BUILDING PERFORMANCE DIAGNOSES USING POST OCCUPANCY EVALUATION FOR LOW ENERGY OFFICE BUILDING PRACTICES

HAMED GANJBAKHSH

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To My parents,

Sibling and

Best Friends,

Who are there for me Every step of the way.

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ABSTRACT

Sustainable environment trend of future directions is toward Low Energy Office (LEO) buildings. There are some shortcomings observed in LEO building practices in most developing countries. Preliminary researches indicated that LEO problematic areas have not been thoroughly investigated. Moreover, many researchers have confirmed on the lack of comprehensive Post Occupancy Evaluation (POE) in LEO buildings. The focus of this study is on LEO buildings, accordingly, it was conducted in two phases, during the first phase, is to identify the comprehensive POE criteria and parameters. At this phase a qualitative and quantitative survey data was analyzed using content analysis. A discussion group with the expert comprised of five professionals has been convened to validate the results of the analysis. At the second phase, Ministry of Energy, Water and Communication (MEWC) has been selected as sources of data in which information were gathered through thirty percent of their technical staff involved in this study. The data was analyzed using Average Index and Frequency Analysis methods. From this study there are three main findings that have been conducted. Firstly, the building performance criteria, economic and cultural were significant in terms of performance problem. Secondly, the most critical building cost performance criteria were functionality and flexibility. Thirdly, the overall satisfaction of the building performance criteria was in the range of high level. .

ABSTRAK

Bangunan dengan ciri rendah tenaga (LEO) merupakan trend dalam memastikan kelangsungan persekitaran di masa hadapan. Walau bagaimanapun, terdapat banyak kekurangan atau halangan yang dikesan dalam pengaplikasiannya terutamanya di negara-negara membangun. Kajian awal menunjukkan masalah LEO masih belum disiasat serta dikenalpasti dengan terperinci. Ini ditambah lagi dengan pengesahan dari para pengkaji tentang kurangnya keberkesanan POE dalam LEO. Fokus kajian ini seterusnya akan dibahagikan kepada dua fasa. Fasa pertama, akan mengenalpasti keberkesanan penggunaan criteria POE dan lingkungan kajian. Pada fasa ini juga, data kajiselidik sama ada secara kualitatif dan kuantitatif akan di analisa dengan menggunakan analisa isi kandungan. Satu perbincangan secara berkumpulan yang terdiri dari lima orang pakar akan dipanggil untuk mengesahkan kesahihan keputusan dari analisa data yang dilakukan. Pada fasa kedua pula, Kementerian Tenaga, Air dan Komunikasi (MEWC) pula telah dipilih sebagai sumber maklumat yang mana data telah diperolehi dari lebih kurang tiga puluh peratus kakitangan teknikalnya yang turut mengambil bahagian dalam kajian. Data-data ini akan dianalisa dengan menggunakan teknik indeks rata-rata and Frