsyah, 2005).

There are seven Marine Parks in Malaysia. Four of them are located in Peninsular Malaysia such as Pulau Redang Marine Park (Terengganu), Pulau Tioman Marine Park (Pahang), Pulau Payar Marine Park (Kedah) and Mersing Marine Park (Johor). All these Marine Parks was established in 1994 under the Establishment of Marine Parks Malaysia Order 1994. Pulau Payar Marine Park is selected as a case study for this research because of its characteristics and issues. The special characteristics of the island are small and rich with diversity of coral and marine life (Li Ching, 1998). Where else the issues are the health of marine ecosystem of this island is decreasing due to the development activity and visitor numbers are swelling to worrying levels. According to the Department of Fisheries Malaysia, visitors arrival at Pulau Payar was 1373 people in

1988 and tremendously increased to 133,775 in 2002 (Goh, 2004). According to Li Ching (1998) the increment of visitors was about 5000% as shown in Figure 5.1.

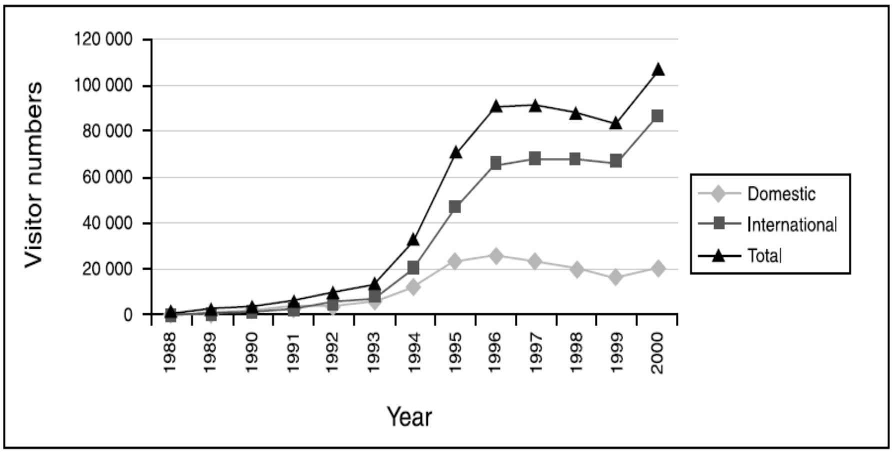

Figure 5.1: The number of increasing visitors to Pulau Payar from 1988 to 2000.

Due to the high numbers of visitors some basic facilities at Pulau Payar are not enough such as toilets, shower room and seating facilities (Li Ching, 1998). Consequently in 2004 Perbadanan Kemajuan Negeri Kedah (PKNK) construct a new visitor centre which consists of 12 chalets (Mohd Khair, 2008). The centre was known as Geodesic Dome visitors Centre. After completion of this centre, this centre was command to vacant due to its severe impact on the health of Pulau Payar marine ecosystem. An immediate study was conducted by State Government on the health of Pulau Payar marine ecosystem (New Straits Times, 15/9/2005). The construction of this centre causes several negative impacts on the ecosystem of Pulau Payar such as soil erosion, sedimentation, signs of nutrient elevation and coral segments break and twisted due to loading and unloading of construction materials during low tide (Mohd Khair, 2008).

There are several regulation and guidelines to protect and conserve the ecosystem of the Marine parks. The main regulation is Fisheries Act 1985 (Part Ix- Marine Parks and Marine Reserves (Section 41-45). Next there are three sets of guidelines. The first set is National Ecotourism Plan (NEP). The NEP is a comprehensive plan for assisting government on the potential of ecotourism activities. Basically the plan is divided into seven parts and consists of 25 set of guidelines for the management and promotion of ecotourism in Malaysia (Cheryl, 2005). Second set is the Island physical Development Planning Guideline under the Department of JPBD (Jabatan Perancangan Bandar dan Desa). The third set is Tourism & Recreation Best Practice Guidelines. Any development on Pulau Payar must be according to Fisheries Act (1985), NEP, Tourism & Recreation Best Practice Guidelines and Island physical Development Planning Guideline (LADA, 2005).

This research attempted to assess only three sets of guidelines. Some of these guidelines guiding principles are similar to each other. In this chapter all three guidelines are merged and the repeated guiding principles are omitted. Where else the Fisheries Act Regulation will be not assessed in this research because it is not related to the planning or building guidelines. It is for the protection of the fisheries industry and marine ecosystems. Figure 5.2 shows the four sets of development guidelines which are being enforced by the Malaysian government for the protection of Marine Parks.

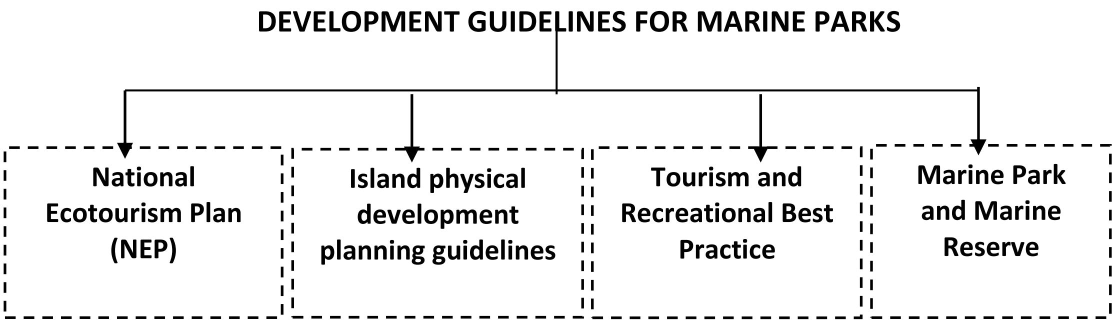

Figure 5.2: Regulation and guidelines for the management of Marine Park in Malaysia (Source: Data obtained from Local development plan of Langkawi Island (2001-2015)

There are many regulation and guidelines for the protection of the Marine Parks but there are still problems causes by development activities in the Malaysian Marine parks. Consequently the aim of this research was to assess how far the development guidelines were adhered in the development process of the Pulau Payar Geodesic Dome Visitor Centre and to determine the impacts caused by this centre on the reef ecosystem.

5.3 Research objectives

The main objectives of this research are stated as below:

i. To analyze the implementation of development guidelines on the Pulau Payar Geodesic Dome Visitors' Centre.

ii. To determine the impact of the Geodesic Dome development on the Pulau Payar marine ecosystem

5.4 Hypothesis

i. Some of the physical planning of Geodesic Dome Pulau Payar visitors centre does not comply with the development guidelines of Marine Park.

ii. The construction of the centre has several negative impacts on the Pulau Payar marine park ecosystem

5.5 Research questions

i. How far was development guidelines complied with the physical planning of Geodesic Dome Pulau Payar Marine Park Visitors' Centre?

ii. What was the impact of the centre on the marine environment of Pulau Payar?

5.6 Methodologies and techniques

Qualitative method (evaluation type) and several techniques are applied for this research such as fieldwork research design, observation with checklist method, semi structured interviews, secondary data and architectural drawing analysis. According to Sarantakos (2000) research is a process through which individuals seek solutions to problems or identity cause and effect relationship between variables. According to Strauss and Corbin (1998) qualitative method is used when the purpose of study is to *'uncover and understand what lies behind a phenomenon about which little is yet to known'.* Therefore it is very appropriate to use qualitative method in this research.

The objective of this research is to uncover and understand on how far the development guidelines was adhere in the physical planning of Geodesic Dome visitor centre and what was the impacts. The quantitative method was not applied in this research because the main method is questionnaire survey. Questionnaires surveys are not appropriated for this research because evaluation of the planning guidelines required experts' opinion rather than public opinion because it involved technical matters. According to Miles and Huberman (1994) evaluation type of research is usually conducted to search for solution to problem, assess the significance of existing policies practices and evaluates the need for new approaches, plans and programs. Evaluation research has various purposes. One of the purposes meets the objectives of this research for example to access the effectiveness of the policies of a program and its impacts. Most of the evaluation research uses multiple techniques in order to gather data which can strengthen the research. Donald. T Campbell (1998) informs that every method has it limitation and multiple methods are usually needed. It is adopted as the weakness in one method can be partially compensated for by the strength of another (Friedmann & Zimring, 1978). The following methods and techniques were employed for the research:

5.6.1 Fieldwork research

According to Sarantakos (2000) a fieldwork is a form of social inquiry into existing situation which takes place in the field that is in a natural setting that is not established for the purpose of conducting research. This research applied this method because it suits the objectives which were to evaluate the implementation of development guidelines and the impacts in the development of the centre on the surrounding marine environment. The researcher carried out direct observation on the existing surrounding of the centre and the beach area. Several techniques are employed such as structured site observation, measurement, photographs and video recording.

5.6.2 Structured site observation using checklist method

Structured site observation was organized and planned before the study began (Sarantakos, 2000). Site observation for this research was conducted twice. The first visit conducted as pilot visit observing and recording generally the centre and the surrounding environment using the checklist. The second visit was conducted to record all the data in detail. Two checklists were prepared for this research as shown in Table 5.1 shows the example of the checklist.

Table 5.1: Example of the checklist for guiding principle for development guidelines

ISLAND PHYSICAL DEVELOPMENT PLANNING GUIDELINES		
Guideline	**Guiding Principles**	**Geodesic Dome Centre**
Building or chalet on the beach and hilly area	Building setback at the sandy and rocky beach is 60m from the mean high water spring (MHWS)	
	Any type of building and structure on the beach until MHWS are not permitted	

The first checklist consists of all the development guiding principles and the second checklist consists of the impacts indicator. The guiding principles were from three sets of guidelines were arranged properly based on the 10 items and the redundant guiding principles were omitted. The guiding principles are as follows:

1. Building or chalet on the beach and hilly area:
    - Building setback at the sandy and rocky beach is 60m from the mean high water spring (MHWS),
    - Any type of building and structure on the beach until MHWS are not permitted,
    - Building plot ratio is 1:3 and building height not more than 2 storey (9 meter),

- For sandy beach building setback of 20 m from MHWS is allowed if erosion control measures are adopted,
- The image of the building should portray the local architecture,
- Developments are permitted on the slope of not more than 20 degrees and not more than 60 m height,
- 30% of the area need to be reserved for vegetation area,
- Trees only on the plinth area are permitted to be cut,
- Trees more than 0.8m diameter and hardwood trees are not permitted to be cut,
- Building density should not more than 5 room hotel or condominium per acre.

2. Pedestrian walkway:
   - Material use for construction should have less impact on the surrounding environment. Hardwood and mangrove timber are preferable
   - Width of the walkway should not more than 3 meter
   - Pedestrian walkway should be on stilt and follow the existing contours

3. Building location and zones to avoid:
   - Limit facilities to low land areas and avoid near to the reef area
   - Avoid development on the very small island less than 5 hectares or rugged coasts with caves, headlands and high cliffs
   - Building should be spaced to allowed wildlife travel pattern and plant to grow

4. Erosion control
   - No forest clearing should occur in areas greater than 20 degree slope
   - Use hard and soft soil erosion control measures
   - Maintain and replant vegetation as practical erosion control measures
   - Avoid cutting down the significant trees.
   - Trail should follow the land contour and design to minimize soil erosion

5. Type of development and architectural elements
    - Building should be screened by trees
    - Only allow the day use facilities in certain area
    - Use locally available materials, recycled and non-toxic materials where as possible
    - Construction methods should be minimizing the impact on the environment.
    - Develop low density and low rise tourist accommodation, while providing adequate services and amenities for tourist. For example frame huts, single storey chalet.
    - Develop unobtrusive structure that do not dominate their natural surrounding nor detract from the intrinsic natural values of the area.
6. Landscaping elements
    - Avoid the use of exotic or introduced species for landscaping ,instead use indigenous species
7. Energy conservation
    - For lighting use fluorescent lamp or energy saving bulbs
    - Used solar energy
    - Use natural cross ventilation and ceiling fans and try to avoid air conditioning
8. Water conservation
    - Provide low flow toilets and efficient showerheads as well as other water saving technologies and practices. For example putting a brick in an ordinary toilet tank
    - Catch and recycled rain water
    - Provided proper freshwater treatment system before discharge to sea
9. Sewage treatment
    - Direct discharge of sewage into the sea are not allowed
    - Sludge should pump out at intervals in order to avoid contamination of the water column
    - Keep grey water (effluent from washing operations) and black water (effluent from toilets) streams separate
10. Solid waste

- All trash and debris are take back to shore and dispose it in an environmentally sound manner

The impact indicators were designed based on the literature review from previous studies on Pulau Payar and include the followings:

1. Soil erosion
   - Any trace of soil erosion within the site area
   - Any attempt or prevention measures for soil erosion
   - Causes of soil erosion
   - Surface runoff and identified drainage pattern
2. Sedimentation
   - Any trace of sedimentation at Pantai Teluk Wangi
   - Any trace of coral species cover by sediment
   - Sea water quality and turbidity at pantai Teluk Wangi
3. Loss of flora and fauna
   - Vegetation damage or any significant trees were cut down
   - significant loss of any wildlife habitat
   - Introduction of any exotic plant
4. Coral condition
   - Damages of coral colonies Sewerage systems
5. Sewerage systems
   - elevation of nutrient level in the marine water- nitrate and phosphate and coral bleaching
6. Solid waste
   - Any waste at the beach and from the centre

There are many other guiding principle and impact indicator but not all was answered by using the observation method. Some the principle are answered using other method such in depth interview with the architect and client, site measurements, building plan analysis and other related research.

5.6.3 Measurements

Several measurements were taken according to the guiding principle such as building setback from mean high water spring, slope angle, tree diameter, walkway width, unit area and height of retaining structure. External measurement was taken using fiberglass measuring tape (Stanley Handyman- 50m). Measurements in the visitor centre are taken using electronic distance meter (Leica Disto A3) as shown in Figure 5.3.

Figure 5.3: The electronic distance meter (Leica Disto A3)

The GPS reader (GPSMap 60csx) was used to show the location plan, north sign, site coordinate, time, sun orientation, and temperature and wind velocity (Figures 5.5 & 5.6).

Figure 5.4: The GPSMap 60csx *Figure 5.5: The Stanley Handyman- 50m*

5.6.4 Photograph and video recording

On site photographs was taken systematically such as photographs of the infrastructure, architectural elements, utilities, spaces within the chalet and surrounding elements. Photographs were taken using digital camera for future references. The whole journey was recorded using a Sony camcorder for references as in Figure 5.6.

Figure 5.6: A Sony camcorder

5.6.5 Interviews

The objective of the interview was to find out what were the impacts of the development of the centre on the Pulau Payar marine ecosystem. According to Sarantakos (2000) there are three type of interview such as structured, semi structured and unstructured interview. This research employed semi structured interview. Each interviews lasted between 45 to 60 minutes. In all the interviews, the researcher started by introducing herself and the purpose of the study and the process of interviewing. Interview was carried out in unstructured manner but there were still some points in the mind of the researcher. The interview was carried out in relaxed environment. According to Friedman (1978) state through unstructured and semi structured interviews, natural and unbiased information could be gained which is produced in the respondent natural habit.

The first interviewee was with Mr Hamid Abdullah the Head of Department of Marine Park Kedah and the second interviewee was Mr Mohd Khair patrol officer of Pulau Payar Marine Park. Interview with Mr Hamid was conducted on 26/7/2008 at (PKNK) and Mr Mohd Khair on 27/7/2008 at the Pulau Payar Island. Both respondents were interviewed using the same set of question. The question was about the background of the centre, development guidelines, environmental impacts and issue. It is important to record the interview in order to secure gathered information, however both of respondents not agreed that the interviews to be recorded.

5.6.6 Building plan analysis from architectural drawings

The third method of data collection for this research is through analyzing the architectural drawings of the centre. The drawing was obtained from the AZZA Architect office. Various information regarding the centre such as floor height, floor area, material, electrical, water and sewage system was obtained from the drawings. The drawings were to scale and gave various information.

5.6.7 Review of Literature and Document Sources

Secondary data are taken from various sources. For example from newspaper, journals, books, map, official documents such as structure plan, annual reports, policies plans and guidelines. The information used to justify and support the findings in the research.

5.7 Summary

All the methods employed for this research was to answer the question of this research. The methods employed was simple and flexible for example structured site observation, semi structured interview, building plan analysis and review of secondary data. Mixed methods are required in order to strengthen the findings of the research. However the main method was qualitative method which is site observation. Observation was made on two separate items such the design of the centre and the impacts of the centre on the surrounding marine environment. All the guiding principle are answered and changed to the percentage of compliance and non-compliance at the end of the research. The quantitative method such as questionnaires was not appropriate for this research because public opinion is not important compare to expert opinion and information. There were several limitations in gathering data for this research. For example visit to this island required permit from Fisheries Department, visit time is limited to half day and travelling cost is expensive. Despite all the limitation the researcher was able to find sufficient data for this research.

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6 Measurement of Quality in Buildings Constructed Using Industralised Building System (IBS) and Conventional Methods

Maisarah Ali

6.1 Introduction

Quality of a project can be defined as meeting the legal, aesthetic and functional requirements (Arditi and Gunayande, 1997). Quality is obtained if the stated requirements are adequate, and if the completed project conforms to the requirements. In the construction industry, quality can be defined as meeting the requirements of the designer, contractor and regulatory bodies as well as the client. Workmanship is not the only factors in determining the quality of a finished product in construction. However the end result of workmanship can be clearly seen physically and commented by most people, even the layman. Quality is subjective and differs from person to person: good quality to one person might be poor to another. Thus a systematic and scientific method must be used to measure quality so that data obtained are reliable and not bias.

Quality studies can be divided into “quality in fact” and “quality in perception” (Culp,G. et al 1993) The providers of services or goods that meet specifications achieve “quality in fact” A service or product that meets the customer's expectations achieves “quality in perception”. Quality can also be in the form of “product quality”, i.e. the quality of elements directly related to the physical product itself, and “process quality”, i.e. the quality of the process that causes the product to be either acceptable or not (Nagasaku, C. and Oda, 1965). For example, “product quality” in the construction industry may refer to achieving quality in the materials, equipment and technology that go into the building of a structure, whereas “process quality” may refer to achieving quality in the way the project is organized and managed in the three phases of planning and design, construction, and operation and maintenance.

In many studies on “product quality” in construction the common method used were by questionnaire survey and interview with the end users, thus the quality measured was “quality in perception”. However not many studies done using “quality in fact” method but rather the “quality in perception”. This chapter describes a comprehensive method to measure quality of completed buildings i.e. “quality of fact” by visual inspection and assessment by experience inspectors, “quality in perception” by questionnaire survey of the end users and using defect list from the agencies managing the construction of the projects (“quality by fact”).

The attempt to use the three methods mentioned above has been carried out by Ali, et. al., (2012) in their study to measure the quality of school buildings and data and experience from that study describe in this chapter. Although the three methods to measure quality are described here, the emphasis is given on the visual inspection and assessment method. The result of data collected using the three methods on school buildings constructed using IBS and conventional methods were compared before a final conclusion was made. The case studies for this study were primary schools located in Klang Valley.

6.2 Quality in Buildings

Quality is one of the main criteria for project success in any construction projects, including building work. The other two criteria are project development cost and its completion period (De Wit, 1988; Wright, 1997; Arditi and Gunaydin, 1997; Frimpong et al., 2003; Williams, 2003; Luu et al., 2003). However, recently environment aspect is also considered as an important element in development projects (Abu Shaban, 2008) especially with the public awareness on the importance of environment protection to prevent global warming and reduction in carbon emission.

Any new public building projects, whatever its size and budget must be of certain quality and able to deliver its services more effectively. This includes schools, hospitals, libraries, museums, and infrastructure projects such as bridges, stations and flood defense schemes, city centre squares and other public spaces. Good and quality design is more than good looks: it means that buildings and spaces function in a way that adds to the quality of life for those who use them (Gann et. al, 2003a). Quality buildings shall also be economical to build, operate and maintain (Leaman and Bordass, 2001), durable, safe and should be accessible to the handicapped (Majid et al, 2010).

Studies have shown that reasons for poor quality in building construction are: unskilled foreign workers; archaic methodologies; ethics; poor knowledge on quality; lack of quality assurance systems and unbalanced supply and demand in skilled workers (Abdul Kadir *et.al*., 2005, Abdul Hamid *et. al.* 2011b, Hassan and Ismail, 2008, Abdul Rahman, 1996, Abdul Aziz, 2001).

The Government of Malaysia has shown its seriousness in addressing the problems in construction industry as well as improving quality and productivity in construction works by introducing Construction Industry Master Plan (CIMP)(CIDB, (2010). CIMP is a 10 years plan to move strategically in transforming Malaysian construction industry to be among the best in the world by introducing innovative construction method such as the Industrialised Building System (IBS) (CIDB, 2007). Generally, the industry worldwide is in the opinion that IBS buildings are superior in quality because they are manufactured in a controlled environment and installed at site by semi-skilled labourers (Lessing, 2005, Lau, 2000, Oostra & Joonson, 2007, Goodier and Gibb, 2007, Pan *et.al*., 2008).

6.2.1 Measurement of Quality

Quality of buildings can be measured in 3 distinct phases throughout the building life cycle:

a) Pre-construction, i.e. Design and planning,(Gann el al., 2003, Abdul Rahman1996, Tan and Lu 1995*)*
b) During construction and upon Certificate of Practical Completion , i.e. workmanship using Construction Industrial Standard 7 (CIS7)*, ISO 9000*
c) Post Occupancy , i.e. technical and energy performance , Post-Occupancy Review of Buildings and their Engineering (PROBE) (Leaman and Bordass, 2001)and customers' satisfaction (Kärnä, 2004)

Most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction which involves among others are the component configurations, material specifications and functional performance. Furthermore, the most important measure in any evaluation of a building's design quality is whether it satisfies user requirements and what users think and feel about it (Gann et al., 2003).There are a few method or systems to measure and evaluate the quality of workmanship of construction works based on the relevant approved standards during the construction stage for example, Quality Assessment System in Construction (QLASSIC) which is CIS 7 (CIS7,2006)and ISO 9000.

Comparative studies between IBS (prefabrication) and conventional method of construction had been carried out by a few researchers (Abdul Kadir *et.al.,* 2006, Chen *et.al*, 2010) to measure construction performance such as productivity, structural cost, crew size, cycle time, constructability and quality. However the data collected for quality were through questionnaire surveys, thus representing "quality in perception". By carrying out visual inspection and assessment by experienced inspectors "quality in fact" could be obtained.

6.2.2 Standard Method for Quality Measurement for Construction In Malaysia

Quality Assessment System for Building Construction Work (QLASSIC) is an independent method to assess and evaluate the quality of workmanship of building developed by the Construction Industry Development Board (CIDB).

It is designed and developed to achieve the following objectives:

a) To benchmark the level of quality of the construction industry in Malaysia;
b) To have a standard quality assessment system for quality of workmanship of building projects;
c) To assess the quality of workmanship of a building project based on the approved standards;

d) To evaluate the performance of contractors based on quality of workmanship and
e) To compile data for statistical analysis.

QLASSIC sets out the quality of workmanship for the various aspects of the construction elements for the general building works. It covers four main components: structural works, architectural works, mechanical and electrical (M & E) works and external works. Assessments on the workmanship are carried out through site inspection and field testing and marks are awarded if the workmanship complies with the standards. These marks are then summed up to give a total quality score (%) for the building project. Assessments for the structural and M & E works are carried out during construction process. For completed building projects the assessment was done for architectural, M & E fittings and external works.

6.3 Research Methodology

Quality of buildings were measured by three methods:

a) By visual inspection and assessment using checklist based on Construction Industry Standard 7 or QLASSIC (CIS7,2006) by CIDB;

b) By quality perception survey i.e. post-occupancy questionnaire survey with the end users;

c) By analysing the defect lists from the agencies involved in the supervision of the projects i.e. the Public Works Department (PWD).

A flow chart showing the framework of the research process is shown in Figure 6.1. The data collected from schools constructed using IBS were marked as 1 and conventional method as 2. Three methods of data collection were carried out on schools constructed using IBS and conventional methods i.e. visual inspection and assessment, defect list and questionnaire survey with end-users. Each set of data later analysed and the results was compared with the corresponding methods before coming up with a conclusion.

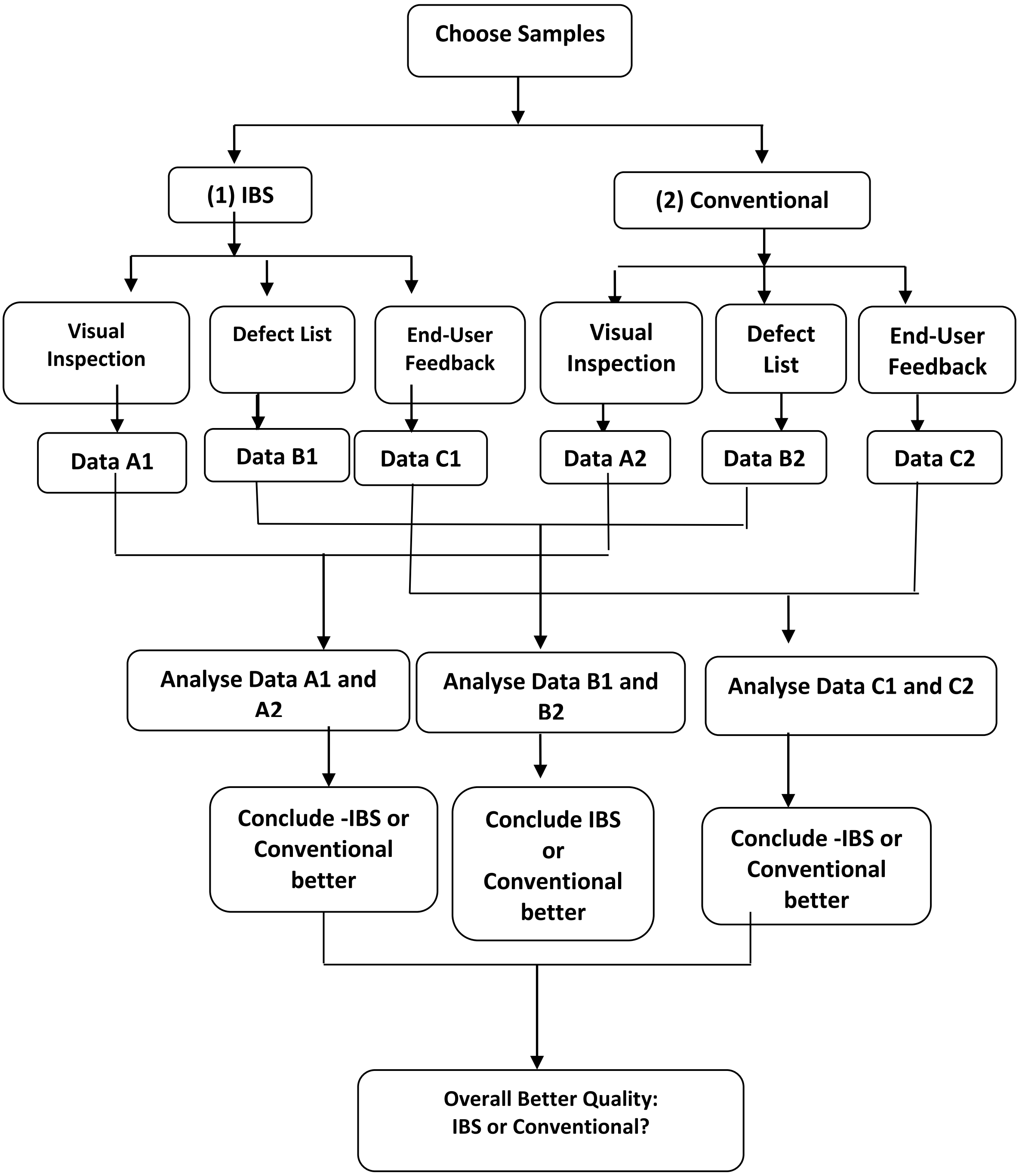

Figure 6.7: Flow Chart of Research Process

6.3.1 Selection of Case Studies

There are several factors that need to be considered in designing the research process. The most important one is based on the validity and reliability of the measurement adopted, how good the measurement was to reflect the real world and what could have affected the results.

The ideal situation is to have buildings constructed by the same contractor with the same sub-contractors and the same group of workers for IBS and conventional methods of construction. This condition is important to avoid variation in the workmanship due to differences in workers, supervisors and managers involved in the actual construction works of both methods. Unfortunately to get such samples is very difficult because procurement method in Malaysia is through competitive bidding and contractors for IBS were mostly specialists and are normally awarded the packages separately from the normal design contracts, thus chances of the same contractor to be awarded with IBS and conventional method very slim.

The best solution is to find buildings which are completed almost the same time, same function, about the same contract sums, and located within the same region but constructed by different contractors. These similarities will hopefully minimised factors that might affect the accuracy of the results.

Thus when selecting buildings for case studies, several factors are taken into consideration such as:

i. Buildings constructed using IBS and conventional method are completed at about the same time thus the “age” of the case studies buildings is almost similar,

   a) The usage of the buildings are similar,

   b) The buildings are about the same size in terms of build-up area,

   c) The buildings are located in the same region.

School buildings were selected as representative of building types as these are average in size and complexity. A list of completed and on-going schools projects was obtained from Public Works Department who is responsible for the construction project management of many Government’s projects. From the list, three schools of a similar age range were selected. Two schools were constructed using the IBS and one using the conventional method. All buildings involved in the research were low-rise (3 stories) buildings of additional blocks to the existing school buildings.

6.4 Visual Inspection and Assessment

6.4.1 Inspection form

For the inspection and measurement purpose, an inspection form was devised based on QLASSIC form CIS 7 for architecture work where it was simplified and modified by adding a column for defect rating.

The defect rating given for building elements are shown in Table 6.1.

Table 6.1: Defect Rating

Defect Rating	Terms	Explanation
1	Satisfactory	Elements contain almost no defect
2	Minor	Element have some defects but defects are minor and not many
3	Medium	Element have some defects but defects are not major and not many
4	Major	Element have many defects and defects are major
5	Severe	Element have many defects and defects are severe and need to be repaired soon

Since the research was carried out after the buildings were completed, only the architectural assessment was carried out. Assessments for the mechanical and electrical were not carried out because the school buildings did not use much air conditioning, except in or two rooms. Architectural works dealt mainly with the finishes as an important element. This is the part where the quality and standards of workmanship are most visible. Examples of architectural works inspected are floors, internal walls, ceiling, door and window, fixtures and fittings, external wall, roofs, driveway, porch and apron. Structural elements that are visible such as beams, columns and staircases were also inspected.

6.4.2 Equipment

The following tools and equipment were also used in the physical measurement during visual inspection of the buildings

ii. Measuring tape

The steel measuring tape of 6m meter length was used in taking measurement of the dimensions of some the components of the building.

a) Electronic measuring device

This device (Figure 6.2) was used to measure distance between two points. The instrument was placed at one end and its face was directed to the other end so that the infra-red light could travel in straight line and hit another flat face object at the other end. The actual distance between the two points is shown on the screen. This equipment is use to measure the size of buildings, classrooms, corridors and staircases.

Figure 6.8: The electronic measuring device

b) Spirit level

The spirit level (Figure 6.3) was used to measure the flatness of a surface for examples floors, staircases and corridor walls. If the bubble lies in the centre within the marked lines, then the surface is flat.

Figure 6.9: The Spirit level

c) L- square

This tool was used to check if the angle between two surfaces was at right angle. Therefore the verticality of the walls could be easily checked using this tool (Figure 6.4).

Figure 6.10: The L-square

d) Steel rod

A small diameter steel rod about 0.5 meter length was used to measure the hollowness of the floor slab or wall. The rod was lightly tap on the inspected surface and any differences in the sound produced would indicate hollowness underneath the surface.

6.4.3 Inspectors

It is important for the buildings to be inspected by inspectors who have experience in building inspection so that they recognized the defect and the extend of the defect and give equivalent defect. Since the areas to be inspected were large and the duration of inspection was limited because the classrooms were used by the students, several inspection teams need to be formed. In this study to two teams were formed; headed by the researchers and assisted by two technicians who have more than 10 years working in the construction industry and had experience in inspection of buildings. All the buildings were inspected by the same team of inspectors in order to achieve consistency in giving the defect rating.

6.4.4 Visual Inspection

The physical observation and assessment of the completed building were carry out by visual inspection and physical measurement on the architectural and some structural elements. Photographs of the defects were also recorded. Two days were allocated per location for the visual inspection. After preliminary discussion with the school authorities, it was mutually agreed that the inspection date was scheduled on a schooling days as all the classrooms were opened on those days.

The inspection commenced from the ground floor level by visually inspecting all the building elements and taking notes on the overall dimensions of the buildings. The defects and quality of the finishes on the building elements such as floors, beams, internal walls, ceiling, doors and windows, roof, gutter and rainwater down pipe, external wall, perimeter drain and apron, corridor and staircase were noted and a defect rating was given to these elements .The inspection form used to record the defect and defect rating were given on every element based on the condition of the element according to the opinion of the inspectors.

The teams would later proceed to the next floor level and the same process was repeated until the whole floors were fully completed. Photos were taken during the inspections to capture the defects and images of all important details. The data and information collected were properly compiled, categorised and systematically labeled for easy reference and retrieval during the analysis process.

6.5 End User Feedback through Questionnaire Survey

6.5.1 Sampling of Respondents

Sampling is the act or process of selecting a sample for testing and analyzing, on a representative part of a population for the purpose of determining parameters or characteristics of the whole population. Webster (1985) defines a sample as a finite part of a statistical population whose properties are studied to gain information about the whole. When dealing with people, it can be defined as a set of respondents (people) selected from a larger population for the purpose of a survey.

Sampling Technique

Sampling may be done either on a *probability* or a *non-probability* basis. This is an important research design decision, and one which will depend on such factors as whether the theory behind the research is positivist or idealist, whether qualitative or quantitative methods are used. Note that the two methods are not mutually exclusive, and may be used for different purposes at different points in the research, say purposive sampling to find out key attitudes, followed by a more general, random approach.

In this research the sampling was done based on a non-probability basis. Here, the population does not have an equal chance of being selected; instead, selection happens according to other factor such as the availability of relevant and significant persons. Another factor to be considered is the rapport with key person responsible and authorised by the management of the intended building. This is an easy way of getting a sample, but may not be strictly accurate, because the factor that has been chosen is based on convenience rather than on a true understanding of the characteristics of the sample. However for this particular study, the factor would not have a drastic effect on the results of the study.

Calculating the sample size

In purposive sampling, sample size is determined by judgment; in other more random types of sample it is calculated as a *proportion* of the sampling frame, the key criterion is to ensure that the sampling is representative of the whole.

In this research a minimum number of 30 respondents consisting of teachers and administration staff were targeted for schools using IBS and conventional method of construction respectively. This figure is necessary to ensure the accuracy of the statistical analysis carried out in analysing the data. However at the end of the survey period only 22 respondents from conventional and 19 respondents from IBS return the questionnaires.

The schools selected are Primary school and the students between seven to twelve years old. Primary school students were not considered as part of the targeted group since they are very young and might not be able to give good judgment in answering the questionnaires

6.5.2 Questionnaire

A well-constructed questionnaire is very important to produce good and reliable data that can be readily and easily analysed. In addition the contents of the questionnaire must also be easily understood by the targeted respondents and consequently can be promptly and accurately answered. The designed questionnaire should be adaptable and thus can be used for both target groups.

Designing Questionnaire

The questionnaires were prepared based on the literature review conducted and to meet the objectives of the study. It was divided into three sections namely demographic of the respondents, perception on the quality of the buildings and ranking of factors that determine the quality of a building. The quality factors investigated were aesthetic, detailing and finishing, functionality of building, comfort, defect, durability and safety and security. From the literature review conducted, in order to achieve quality in buildings would require an interactive approach to the design process over and above just aesthetics, detailing and finishing (Gobster and Chnoweth, 1989, Susilawati *et.al.*, 203, Vilnai-Yavetz *et. al.*, 2005, Rustom and Amer, 2006). A pilot survey was carried out to verify the relevance of the intended questionnaires in capturing the factors or aspects contributing to the research objectives and to ensure that the questionnaires were adequately understood and not misleading. The questionnaire was subsequently refined accordingly. The survey questionnaires were printed in both English and Bahasa Melayu. The three pages questionnaire consists of three sections. *Section A* is the demographic information about the respondents.

Section B is the core of the survey questionnaire as the quality of the building is valued in this section. A five-point Likert scale is devised to quantify every element or factor that might affect the perception on the quality of the building. The factors considered in the study are aesthetic, detailing and finishing, functionality of building, comfort, Defects, durability, safety and security and innovation.

In Section C the respondent was asked to rank from 1 to 8 to rank the importance of the factors affecting the building quality as mentioned earlier in Section B. Overall the questions set can easily be answered and the respondent was expected to complete the whole questionnaire in less than ten minutes.

6.5.3 Pilot Survey

The draft questionnaire was distributed to a few students and lecturers, a combination of those with and without knowledge and experience in construction. The feedback collected was carefully considered and later used to amend, refine and improve the questionnaire. The most common comments were that the questions on aesthetic, function and safety aspects of the building needed to be simplified for better understanding of the end-users who were mostly without the technical and construction background.

6.6 Defect List

During the handing over of completed buildings from the contractor to the client, a final inspection is usually carried out and a defect list will be prepared by the consultants. The defect list contained all the defects that had to be rectified by the contractor during the defect liability period. The more the number of defects present in a completed building the poorer the construction quality. Usually the bigger the building the more defect it may contain, although not necessarily so. To make the comparison between buildings to be more appropriate and objective the number of defects in the list was divided by the area of building. Thus the unit used is number of defects per square meter.

6.7 Data Analysis

From the physical and visual inspection, a defect rating for each element was summarized for the whole building. The highest rating that represents the worst in quality for each element was then taken and summarised. This is to reflect the worst condition for the elements in the whole building. The same process was carried out for buildings under studied constructed using both the IBS and conventional method of construction.

For the quality perception survey, a 5-point Likert scale method was used to indicate the level of agreement to the statement about quality in buildings. The ratings for the level of agreement by the respondents are as follows:

1 = Very low degree of agreement
2 = low degree of agreement
3 = Neutral
4 = High degree of agreement
5 = Very high degree of agreement

The data were analysed using the Relative Indices (RI) technique adopted by Holt *et al*. (1995)

$$RI = \frac{\Sigma\,(5n5 + 4n4 + 3n3 + 2n2 + 1n1)}{5(n5 + n4 + n3 + n2 + n1)}$$

where RI is the relative index
and n5, n4, n3, n2, n1 are the number of responding indices
The computation of the RI using this formula yields values ranging from 0.2 to 1. The RI range and what it represents are shown in Table 6.2.

Table 6.2: Categories for Range of Relative Index

Categories	RI Range
Very low level of agreement	0.20 – 0.35
Low level of agreement	0.36 – 0.51
Neutral in agreement	0.52 – 0.67
High level in agreement	0.68 – 0.83
Very high level in agreement	0.84 – 1.00

The respondents were also asked to list quality factors in the order of importance and the data were described using descriptive statistic. In addition, the number of defects from the defect list was manually counted. It was expected that the number of defects to be larger when dealing with bigger size of building. Since the size of the buildings in this study was not the same, the number of defects was divided by the total built up floor areas of building under studied respectively. This was to allow for a more objective comparison to be made between the buildings regardless of its size. Finally qualitative and quantitative comparisons were made between the physical and visual inspection, quality perception survey and defect list for the buildings constructed using both the IBS and the conventional method of construction.

6.8 Results and Discussion

6.8.1 Result of visual inspection and assessment

Table 6.3 is the comparison of summaries of the Quality Checklist for the schools understudied.

Table 6.3: The Comparison of Summaries of the Quality Checklist

BUILDING ELEMENT	Inspection Standard	Defect Rating IBS School A	Defect Rating IBS School B	Defect Rating Conventional School C
FLOOR	Finishing	2	2	4
	Alignment &Evenness	2	2	4
	Crack and Damage	3	2	4
	Hollowness/ Delamination	3	1	4
	Jointing	2	2	4
	Tiled floor	1	1	3
INTERNAL WALL	Finishing	1	2	3
	Cracks and Damage	1	1	4
	Hollowness/ Delamination	1	1	4
	Alignment & Evenness	1	1	4
	Tilled Finishes	1	1	4
	Painting	1	1	4
CEILING	Finishing	1	1	4
	Crack and damages	2	1	3
WINDOW	Joint and gap	1	2	4
	Material and damages	1	1	4
	Functionality	1	2	3
DOOR	Joint and gap	3	1	5
	Material and damages	1	1	4
	Functionality	1	1	3
ROOF	Pitched roof	1	1	4
GUTTER & RAIN WATER DOWNPIPES	Visible damage	1	1	3
EXTERNAL WALL	Finishing	1	1	4
	Crack and damage	2	2	4
	Roughness	2	1	4
	Painting	2	1	4
PERIMETER DRAINS & APRONS	Drain	2	2	3
	Apron	2	1	4
STAIRCASE	Tread & Riser	1	1	4

Notes: Defect Rating : 1 - Satisfactory 2 - Minor, 3 - Medium, 4 - Severe , 5 -Very Severe

From Table 6.3 it was found that the defect ratings for the school constructed using the conventional method of construction are predominately 4 which is classified as severe, while the buildings constructed using the IBS method of construction showed a rating of mostly 1s or 2s which falls under the classification of satisfactory and minor. This statement is almost true for every building element in the buildings understudied which indicated that the IBS-built schools have a better quality than schools constructed conventionally. This is further verified when analysing the defect photos taken during the buildings inspection

6.8.2 Results of the Quality Questionnaire Survey

Most respondents in this questionnaire surveys were teachers teaching in the buildings under studied. Their ages ranging between 35 to 43 years with an average working experience of more than ten years and an average of eight year tenure at their respective schools. These periods were considered as reasonable and adequate for them to give accurate and effective answers to the questions posed as they also have the experience of teaching in the old blocks in their respective schools. This is an important consideration so that they can feel the difference in the building quality between the old and the new blocks in their respective schools. In addition, between of 30% to 50% of the respondents are degree holders indicative of a high level of education amongst the respondents.

Table 6.4 shows the respondents' relative index to the questions posed about factors that contribute to quality in buildings. The results show that the respondents from school that were constructed using the IBS method of construction do not agree or disagree (neutral level of agreement) to all the questions regarding factors that contribute to the quality of a building except for defects in buildings. The relative index for all the factors that contribute to quality are 0.67 for aesthetic and functionality, 0.64 for comfort, 0.60 for durability, 0,58 for detailing and finishing and 0.56 for safety and security. The respondents, however, have a low level of agreement (0.44) on the defect factor which literally indicated to them that the buildings built by the IBS method of construction have fewer defects. For buildings constructed using the conventional construction method, comfort (0.71) and functionality of the buildings (0.68) have a relative index that indicated a high level in agreement. The rest of the factors that contributed to the quality of a building such as aesthetic, detailing and finishing, durability, safety and security and defect, the respondents registered a natural level of agreement. It is interesting to note that whilst respondents from schools constructed using the IBS method of construction were in a natural state of agreement pertaining to the five main factors that contributed to quality namely aesthetic, detailing and finishing, durability, safety and security; the RI recorded was a little higher as compared to values obtained from respondents addressing quality in buildings constructed conventionally.

Table 6.4: Respondents' Satisfactory Average Relative Index

BUILDING ELEMENT	Inspection Standard	Defect Rating IBS School A	Defect Rating IBS School B	Defect Rating Conventional School C
FLOOR	Finishing	2	2	4
	Alignment &Evenness	2	2	4
	Crack and Damage	3	2	4
	Hollowness/ Delamination	3	1	4
	Jointing	2	2	4
	Tiled floor	1	1	3
INTERNAL WALL	Finishing	1	2	3
	Cracks and Damage	1	1	4
	Hollowness/ Delamination	1	1	4
	Alignment&Evenness	1	1	4
	Tilled Finishes	1	1	4
	Painting	1	1	4
CEILING	Finishing	1	1	4
	Crack and damages	2	1	3
WINDOW	Joint and gap	1	2	4
	Material and damages	1	1	4
	Functionality	1	2	3
DOOR	Joint and gap	3	1	5
	Material and damages	1	1	4
	Functionality	1	1	3
ROOF	Pitched roof	1	1	4
GUTTER & RAIN WATER DOWNPIPES	Visible damage	1	1	3
EXTERNAL WALL	Finishing	1	1	4
	Crack and damage	2	2	4
	Roughness	2	1	4
	Painting	2	1	4
PERIMETER DRAINS & APRONS	Drain	2	2	3
	Apron	2	1	4
STAIRCASE	Tread & Riser	1	1	4

Notes: Defect Rating : 1 - Satisfactory 2 - Minor, 3 - Medium, 4 - Severe , 5 -Very Severe

Ranking of Factors that Contributed to Quality

Apart from asking the respondents of their perception on quality of the under studied buildings which they use, question B8 asked them to rank from 1 to 8, all eight factors that contributed to quality; with 1 being the most important and 8 the least important. Table 6.5 shows the results for respondents from schools constructed using the IBS method and Table 6.6 are for schools constructed using the conventional methods. From Table 5 it was found that 71% of respondents from IBS-constructed schools had ranked safety and security as the top most factor, comfort (27%) second, functionality (35%) third, detailing (27%) fourth and fifth, functionality and innovation (20%) sixth, innovation (40%) seventh and 67% of the respondent has ranked aesthetic as the least important at number eight.

Table 6.5: Quality Factors Order of Importance to the Respondents (IBS method school)

Order of importance	1st	2nd	3rd	4th	5th	6th	7th	8th
Aesthetic (%)	0	0	12	7	7	7	13	67
Functionality (%)	0	13	35	20	7	20	0	0
Durability (%)	18	20	18	20	7	7	7	0
Innovation (%)	0	7	0	7	20	20	40	7
Detailing (%)	0	0	6	27	27	20	20	0
Comfort (%)	6	27	24	13	20	7	0	0
Form (%)	6	13	6	7	13	20	20	13
Safety/security (%)	71	20	0	0	0	0	0	13

Table 6.6 illustrated that the respondents from school constructed by the conventional method also ranked safety and security (82%) as the most important and aesthetic as the least important (72%). They had ranked durability in buildings (60%) second, comfort (71%) third, functionality (69%) fourth, form (44%) fifth, innovation and form (36%) sixth and detailing (57%) seventh.

Table 6.6: Quality Factors Order of Importance to the Respondents (Conventional method school)

Order of importance	1st	2nd	3rd	4th	5th	6th	7th	8th
Aesthetic (%)	0	0	0	0	0	21	0	72
Functionality (%)	0	7	0	69	25	0	0	0
Durability (%)	12	60	29	0	0	0	0	0
Innovation (%)	6	0	0	0	6	36	43	11
Detailing (%)	0	0	0	25	19	7	57	0
Comfort (%)	0	13	71	6	6	0	0	0
Form (%)	0	7	0	0	44	36	0	17
Safety/security (%)	82	13	0	0	0	0	0	0

It is interesting to note that the majority of the respondents regardless whether they are users of schools constructed using the IBS or conventional method of construction, are of the opinion that safety and security is the most important factor while aesthetic is perceived as the least important factor. Hence it can be concluded that the important factors to be considered in the design of buildings depend on the types of building and its intended usage. For schools, safety and security of the staff and students are paramount for the end-users as indicated from this study.

6.8.3 Defect lists

Table 6.7 shows the number of defects per 100 square meters of the respective schools. It was found that school buildings constructed using the conventional method of construction (School C) had the highest number of defects/100m2 (6.2) as compared to buildings constructed using the IBS method (3.1 and 0.3). In fact the defect intensity of school buildings built using the IBS method are found to be less than half that for the conventionally built schools. In the case of School B (IBS method of construction), the defect intensity is lower than that for school buildings constructed using the conventional method by a factor of 20. Between the IBS-built schools, there was a big difference in defects between School A and School B. The unstructured interview with the supervisor of the projects revelled that that contactor for School B was a better contractor compared to that for School A and this was reflected in the less number of defects registered. Result from Table 6.7 clearly revealed the superiority of the IBS constructed schools over the conventionally built schools in terms of their defect intensity and quality. The data also verified and concurred with the findings obtained from the site inspection whereby the school buildings using the IBS construction method again proved that they were of much better quality compared to the conventionally built school buildings.

Table 6.7: No of Defects per 100 Meter Square of Built up Area

Item	IBS method School A	IBS method School B	Conventional method School C
No of Defects	56	6	199
Built up area (m2)	1791.1	2133.8	3205.8
No of Defects/100m2	3.1	0.3	6.2

6.9 Comparisons

From the visual inspection and assessment it was found that the school buildings constructed using the IBS method showed a rating of mostly 1s or 2s which falls under the classification of satisfactory and minor while those constructed using the conventional method of construction are predominately 4 which is classified as severe. From the quality perception survey for most factors that contributed to quality, the IBS built buildings respondents answers were in the neutral state of agreement (neither agree or disagree) but when asked about the defects, they have a low level of agreement (0.44) which meant that the buildings built by the IBS construction method had less defects. From the defect lists, it is found that the defect intensity of the school buildings using the IBS construction method was less than half that of the conventionally built schools. From these comparisons it can be concluded that the school buildings using the IBS construction method displayed higher and better quality than those constructed conventionally.

6.10 Conclusions

Each method of measurement of quality reveals its own findings. Findings from visual inspection and assessment showed that school buildings constructed using the IBS method has a higher and better quality as displayed by the ratings adopted. The school buildings constructed using the IBS method showed a rating of mostly 1s or 2s which falls under the classification of satisfactory and minor while those constructed using the conventional method of construction are predominately 4 which is classified as severe.

From the quality perception surveys, respondents from school buildings constructed using the IBS method had a low level of agreement (0.44) when asked about defects indicative that school buildings built by the IBS method have less defects compared with schools constructed conventionally. Both groups of respondents from schools constructed using the IBS and conventional method are of the opinion that safety and security are most important whilst aesthetic was perceived as the least important factor.

From the defects lists, it was found that the defects intensity (number of defects/100m2) of school buildings built by the IBS method of construction was less than half that of the conventionally built schools. If two or all methods show similar results then it confirmed the findings. In this research, the site inspection and defect list showed that the buildings constructed using the IBS have better quality as compared to building constructed using the conventional method. This finding is similar to the findings in the literature review.

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7 Research Methods for Visual Comfort Study

Zuraini Denan

7.1 Introduction

Research method in visual comfort area developed from a general to a more specific framework: from a consideration of window and lighting of office buildings in general to the specific daylight assessment of an experimental office. The investigation is divided into 4 parts: the survey-questionnaire, the field measurement, the subjective assessment under controlled daylight experiment and the advanced lighting calculation (computer simulation). This paper describes each method of data collection, the equipment used, and limitations.

7.2 Aims of Research

This paper aims to describe and justify the methods selected for this research. There are four aims relative to the methods of investigations:

- The first and second methods selected aim to further identify and test the problems related to windows and lighting in the office environment
- The third method is aiming to test the subjective assessment of visual and task performance under a day-lit environment
- Finally, the fourth method is attempting to examine lighting quantity and quality in order to identify detailed lighting performance using computer simulation.

7.3 Background

The study is an exploration of issues relating to the daylighting of office environments in Malaysia. The study progresses from a general view of the problem of window design and lighting in office buildings to a specific assessment of daylight under an experimental condition. In order to understand the whole scenario the problem and potential of daylighting and its contribution to visual comfort in office environments in Malaysia, an applied research approach was selected. Applied research is research that combines both an evaluation and action research, while searching for practical solutions rather than testing hypotheses (Smith, 1975). Smith described evaluation research method as a method that deals with the assessment of existing programmes or practices designed as tentative solutions to the problems identified, while an action research

search mechanism to solve these problems. It combines both qualitative and quantitative methods that are particularly useful for practitioner-based research (Wisker, G, 2001). According to Borg (1987:5, pp: 283-284),

> *"…action research aims at gathering evidence that relates to a specific local problem. Therefore, in action research the selection of an appropriate sample is less likely to be a problem, a smaller number of subjects can often be used, and only the simplest kinds of statistical analysis are needed…(This) research is called for when the literature does not provide…(the researcher) with sufficient basis for making an important decisions (or evaluation)…An action researcher is much more interested in practical significance than statistical significance… (He) is not interested in generalising his result beyond a specific area of locality."*

Therefore, based on this definition, the methodology of the investigation is planned as such:

- Firstly, the research attempt to gather information relative to the problem of inappropriate design of windows that lead to the high use of electric lights and blinds by assessing windows and lighting design of the current office buildings based on occupants' assessments anf lighting measurement-evaluation research.

- Secondly, the research is focused upon its eventual application and solution in practice (practicality): whether day-lit condition is acceptable and can daylight provide sufficient lighting for comfortable completion of visual performance - action research.

The summary is shown graphically in Figure 7.1.

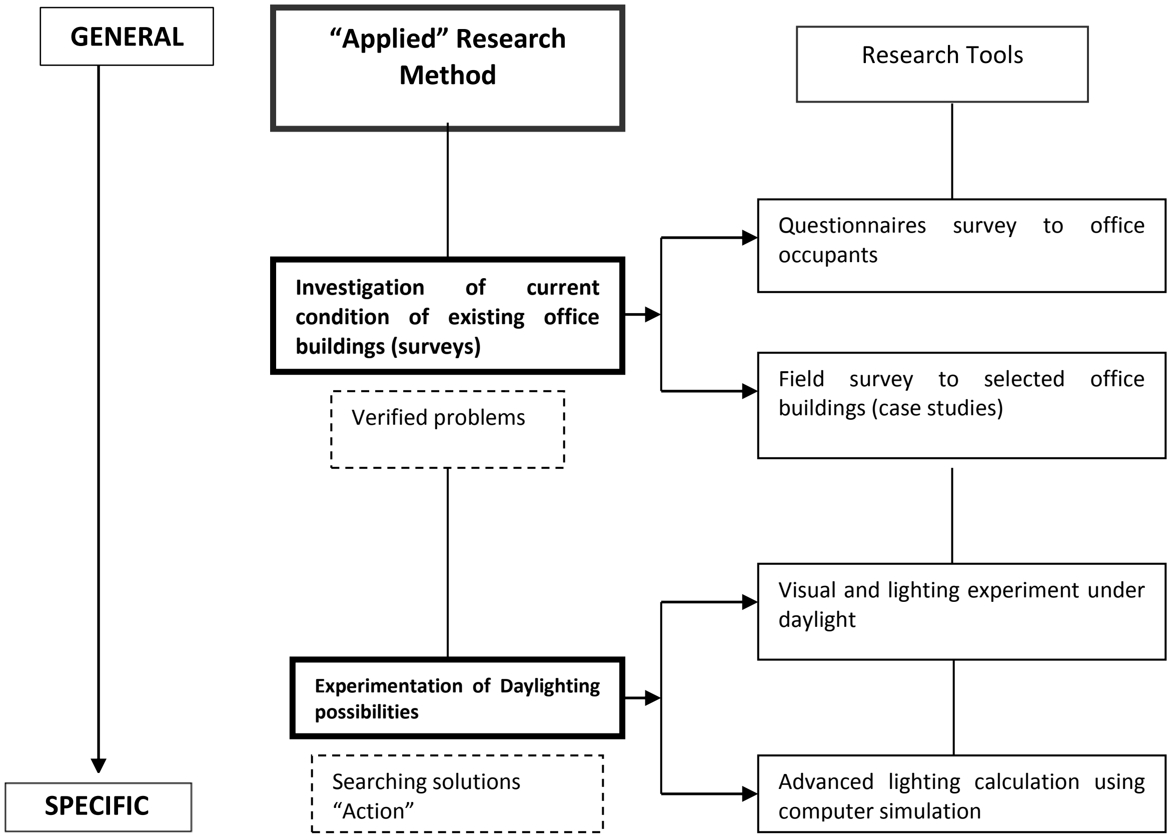


Figure 7.1: The Research Framework.

7.4 Methods selected

There are four methods for the lighting related study of office buildings, namely, surveys, field studies (observation and measurement), laboratory experiment and simulation (scale model and computer). These methods involve either subjective assessment or objective measurement of lighting or visual parameters. The selected research tools range across four different methods of investigation: questionnaire survey, field measurement, controlled subjective experiment and advanced calculation using computer simulation. Each method is attempting to answer research questions, which will support the aim and objective of the investigation as summarized in Table 7.1.

Table 7.1: Summary of research stages

Stage /Method	Aims	Research Questions
Part One: Background study of window and lighting design in office buildings Method: Survey of questionnaires	To ascertain workers' assessment and opinion relative to their luminous environment.	Which kind of glazing is mostly used in office buildings and which was preferred by the workers? How often did office workers use electric lighting and did they use it regardless of the brightness outside? Did the windows near the office workers provide enough light without electric lighting? What type of light source do the workers prefer? Did office workers use blinds during most of their working hours? Did office workers prefer working by the window? Did workers encounter any glare? Was office workers' satisfaction related to daylight, glare, view, light level on work surface and overall visual comfort? Are office workers aware of any health and mood effects due to the existing lighting conditions and their visual comfort?
Part Two: Observation of office building. Method : Field measurement	To evaluate the condition of the luminous environment for various window designs of office buildings in Kuala Lumpur, Malaysia.	How effective is each window design at controlling daylight into the office space? How did office workers' physical respond relate to the window design? How does the daylight availability in the workspace reflect the application of lighting guidelines?
Part Three: Visual and lighting assessment under a daylit office condition Method: Laboratory experiment	To assess a daylit office based on lighting assessment and visual performance at specific seating positions or orientations relative to windows.	Was there a significant difference in visual performance between the three selected seating positions? Did subjects feel comfortable working under a daylit office at all seating positions? Can subjects work efficiently under a daylit office at all seating

Stage /Method	Aims	Research Questions
		positions? Is the quantity and quality of daylight associated with the performance of the visual task? Did the subjective assessments relate to the visual performance result?
Part Four: Advanced calculation and assessment of glare Method: Computer simulation	To investigate computer simulation in evaluating glare	According to computer simulation which seating is preferable? Does the result of computer simulation match the results of the visual and lighting experiment?

7.4.1 Part one: Questionnaire survey

The following describes the definition, procedures and equipment, and limitations of the questionnaire survey:

Definition

A survey is a subjective assessment seeking response from selected or random samples that answer pre-designed questionnaires. It is a useful tool "…to cover an extensive amount of information-from demographic characteristics, to behavioural habits, to opinions or attitudes on a variety of topics-across a large number of people in a limited amount of time." (Groat and Wang, 2002: 219). Questionnaire survey is commonly utilised for many areas of built environment research (Holt, 1997). Not only questionnaire surveys commonly used for "… social-cultural interactions or perceived meaning of environments, but they also can be very effective tactics for a variety of other architectural research topics." (Groat and Wang, 2002: 223). This type of survey has been applied in Post Occupancy Evaluation surveys (POE). It is considered an effective method to discover occupants' response to their environment.

The questionnaire survey method of assessing environmental issues in building has been used for many years, and is also one of the common tools used in assessing lighting conditions in office buildings. Based on lighting surveys of the past, lighting is chosen as one of important factors and ranked the fifth out of 17 aspects of the office environment in the survey of U.S. office workers completed by Louis Harries and Associates (1978). On many occasions questionnaire surveys have been used to assess workers' satisfaction regarding related parameters such as windows and the natural light (Hedge, 1982; Langdon, 1966; Wells, 1965; Manning, 1965). The results of these surveys showed that natural light is preferred and appreciated by many office workers, as a high percentage of people prefer working by the windows that provide views out from the working environment. Questionnaire survey is used not only by private researchers but also local authority and research organisations in assessing lighting-related conditions in office buildings.

Procedures and Equipment

Some of the most common questions asked in the survey of windows and lighting relate to occupants' or workers' preferences:

a. preference of lights (Langdon, 1966; Markus, 1967; Neeman, 1974)
b. preference of work station location relative to windows (Manning, 1965),
c. preference factors related to windows (view, light, time/weather information, psychological effects; etc.) (Heerwagen and Heerwagen,1986)
d. estimation on the natural light contribution on their desk (Wells, 1965), vdu (Roche et al., 2000)
e. assessment of glare or visual discomfort (Roche et al, 2000)
f. satisfaction with the lighting condition (Louis Harris and Associates, 1978; Langdon, 1966; Hedge, 1982).

Some questions can be answered using simple Yes and No but others involve the respondent selecting from multiple choice options, particularly when the question is aimed at finding information about the office condition. Others will usually instruct respondents to value their opinion using a scale rating this occurs when respondents' assessment or evaluation of satisfaction is needed.

The questionnaire is designed as a self-administered survey and the samples of population was selected using the random sampling method as a result of the aim to get large number of respondents and collect information on office luminous condition, which is currently lacking. For similar reasons the simple data analysis method was selected, descriptive analysis (histogram and cross tabulation) using SPSS program version 10. The analysis selected is sufficient enough to confirm the findings and fulfil the objectives of the investigation.

Limitations

Dealing with human assessment in the form of questionnaire survey can often produce unpredictable results. Questionnaires of an architectural type are not very familiar to the Malaysian public. Technical questionnaires can sometimes confusing for the respondent and feedback may influence by the individual's psychological state of mind at the time of completion. The result of the questionnaire survey depends not only on how well the questionnaire has been designed, but also the attitudes of respondents towards such surveys. The random sampling used in the survey may in addition produce a biased result.

Questionnaire survey is a first-hand tool to explore the existing condition of the building and the opinion of the occupants regarding their environmental effect. This type of survey, especially in this topic area, may seem new to office workers in Malaysia. However, it is a common method established for many years overseas and is still one of the most popular methods in assessing occupants' and workers' satisfaction with their working environment.

The Questionnaire survey in this study is mainly focused upon gathering information about the window design and lighting of office buildings in Malaysia and to examine workers' assessment of their luminous environment, explicitly regarding window design and lighting utilisation. The simple random sampling used in this study is employed in order to gain information and evaluation from the occupants on the window design and lighting application of their office buildings despite the unfamiliar topic and attitudes toward surveys in the local context. The qualification of the sample is very general; respondents can be anyone working at a common office task (reading, writing and using VDU) in an office building. It is understood that choosing other classified sampling methods may have produce lower levels of feedback from office workers. The aim of the result is merely to confirm the observation and to answer research questions concerning the window condition and lighting practise in most office buildings in Malaysia.

7.4.2 Part two: Field measurement-case studies

The following describes the definition, procedures and equipment, and limitations of the field measurement:

Definition

A field measurement is a physical measurement done at a selected site in order to assess and evaluate the specific conditions of the case studies. It is onslaught test on a building to analyze and assess the quality of its performance (Schiler and Japee, 2001:57). It is considered a traditional way of undertaking building assessment, which still in use today, through the assessment of "every measurable quantity". Physical building measurement, relative to lighting studies involves a measurement of light level, researcher's personal observations occupants' observations along with assessment and photographic documentation of the site. This type of survey constitutes a major part of Post Occupancy Evaluation (POE), which is an important tool in finding and rectifying any environmental problems in a building through the use of simple changes.

Researches based on field measurement of case studies have been conducted by many lighting researchers (Nemecek and Grandjean, 1973; Rea et. al, 1990; Boyce, 1975; Escuyer and Fontoynont, 2001; BOSTI project, 1981) in order to assess the lighting condition in various office buildings. Field surveys have also been undertaken by many building authorities and councils in order to assess building performance, examples include the Barrow-in-Furness Survey, the City of London Survey (Manning, P., 1965) and the Building-in-Use Assessment by Public Works Canada, Ottawa (Schiler and Japee, 2001).

In this research, field measurement under daylight is used as an assessment of case studies. The case studies present the current window designs and lighting conditions in existing office buildings. Subjective assessment will be supported by technical measurement. A case study has been described as "…a strategy for doing research which involves empirical investigation of a particular contemporary phenomenon in its real life context using multiple sources of evidence" (Robson, 1993:52)

Procedures and equipment

A comprehensive field survey process normally involves a long period of preparation time. Permission to conduct the survey has to be obtained first in order to measure lighting levels or observe occupants whilst on private premises. Forward-planning and a preliminary visit are required before the real measurement can begin. Portable tools and equipment need to be kept available and ready for use in measurement. A portable photometer is used to measure illuminance (inside and outside) and luminance values (on the work surface), and a camera is used to document the scene of study.

The sample of buildings selected in this study is based on the group sampling of different window-facade designs: no shading, simple shading and complex shading. Furthermore, a factor of accessibility based on the researcher's time allocated at the site has also influenced the choice of sample. A standard lighting measurement procedure, as illustrated in Figure 6.2a, was applied at all the measured offices. The use of same colour board and Kodak gray scale (Figure 6.2b) next to the visual display unit (VDU) was meant for a standard reference to the brightness of the daylit environment. The equipment (lightmeter, photometer and camera) used in the field measurement is presented in Figures 7.2 c, d and e.

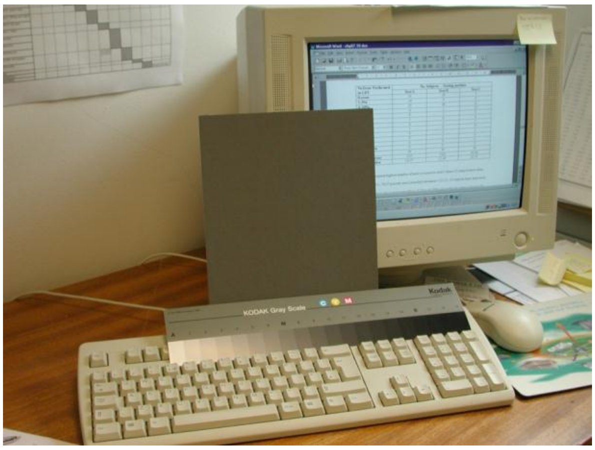


Figure 7.2a: The position of a Kodak gray scale and grey board on a work surface for luminance measurement.

Figure 7.2b & 2c: Kodak gray scale (Q-14), grey board and the TES Photometer.

Figure 7.2d & e: Hagner photometer (d) and Nikon digital camera and fish eye lens

Limitations

A real setting can sometimes create unexpected problems or difficulties. Daylight investigation might prove difficult if the chosen office normally uses electrical light during the daytime. Prior arrangement with the building maintenance chief or manager is also essential for offices, which operate a centralised lighting system. The conduction of such investigations is often unfamiliar to Malaysian offices, and the time or date decided by the building manager for the measurement have to be respected and the privacy of the office respected. Commonly, permission for investigation is hesitantly granted by building owners, tenants and architects always presume a negative implication (Mohd Hamdan, 1996). Gaining access is considerably complicated and involves a drawn-out process. Once permission is granted, it often creates more restrictions as the researcher's time spent at the studied site is often constrained. With both short term and long term field studies caution has to be employed to ensure the research does not interfere with occupants' daily task.

Measuring daylight in a real building under real condition, particularly in Malaysia, is also difficult as the sky condition often changes within minutes (Mohd Hamdan, 1996, Zuraini, 1999 and Gurupiah, 1999). Therefore, these daylighting researches mainly based their analysis on relative measurement, Daylight Factor (DF). Schiller and Japee (2001) has also suggested similar method of measurement for rapidly moving sky and taking an average of the sky illuminance before and after the experiment in the case of limited number of photometers.

The main objective of the field survey is to observe and document the lighting performance of selected office buildings using numerical data and subjective assessment. Although the duration of time at the test area is limited, the results aim to analyse the effectiveness of different window-facade designs in allowing or screening daylight to the interior space. The results also aim to observe occupants' use of windows, blinds and light sources. Although the analysis, due to method of sampling, could be biased, it does not generalise the performance of window-façade design style as a whole.

There are two types of laboratory experiment with different technique of operations that are selected in this research. First is a controlled subjective experiment and later is a computer simulation.

7.4.3 Part three: Visual and lighting experiment

The following describes the definition, procedures and equipment, and limitations of visual and lighting experiment:

Definition

In the past, subjective assessment of real scale experiment have been conducted by many lighting researchers in order to find associations between lighting level and visual comfort or visual performance. Past laboratory experiment exploring lighting parameters assessed the effects of two sources of light; electrical lighting such as those completed by Saunders, 1969; Flyn et al., 1973; Bean and Hopkins, 1980; Loe, Mansfield and Rowland, 2000; Perry, 1996) and daylight or simulated sunlight such as those completed by Takarada et. al, (1994). This method of experiment is also popular in assessing visual comfort or relating quality or quantity of light to work performance (Blackwell, 1959; Blackwell and Scott, 1973; Weston, 1945; Boyce; 1974). Commonly, experiments on visual comfort done consist of subjective assessment and visual task performance, depending on the intention of the studies. Visual tasks used in laboratory experiments usually involve detection, recognition and identification (Egan, 1983).

Laboratory experiment done suggested that people are satisfied with lighting of modest intensity between 30-35 footcandles (300-350 lux) in two studies. "More light added slightly to satisfaction, but eventually brought some complaint of glare. Other findings suggested that quality of lighting is important to satisfaction, and is rated highest and most satisfactory when non-uniform (Sundstrom, 1986:97). The experiment used real scale office under daylight with human beings as the subject. The experiment was focusing on the subjective assessment, visual performance and daylight measurement in order to explain the visual comfort of working under daylit office conditions.

Procedures and Equipment

Subjects were placed in a simulated office setting with various seating positions relative to the windows. The test was conducted under daylight as it is the main objectives of the research. In the experiment, subjects were given questionnaires and visual tasks to be completed. Questions asked relate to: impressions of the room and work surface, the level of contrast of two surfaces within the subject's visual field, the level of glare or shadow at surfaces close to subjects, an overall assessment of the lighting conditions and open-ended questions on lighting choice and suggested improvements to the quality of lighting in the room. A semantic differential rating scale is commonly used in recording workers' opinion on the quality and quantity of light in an office environment.

> *"Semantic differential consists of a set of bipolar, seven category rating scales. The ends of each individual rating scale are defined by polar opposite adjectives (e.g. good-bad, large-small, spacious-cramped, hazy-clear)."*
>
> *(Tiller and Rea, 1992:43).*

In this experiment a visual task called the Landolt Ring chart (Figure 7.3a and b) was used. It was considered one of the oldest visual tasks that has been developed and still used in current lighting research (Weston, 1945; Boyce, 1973 and Rea et al., 1990). The aim of the visual task is to examine whether workers can perform a standard visual task under daylight that comes from various different angles. A set of Landolt rings with various angles was arranged on one sheet of white paper, and participant was instructed to identify only specific ring that orientated towards same angle. Number of mistakes done would be considered as percentage of inefficiency in standard secretarial task.

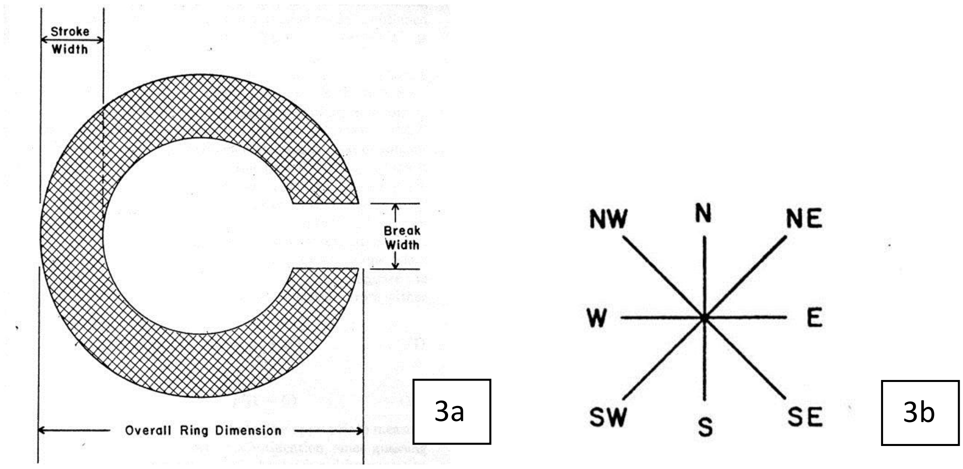
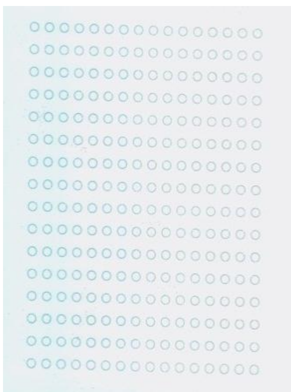


Figure 7.3a and b: The Landolt Ring and the eight orientations of the ring gap. Source: Blackwell and Scott (1973)



3c

Figure 7.3c: Sample of test paper consists of the arrangement of Landolt Ring.

Participants were asked to take the visual performance task (reading, perception of the daylit environment, and Landolt ring test) at three different locations in relation to the window positions. Figure 7.4 shows the location of the seating plan and Figures 7.5 a, b & c shows the interior conditions of the room.

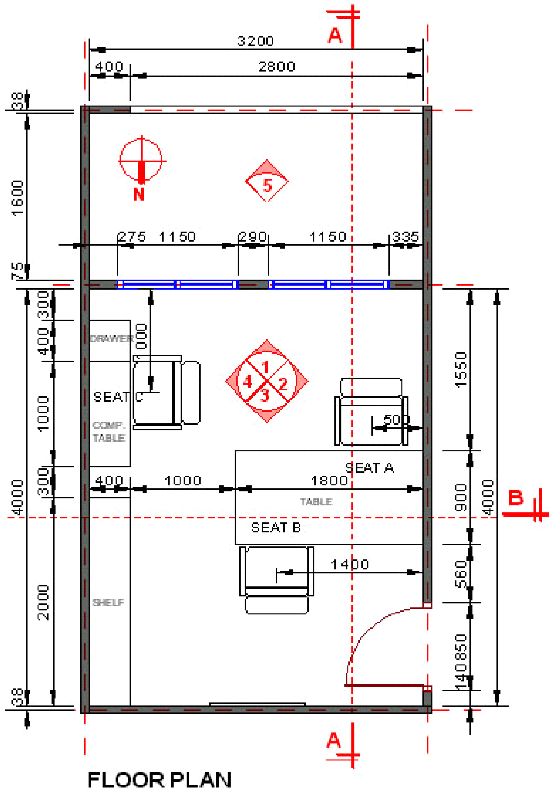
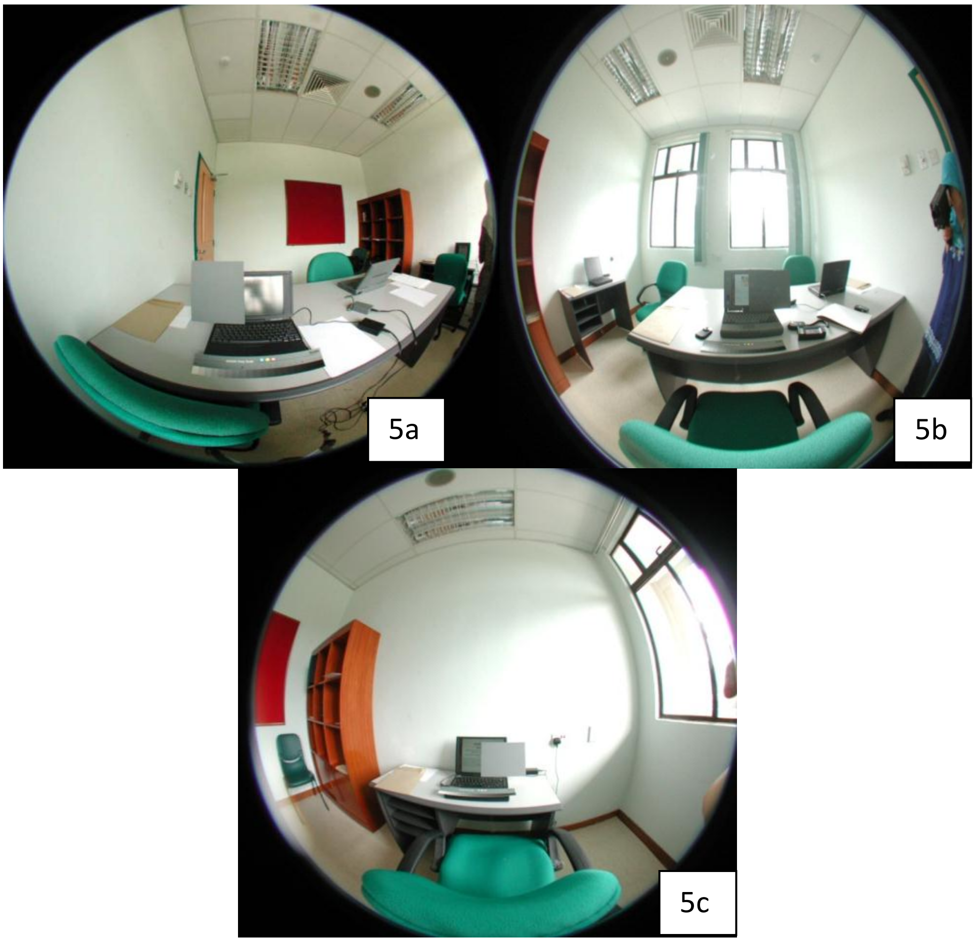


Figure 7.4: Floor plan showing 3 different seating locations relative to the window. Seat A - back to window; Seat B - Facing window and Seat C - window at the side.



Figures 7.5 a, b & c: Showing the real interior conditions of the experiment room.

Limitations

In this laboratory experiment daylight was a changing parameter. Subjects were the students and staff of the university where the experiment was conducted. The sample was limited to the particular main ethnic group of the students and staff in the test location. Arrangement of furniture was limited to the size of the room that was available for the test. The distance of each seat was constrained by furniture size and arrangement.

The controlled subjective experiment in this study had been closely matched to the real office condition as it was conducted in an individual office under a real sky and natural light. The same technique had been applied by Bean and Hopkinson (1980) and Rea et. al, (1990). The aim was to find out subjects' assessment of the daylit environment and their performance of a visual task under the daylight source. The different seating positions, which reflect common office workers' seating positions, were used to analyze the visual comfort levels of quantity and quality of light received at each seating position and to analyze whether the angle of the source of light can influence visual performance.

6.4.4 Part four: Computer simulation experiment

The following describes the definition, procedures and equipment, and limitations of visual and lighting experiment:

Definition

Experiment using computer simulation is one of the latest innovatory methods to be employed in environmental research. It provides great flexibility, with a high accuracy result and realistic photo-imaging capabilities. Lighting calculation using computer simulation is widely used today due to the widespread use of computers in architectural practice, education and research. Many computer modeling programs which have been developed have emphasized their user-friendly system whilst some have more limitations than others. Lighting calculation and modeling software is a fast tool enabling the visualisation of space, with selected light source, and the calculation of light levels at the same time. It is useful in predicting the lighting quality and quantity of an intended design for all seasons.

Procedures and Equipment

In this study, further investigation of the subjective experiment in part 3 was conducted using the computer calculation in order to assess the quality of light and its negative aspects such as glare. The experiment space would be drawn in the ECOTECT modeling program (as shown in Figure 7.6), a 3-D modeling program, from which outputs can be directly converted to RADIANCE, an advanced lighting simulation program.

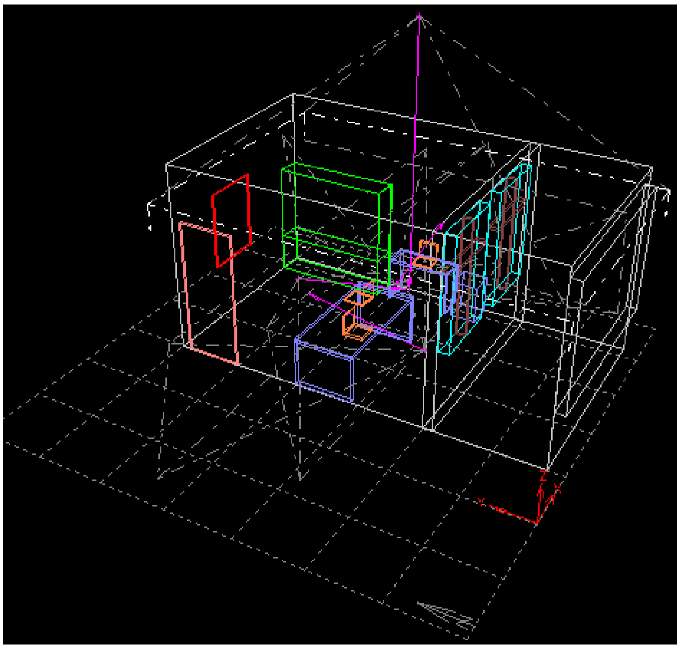


Figure 7.6: The wire frame model drawn in Ecotect before exporting to Radiance

The result of the simulation provided advanced lighting calculation such as glare, in order to justify findings. The ECOTECT program was easily available and very user-friendly in modeling a 3d space. However, in calculating a complicated lighting parameter such as glare, the system has limited capabilities as do many other lighting programs on the market. The only advanced lighting software on the market that could perform the glare calculation is RADIANCE. RADIANCE currently can be operated using a personal computer, but for a more complicated calculation, such as glare, a UNIX system is necessary. Same as other lighting calculation program, the design sky used was based on the varieties of standard CIE established sky. Details of the sky parameters input were needed in order to simulate the real setting condition. The data of the most extreme conditions relative to the real controlled experiment results would only be applied as selected daylight conditions. Testing the most critical sample as a representative of the investigation was considered practical as time do not allow testing of all available data (Murray et al., 2001). Then, the materials of the room structure and furniture would be specified, before running the simulation. The analysis would be based on the glare calculation index chosen and images of the simulated conditions.

Limitation

The lighting calculation performed in the simulation is based on the available sky data and calculation set by the program. The advanced lighting calculation such as the one that exists for glare can only be performed by RADIANCE in the UNIX system, which can only be accessed with the help of a computer assistant with a high degree of expertise and familiarity with the program. Therefore, the researcher's working of the particular system was limited to the theory. The glare calculation was based on the various glare indices generated by previous literature. For example the glare index was calculated using DGI, VCP and UGR glare formulae, which were formulated based on overseas condition.

Computer simulation was the most common method used to evaluate complex lighting performance as it is fast (wide use of computer software nowadays) and provides a near, accurate result. The model of the experiment room was drawn in ECOTECT, which is a user-friendly program with proximate availability of technical support. Calculating glare manually is a tedious task; therefore a computer program is needed. Combining methods such as field measurement or experiment and computer simulation was necessary in order to allow the researcher to validate the result as well as correlate the findings (Mardaljevic, 1995; Kim, 1987). RADIANCE has previously been used successfully in lighting research (Ng et al, 2001) and able to calculate accurate lighting and daylighting design. It has the capacity to calculate complex lighting performance and it is the only advanced lighting software currently available. The researcher did not handle the advance operation of the RADIANCE program and UNIX systems, as the program requires specialist programmer and those with a higher degree of computer proficiency (Mohd Hamdan, 1996). In reality, this constraint of not operating part of the glare calculation by the actual designer does not produce any significant effects: in fact, it was perceived as one way of communication and collaboration between designer and specialised consulting engineer (Compagnon, 1997). In addition, the program was selected merely as tool to produce an output that can be analysed and interpreted by the researcher.

6.5 Summary

In general, the methods used were trying to confirm the problem and justify the possibilities of the visual comfort of daylighting in office building in Malaysia. Therefore, the applied or action research method was adopted. The investigation selected four different tools of investigations: questionnaire survey, field measurement/survey, and laboratory experiment and computer simulation. The methods applied are also within the limitation of the local unavoidable circumstances which were justified and rationalized.

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8 Triangulation Methods in Thermal Comfort Studies

Noor Aziah Mohd Ariffin

8.1 Introduction

This paper describes the methodology used in the investigation of thermal comfort studies with the notion that energy efficient design adapted to double storey terraced houses in Malaysia can increase thermal comfort and decrease energy consumption. The study requires a method of exploring the thermal performance of existing and hypothetical dwellings. Hence, the chapter aims to determine that, if from the outset, houses are designed taking into consideration energy efficient design strategies (for example, orientation studies and the utilisation of passive design features) the result will be dwellings with lower internal temperatures and lower energy consumption.

8.2 Background

Malaysia has experienced rapid economic development and social transformation in the past four decades, characterised by rapid urbanisation due to substantial population growth, which has in turn resulted in intensification in the demand for housing (Mohd Razali 2002). Due to this phenomenon, many houses were urgently built, frequently being planned and designed without much forethought about the attributes of the local climate. As a consequence, these newly built houses are uncomfortable and hot (Davis, Shanmugavelu, & Adam 1997) and this has resulted in an increased use of energy for cooling (Byrd 2006).

Housing stock in Malaysia has increased and the latest residential property stock report for the second quarter (Q2) in 2009 puts the housing stock in Malaysia of all residential types at 4,264,649 units (National Property Information Center 2009). Terraced house types, consisting of single, double and even triple-storey houses, from all price brackets, constitute the largest type division, 40% or 1,712,808 units of the national housing stock and represent the most popular housing type (Phoon 2004).

With the rise of the housing stock the use of electrical energy in the residential sector inevitably increases as well. According to the national energy data available, energy consumption in the residential sector has increased from 17.5% in 2002 to 21% in 2006 (Energy Commission Malaysia 2005). This increment is interlinked with the rise in the progressive efforts of the nation to develop which resulted in the emergence of the middle-class population in Malaysia (Torii 2003) which is, in turn, partly responsible for steering the trend toward an energy–intense lifestyle.

8.3 Aim of the study and questions

The aim of the study is to investigate the potential passive design strategies in typical medium density terraced houses in Malaysia in order to be energy efficient and yet achieve thermal comfort for the occupants as well. The paper seeks to answer three key research questions: whether the existing terraced houses provide satisfactory and adequate thermal comfort; do orientations of the houses have any impact on thermal comfort conditions and energy consumption and can any passive design strategies improve the conditions and reduce energy use? The information gathered will become basis for all involved in the designing of the residential sector (especially for terraced houses) in Malaysia to rethink of a new design paradigm for the conventional approach of house building with particular attention to medium density construction.

8.4 The Problem

Malaysia is situated in the hot and humid equatorial region, where daily temperatures are always hot between 24˚ - 34˚C. It is slightly cooler when it rains. Coupled with high humidity (averaging more than 80% most of the year) and compounded by a lack of wind flow, thermal comfort is difficult to attain naturally. As a consequence, artificial ventilation is required almost all the time because internal conditions become hot and uncomfortable, not only during the day, but also well into the night. Studies have found that night-time internal temperatures in terraced houses usually remain on the upper limit of the thermal comfort zone until the early hours of the morning (Davis, Shanmugavelu, & Adam 1997, Noor Aziah 2008). This necessitates some form of artificial cooling and of late the use of air conditioning has become ubiquitous. Due to this the use of electrical energy in the residential sector has increased tremendously in recent years. On top of that, ownership of air conditioner units in 2005 had increased by 32% since 1999 and this is predicted to increase to almost 60% by the year 2015 if the present trend persists (Saidur, Masjuki, Jamaluddin & Ahmed 2007. As a consequence, energy demand will increase as well. The availability of cheap and affordable air conditioner units due to the boom in the industry has made their purchase easier.

8.5 Research methods

The research methods applied in this study aim, first of all, to investigate the research aims outlined above and then to corroborate and validate them with different methods in order to consolidate the study. To assist in understanding the whole scenario of thermal problems and their contribution to thermal comfort and energy consumption as previously described, an ‘applied’ research approach was selected. In other words, the chosen method addresses real life situations that require immediate attention, being *“…primarily interested in identifying problem areas, searching for relevant solutions and* *producing direct answers"* (Sarantakos 2005, pp: 322). The methodology involved three research instruments:

- The first tool provides a method of investigating and analysing existing conditions in double storey terraced houses through a field survey using a questionnaire and interview technique.
- The second tool also analysed existing conditions but through a temperature monitoring procedure where data loggers were used to collect temperature data.
- The third tool is computer simulation studies which seek to predict the most suitable and appropriate energy efficient design strategy for double storey terraced houses.

8.5 Research process

In seeking answers posed by the research questions, three distinct approaches were adopted, as illustrated in Figure 8.1 and explained below:

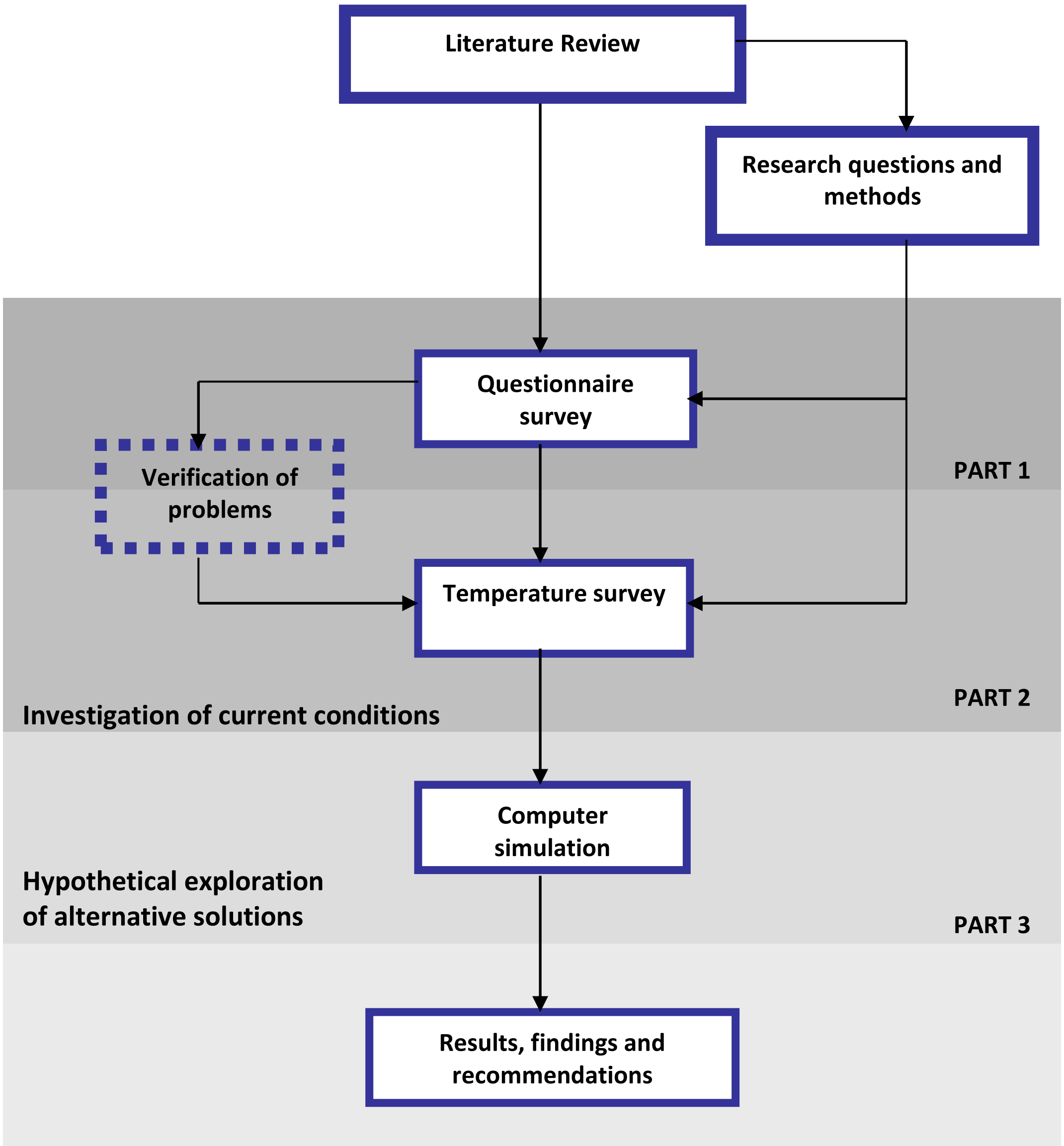


Figure 8.1: The research process

Part 1 seeks the residents' opinions with regard to their thermal comfort and the factors affecting it within their houses. This is established through a questionnaire survey of their opinions. These opinions will underpin the crux of the research statement and claim that most terraced houses in Malaysia are indeed overheated and uncomfortable to live in for most parts of the day. The occupants' perceptions of what is suitable or unsuitable about their dwellings are also important, as this will form the basis for the implementation of design solutions within the context of passive design for thermal comfort and energy use.

In **Part 2** the current conditions of the terraced houses are surveyed by monitoring the internal temperatures of the houses. This investigation will reveal the indoor thermal conditions of the houses and whether houses facing different orientations display different thermal conditions and performances. The findings from this part will be used to corroborate results found in the first and third investigations.

For Parts 1 and 2, a cross-sectional survey was considered the most feasible means of research. The reasons for the use of the survey are, firstly, that it studies only a small sample of the population in its existing settings at a given moment, investigating a particular set of conditions with no manipulations being involved, to reduce bias in the study (Babbie 1990); and secondly, an empirical generalisation and representation from studying a small sample can be maximised in relation to a bigger population (Hammersley 1993). Finally, and most importantly this method is prudent in regard to time and money, compared to the daunting task of conducting a large-scale study involving all terraced houses in Malaysia.

Part 3 is a parametric exploration of the energy and thermal performances of hypothetical dwelling models, tested through computer simulation. The exploration will be based on findings from data collected from the first two investigations above. The computer simulation will also facilitate passive design strategies for the houses, focusing on variation of orientation and envelope design as the main considerations. Findings from this investigation will consolidate all results and form the basis for design guidelines for future energy-efficient design of terraced houses.

8.5.1 Data required from field survey

Data sought in the study were collected in two parts:

- For users' opinions and perceptions a questionnaire survey research (De Vaus 2002) involving households was undertaken. This method uses traditional survey techniques including questionnaire construction, sampling procedures, data collection, data analysis and interpretation and reporting of the findings. Information on energy consumption and usage patterns in relation to cooling are sought.

- To analyse current conditions of the houses a temperature survey, monitoring the indoor temperature of the houses with pre-programmed data loggers, was used. The temperature data collected through the pre-programmed loggers was then uploaded into the appropriate analysis software (Excel and SPSS) for further analysis and reporting of the findings.

8.6 Context of study

The context of the study is discussed in the following sections. The selected location and a description of the characteristics of the terraced houses under study are described.

8.6.1 Location selected

The study is concerned with terraced houses in Malaysia, which at the present moment constitute 40% of the available housing stock (National Property Information Centre 2007). According to the National Property Information Centre, it is also the most popular housing type in the country, and double storey houses make up approximately 52% of the total number of terraced house types. The housing estate concerned in this study is located at Kota Damansara in Selangor, as shown in Figure 7.2. Kota Damansara is a mini township of mixed development, comprising all types of residential buildings from the various price brackets, commercial and industrial areas. It is about 25 km from Kuala Lumpur and due to this close proximity; it enjoys a suburban style of living with increasing property values.

Figure 8.2: Site Plan of area where survey was undertaken at Section 6, Kota Damansara. Figure shows the different orientations under study. The orange lines are zones surveyed and green boxes are houses involved in the survey. (Source: Perbadanan Kemajuan Negeri Selangor, Petaling Jaya)

The housing area was chosen because the development criteria fit into the selection parameters of the study which included being in a suburban location; development being completed between 5 and 10 years ago, which means it is likely the houses are still new with little or no renovation work; exclusively double storey, medium cost[5] houses, but with various orientations; the use of conventional reinforced concrete post and beam construction with brick infill and concrete/clay-tiled roof over timber trusses; house subdivision sizes being 6 to 8 m wide and 20 to 30 m long (180 m^2); and

1 Houses costing less than RM250,000 (Ministry of Housing). Houses costing more than this are termed as High-Cost and are not suitable for this research. This is because these types of houses are much bigger with better finishes and features and could be perceived as providing more comfort, certainly psychologically and possibly thermally as well.

the housing area is relatively new, within a new township development, with the price of houses being within the reach of most young working class people. Hence, the household is expected to consist of between 4-6 occupants (i.e. a young family with an average of three children[6] (Crawley et al. 2001) and a maid or grandparent/s staying at home most of the time. The assumptions above are important to establish a consistent occupancy level and energy usage profile for data analysis. This is required in order to answer one of the research question – whether any correlation exist between the orientation of a house and its energy consumption.

The selection of terraced houses for the field survey was based on a study conducted by Al-Obaidi (2004) in establishing the typical Malaysian terraced house characteristics. His findings after incorporating the most commonly occurring layouts, space types and sizes revealed that a typical terraced house as two-storeyed where each floor is divided into four or five spaces for the average Malaysian family of five persons. The house consists, on the ground floor, living and dining areas, kitchen, utility/bedroom bathroom and staircase. On the first floor, there is commonly a master bedroom with bathroom en-suite, two other bedrooms, another bathroom and a landing space/ family room to receive the stairs from the ground floor (Al-Obaidi & Woods 2006). Terraced houses selected for this study in the Section 6 housing estate have similar characteristics to those described above and is presented next.

8.6.2 House description

The double-storey terraced houses under study are either made up of intermediate lots or end or corner lots, but all are of similar design. The only difference is that the corner or end lots have windows and openings on the side walls, as shown in Figure 8.3.

Figure 8.3: Terraced house used in the study. (Source: Author)

2 Present fertility rate in Malaysia is 3.1 children born/woman (Department of Statistics 2001)

A typical unit in this study has a total floor area of approximately 180 m² on a subdivision of approximately 6.7 meters wide by up to 22 meters long. The house has a large, high portico covering both front porch and balcony and smaller shading devices over windows and other openings as seen in Figure 8.2. It is built of reinforced concrete post and beam construction with clay or concrete brick infill and concrete floor slabs. The roof is, for the most part, pitched with a timber truss system. Insulation mainly consists only of sisalation or reflective aluminium paper just under the roof tiles. Windows have either timber or aluminium frames with clear float and single glazing. The layout of an intermediate terraced house is shown in Figure 8.4.

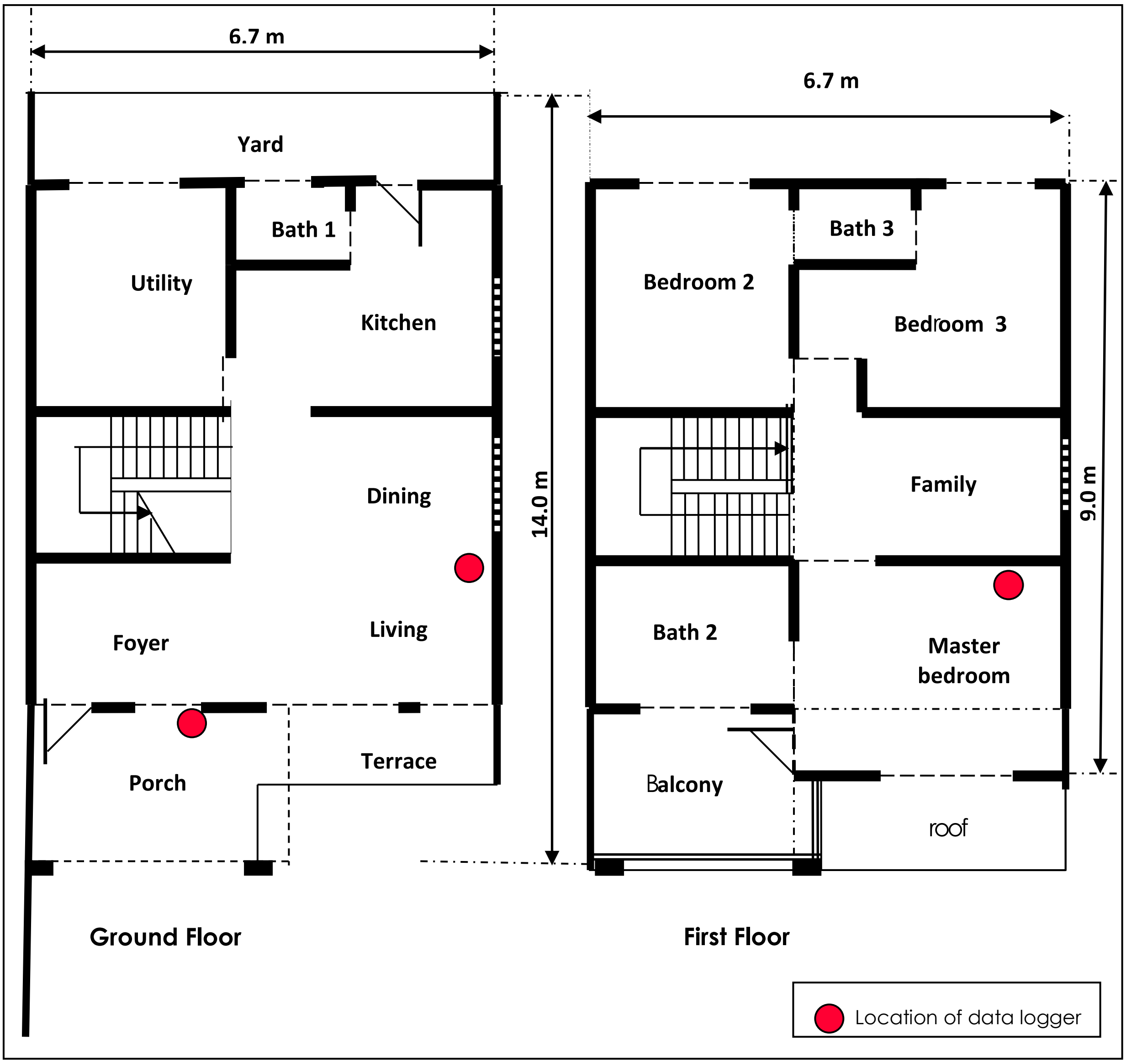


Figure 8.4: Floor plans of the terraced house under study

It is open-planned on the ground floor, with the living, dining and foyer combined to make one large space at the front. The kitchen, utility room and bathroom 1 are located at the back. A stairwell facing the dining room leads up to the family room on the first floor which serves as a transition space to all three bedrooms. The master bedroom is located facing the front of the house with an en-suite bathroom and also has a large balcony. Bedrooms 2 and 3 are located at the back and share the third bathroom. All rooms have windows on the external walls with the exception of the family room which is top lit. As with most intermediate terraced houses, it has only two facades of opposing orientations. However, the end or corner lots will have windows on the side wall adjacent to the dining and kitchen on the ground floor and the family room on the top floor (denoted by white dotted lines in walls of adjacent rooms in Figure 8.4).

The next section will describe and explain the three research methods undertaken for the study, starting with descriptions of the questionnaire survey; temperature survey and finally the computer simulation.

8.7 Questionnaire survey – Part 1

For extracting information regarding occupants of the houses a cross-sectional survey was conducted, which, *"…solicits response at one point in time from a sample selected to describe some larger population at that particular time"* (Babbie 1990, pp: 72). This procedure is a method of gathering information from a sample of individuals, drawn from just a fraction of the total population being studied. One of its advantages is that it, *"…enables a researcher to cover extensive amount of information – from demographic characteristics to behavioural habits, to opinions or attitudes on a variety of topics – across a large number of people in a limited amount of time"* (Wang & Groat 2002, pp: 278).

This survey method is particularly suitable for the first part of the study, which aimed to ascertain whether or not the occupants were currently thermally comfortable in their variously oriented houses, and what efforts were made to achieve and maintain thermal comfort. To achieve this, the survey sought the following information:

- demographic and basic information of the houses under study;
- duration of cooling to establish the usage pattern pertinent to the creation of the energy operation profile required for simulation studies;
- information on electricity consumption through monthly bills from the utility company Tenaga Malaysia Berhad;
- assessment of thermal comfort perceptions (Parsons 2003; Kishnani 2002; de Dear, Brager & Cooper 1997; ASHRAE 1992; Fanger 1972) of occupants living in the varying orientations;

- perceptions of the occupants of the benefits and drawbacks of their dwellings and on their adaptive behaviour and physical thermal improvement activities in overcoming thermal problems.

The questions were designed to ascertain if there were any relationships between the orientations of the houses with their occupants' perceptions of thermal comfort. Occupants were also asked about their adaptive activities in response to discomfort, such as opening or closing windows. These would later form the basis for determining occupants' acceptance of higher comfort temperatures, as suggested by adaptive thermal comfort standards. Questions on thermal comfort were based on tested studies and referred literatures (Parsons 2003; Kishnani 2002; de Dear, Brager & Cooper 1997; ASHRAE 1992; Fanger 1972).

Questions were deliberately kept simple, acknowledging that respondents may not be familiar with design and environmental concepts. The questions could be answered using simply Yes or No prompts and when this was inadequate, as was the case with questions that sought information on thermal conditions and sensations, respondents were asked to choose from multiple choice options. The opinions were presented using a semantic scale rating assessment based on ASHRAE comfort scale. The questionnaire was designed to be either self-administered or through interview. Interactive semi-structured interviews were undertaken in the respondents' own dwellings. The interviews were designed to take between 30 and 40 minutes for each household.

8.7.1 Questionnaire preparation

The questionnaire was prepared in accordance with the requirements of the research questions and from thermal comfort studies identified in Parsons (2003) and Kishnani (2002). The questionnaire's development closely followed guidelines designed to allow responses to be statistically analysed using the software SPSS 14.0. In order to extrapolate answers to the research questions, the questionnaire was designed with reference to the aspects below (De Vaus 1990):

a) Background measures: general questions on characteristics of the population sample that can establish if patterns differ for the different orientation subgroup.

b) Measures of the dependent variable: energy consumption and thermal comfort.

c) Measures of independent variable: orientation of subdivision of the houses.

d) Measures of test variables: variables that help clarify the nature of the links between independent and dependent variables, such as physical or adaptive measures undertaken by respondents in maintaining comfort or to reduce energy consumption.

Finally, the completed questionnaire, written in English and Malay, consisted of twenty-eight questions, of which five were open-ended. The questionnaire was divided into 5 parts, with each part covering a specific topic, as follows:

- **Part I: House Criteria** – general demographic background information of respondents and houses.
- **Part II: Occupancy Criteria** - information on the number of occupants and average time spent in the house during weekdays and weekends.
- **Part III: Cooling Criteria** - information on cooling systems available for the house, their usage patterns and the resultant energy bill.
- **Part IV: Thermal Comfort** - information on thermal comfort perception.
- **Part V: Thermal Improvements** - information on adaptive, passive and/or active strategies undertaken and considered to increase occupants' thermal comfort.

Most of the answers required the ticking of multiple choice boxes or ticking Yes or No prompts. These were designed to provide ease of answering and ease of converting data into SPSS format for analysis. However, semantic differential scales were used to answer questions in Part IV. This format was used to represent the two extremes of a continuum and respondents were asked to put a mark between the two extremes. This type of question is based on the ASHRAE's thermal sensation scale (ASHRAE 1992) (1= cold, 2=cool, 3=slightly cool, 4= just right or neutral, 5= slightly warm, 6=warm, 7=hot) which is widely used for thermal comfort studies (Part IV: Question 18). As noted, the numbers were changed from the original format (-3= cold, -2= cool, -1= slightly cool, 0= neutral, 1= slightly warm, 2= warm, 3= hot) to avoid any possibility of confusion for the participants. The objective of these questions was to establish whether or not the houses are actually hot and uncomfortable by analysing the responses. This information was corroborated with logged temperature data, which was done simultaneously during the field work. It should be noted that respondents were asked to answer these questions under normal conditions, with fans switched on but no air conditioning.

8.7.2 Sampling method

The samples of population from the Section 6 housing area were initially selected using random sampling. There was good representation of houses from the varying orientations, as previously shown in Figure 8.2. After the initial round of sending letters to solicit participation from all residents of Section 6, for which the responses were very poor, a different strategy was undertaken. A purposive sampling method was employed instead, whereby respondents who had already been interviewed recommended other potential participants. This method proved to be more successful and the number of participants later snowballed. In this endeavour, the judgment of the researcher in purposely choosing subjects suitable for the research topic was more important than obtaining a probability sample (Sarantakos 2005). This system proved more successful and respondents were more comfortable participating once they knew their friends or neighbours had participated and recommended them. As the interviews were being conducted, temperature logging was also underway in the terraced houses. Each house was required to have three data loggers and was logged for a period of five to seven days.

After intensive and exhausting fieldwork, which took a period of almost three months, a total of 85 households had been interviewed and temperatures from 22 houses had been logged. Although purposive sampling was employed, the criteria still adhered to the parameters of the study; which required houses with different orientations and locations. The total number of cases corresponded to 35% of N (total population of 240) and 58% of S (sample size of a given population, according to the table for determining sample size of a given population, pp: 173 in Sarantakos (2005)). According to Sarantakos (2005) this is considered as probable for the number to be meaningful for analysis purposes. Table 8.1 shows the final numbers of respondents with respect to the orientation groups.

Table 8.1: Number of houses interviewed in relation to orientation groups.

Orientation Group	No. of respondents
1. North West – North East (NW-NE) (316-360˚ & 0-45˚)	23
2. North East – South East (NE-SE) (46 – 135˚)	18
3. South East – South West (SE-SW) (136-225˚)	25
4. South West – North West (SW-NW) (226-315˚)	19
Total	**85**

8.7.3 Energy consumption data collection

The energy consumption data collated from the occupants is concerned only with electricity accounts, since only electricity is supplied by grid to the houses. The local gas supply is in the form of bottled liquefied petroleum gas (LPG) and is used for cooking purposes only. It was difficult to acquire a year's electricity bills from any one occupant: some occupants were wary about parting with their bills and in any case, most of them do not keep records of all monthly bills. From whatever bills were presented during the interview, the researcher averaged the electricity consumption and the result was confirmed by each occupant as the most accurate representation of their monthly consumption. Tang (2007) estimates the percentage of energy used for thermal cooling in a typical terraced house is approximately 23%. The energy consumption for each house was then collapsed into an index of kWh/year for further analyses.

8.7.4 Analysing data

The data gathered from the questionnaire survey were analysed using statistical methods. Most of the data were nominal and ordinal therefore descriptive statistics such as frequency; cross tabulation and analysis of variances (ANOVA) were used as the methods of assessment. Data reduction was also done when required to assist the researcher in grouping some of the feedback to make more sense of their relationships. The statistical software SPSS 12.0 was used initially and was later upgraded to versions 13.0, 14.0 and 15.0. The main aim of the analyses was to establish the relationship between orientation, energy consumption and usage patterns towards achieving thermal comfort.

8.8 Temperature survey – Part 2

Having addressed how the occupants perceived their houses' performances, we then considered how the houses actually performed in terms of indoor conditions to corroborate findings from Part I. A temperature survey was conducted, intended to establish if a significant difference is evident in the indoor temperatures and energy consumption of houses of differing orientations. Data monitoring was undertaken as a complimentary method to help substantiate findings from the results of the questionnaire survey above.

8.8.1 Measurement of indoor temperatures

The survey of indoor conditions was conducted concurrently with the questionnaire survey. Selected houses were monitored for a period of at least five to seven days. This was assumed to be adequate for obtaining consistent indoor conditions since the climate of Malaysia has little daily variation. The data loggers used were the Gemini 'Tinytalk II' automatic data loggers with external sensing probes. They have a sensor range of -40º to +50°C and an accuracy of plus and minus 0.2 K, which complies with the requirements of the standard ISO 7726 (1998). The loggers were programmed to measure dry-bulb air temperature at one-hour intervals. The dry bulb temperature in two different rooms was monitored along with the outdoor conditions. The data loggers were placed in the living room in the lower level, the master bedroom on the upper level and under the porch area in the front of the house (refer to Figure 8.3). Each data logger in the rooms was placed at the body height of a seated person between 0.9 to 1.5 meters as referred to in ISO 7726 (1998). In each case the loggers were positioned away from direct sunlight and from any obvious direct heat and cold sources and windows or other external openings. External climatic data including temperatures, relative humidity, wind speed and direction, rainfall and solar irradiation data were collated from the Malaysia Meteorological Services from Subang station during the logging duration.

8.8.2 Analysing data

All logged data were offloaded from data loggers into the 'TinyTalk' program before being further exported into spreadsheets for analysis, using the Excel and SPSS programs. Graphs and charts in Excel indicate trends, enabling the making of comparisons between the data. Analysis of variance (ANOVA) and t-test using the SPSS program were conducted on the temperature data to see whether any differences of temperature occurred among houses of varying orientations.

8.9 Computer simulation – Part 3

Parametric analysis has been widely used to investigate the influence of building characteristics on thermal and energy performances of buildings (Norhati 2006; Jahn Kassim 2004; Hong, Chou & Bong 2000). This part of the study took a predictive approach, whereby the performance of a base-case model and potential improved models with varying passive design features were tested and quantified using computer simulation techniques on a number of orientations.

This tool enabled exploration of the most suitable and appropriate passive design strategy for more energy-efficient double storey terraced houses. The passive design measures examining factors affecting thermal requirements and energy consumption were the orientation and envelope parameters. To be able to understand the performances of the houses according to orientation, the computer simulation study aimed to predict energy and thermal performance for directions covering the full 360° at 10° intervals. The simulations were done to discover whether houses facing different directions have different energy loads and consequently, different thermal performance, as shown in Figure 8.5.

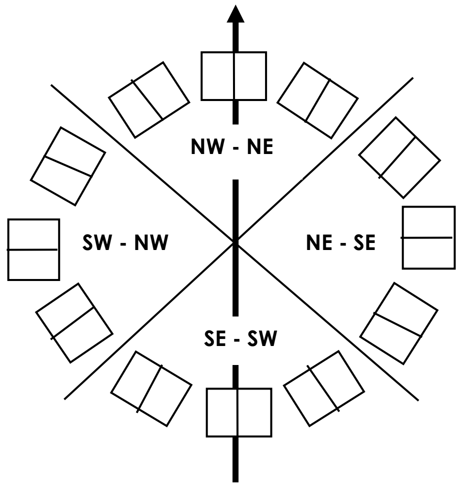


Figure 8.5: The orientation parameters of terraced houses studied.

and the following simulation steps are shown in Figure 8.6.

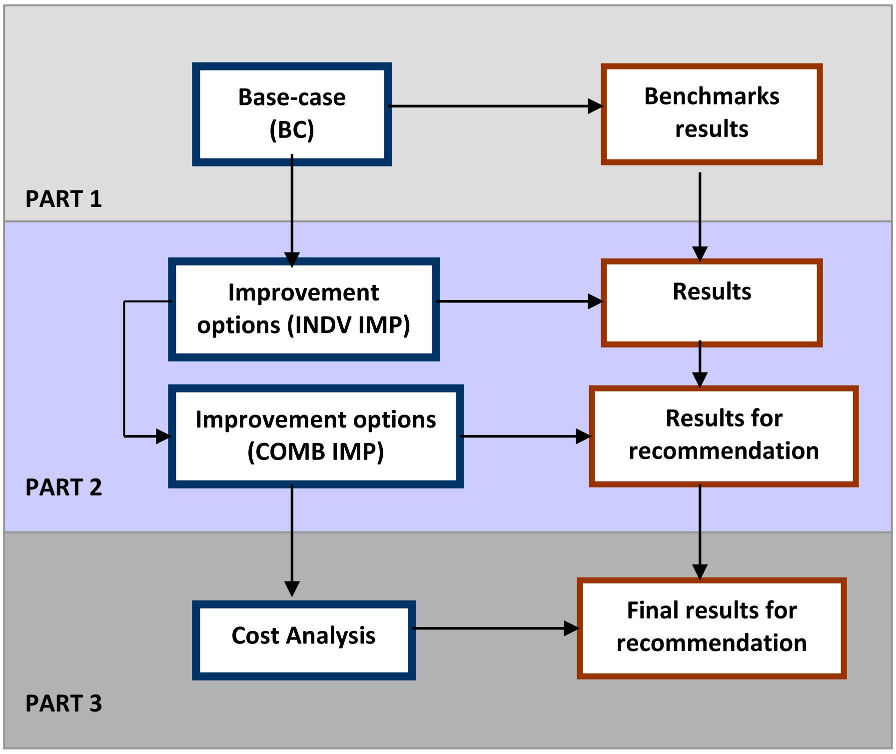


Figure 8.6: Components of simulation study and cost analysis

Part 1 simulates the Base-Case (BC) conditions; Part 2 simulates the Improvement (IMP) conditions, while Part 3 is the cost analysis based on the simulation results.

8.9.1 Tool for parametric analysis - IES <VE>

To be suitable for use in this study, a tool must be one that is used in the building energy field and utilises whole-building energy simulation programs that provide key building performance indicators, such as energy use and demand, temperature, humidity and costs (Crawley et al. 2005). The tool should also allow users to predict the thermal performance of buildings and also to predict the cost effectiveness of energy use and consumption. Another important criterion in the selection of the most appropriate tool is the availability of technical and software support (Mason 1999). The Integrated Environmental Solution (IES <VE>) thermal simulation package, consisting of a range of design-oriented building analyses within a single software environment, conformed to all these selection criteria and was chosen as the most appropriate tool for the study.

IES <VE> incorporates the thermal simulation program ApacheSim with various other sub-programs of particular interest for this study. The idea is that the single model allows easy data exchange among applications. The philosophy behind the IES <VE> program is to provide an integrated suite of programs linked by a common data model generator, the Integrated Data Model (IDM). The accuracy of thermal analysis within the APACHE system has been validated by various studies including the Low-Energy Office Building for the Ministry of Energy, Communication and Multimedia in the Administration Capital at Putrajaya (DANIDA & MECM 2002; Lomas et al. 1997) and can be generally accepted as providing realistic conditions.

Data input

To enable energy and thermal analysis of a space in the terraced house model to be simulated, information on the geometry, construction and energy usage patterns of the house was required. The data input preparation consisted of three main tasks which included:

- specification of building geometry and Subang TRY weather data (Zain-Ahmed, 2000);
- specification of building element data (properties of building construction and fabric);
- specification of energy usage data: air-conditioning and lighting operating profiles.

The program calculates hour-by-hour cooling and total energy loads and a whole range of temperatures for every room in the house, using hour-to-hour Subang TRY Weather data, as mentioned previously, for an entire representative year.

8.9.2 Simulation Part 1: Base-case (BC) model

In this thesis the areas of concern that will affect the energy consumption and heat gain are the envelope components: roof, external walls and glazing on windows or doors. Therefore, these three components were employed with various interchangeable materials. Table 8.2 indicates the construction properties and U-values of the BC model.

Table 8.2: Base-case model profile for external wall, roof and glazing for simulation studies

Building Component		**Thickness (mm)**	**U-value (W/m²K)**
Wall1 [W1]	½ - brick thick with plaster on both sides	150	1.7731
Roof1 [R1]	Concrete roof tile with aluminium foil on timber truss and plasterboard ceiling		1.7201
Glazing1 [G1]	Single clear float	6	5.600

8.9.3 Simulation Part 2: Parametric analysis of Improvement (IMP) model

In Part 2, parametric analyses were performed to assess, primarily, the annual energy consumption (AEC) and thermal performance of IMP models, considering various envelope configurations as tabulated in Table 8.3.

Table 8.3: Modified improvements to BC conditions undertaken for the simulation studies

	Improved Roof	Thickness (mm)	u-value (W/m²K)
Roof2 [R2]	Concrete roof tile on timber truss with 25 mm glasswool insulation		0.8620
Roof3 [R3]	Concrete roof tile on timber truss with 50 mm glasswool insulation		0.5624
Roof4 [R4]	Concrete roof tile on timber truss with 75 mm glasswool insulation		0.4071
Roof5 [R5]	Concrete roof tile on timber truss with 100 mm glasswool insulation		0.3245
Improved Wall			
Wall2 [W2]	½-brick thick wall with 25 mm glasswool insulation and plasterboard	170	0.5854
Wall3 [W3]	½ brick thick wall with 50 mm glasswool insulation and plasterboard	195	0.4286
Wall4 [W4]	½ brick thick wall with 75 mm glasswool insulation and plasterboard	220	0.3380
Improved Glazing			
Glaze2 [G2]	Double-tinted glazing	10	2.805

The next sections describe the various improvements to the building envelope components undertaken for the simulation study.

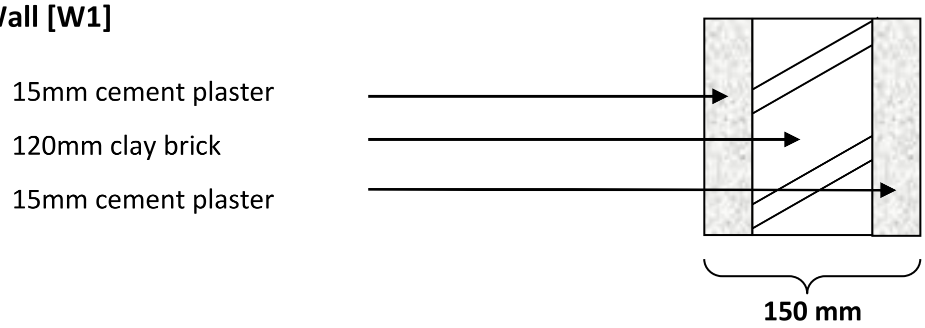
Roof: Improvements using insulation

The improved roof component, utilising varying thicknesses of glasswool insulation (25mm, 50mm, 75mm and 100mm). The existing roof construction consists of (in order of external to internal): 10mm thick concrete roof tiles; on 25mm timber battens; aluminium foil; 150mm timber rafter and 10mm gypsum plasterboard. The improved roof [R2-R5] included varying thicknesses of glasswool insulation between the rafter and plasterboard ceiling.

Walls: Improvements using insulation

For improvement studies of the wall, three varying wall constructions were investigated. The BC is represented by 150mm plastered ½-brick wall [W1] with a u-value of 1.7731 W/m^2K. Walls with insulation are uncommon, but were investigated. Figure 7.6 shows the different types of wall constructions used in the investigation.

BC Wall [W1]



Insulated walls [W2-W4]

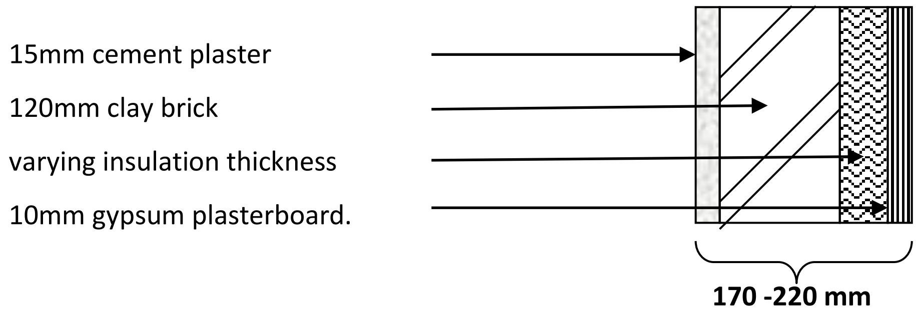


Figure 8.6: BC wall and insulated wall constructions

Glazing: Improvement using lower-transmittance glass

Glazing used in the BC model is 6mm thick clear float glass. For the improved model [G2] tinted double-glazing 10 mm thick was used.

8.9.4 Simulation steps for IMP models

The simulation was done in two steps: Step 1 simulated the improvements to the building envelope individually. For the Individual Improvement (INDV IMP) tests each building component was tested on its own, with the other two components remaining constant in line with the BC. For example improvements [R2] to [R5] were tested with [W1] and [G1] remaining constant and consequently improvements [W2] to [W4] were tested with [R1] and [G1]. Lastly improvement [G2] was tested with [R1] and [W1]. A total of eight (4 Roof; 3 Wall and 1 Glazing) INDV IMPs were simulated for 36 orientations giving a total of 396 permutations (excluding the BC). The steps are shown in Table 8.4.

Table 8.4: Series of INDV IMP permutations for Roof, Wall and Glazing options

Roof	Wall	Glazing
R1W1G1(BC)	W1R1G1 (BC)	G1R1W1 (BC)
R2W1G1	W2R1G1	G2R1W1
R3W1G1	W3R1G1	
R4W1G1	W4R1G1	
R5W1G1		

Based on findings from Step 1, Step 2 takes the parametric studies further by simulating the remaining combined effect of the improvements. The results of these simulations will provide further analyses for cost analysis as will be explained next.

8.9.5 Cost Analysis

Cost analysis is not part of the IES<VE> simulation: however, results from ApacheSim can be downloaded into an Excel spreadsheet program for final analysis. Here the energy consumption data in kWh was converted into Ringgit Malaysia (RM) to look at the cost viability of the strategies. Findings from the analysis were used to provide final recommendations.

8.10 Summary

The chapter has summarised all three research methods undertaken in the study: the **questionnaire survey**; the **temperature survey**; and the **computer simulation**. The first two methods are in the nature of an enquiry, seeking to investigate and establish the first two Key Research questions about thermal comfort: whether the houses have acceptable thermal conditions, whether occupants feel comfortable and whether the orientation of the houses has any impact on thermal conditions and energy consumption. The third method, undertaking computer simulation, is exploratory and predictive in nature. This method aims to consolidate data found by the first two methods by simulating models that are close to real situations. In answering Key Research question 3 this method will also predict the energy and thermal performance of hypothetical models for all orientations utilising passive design features and strategies.

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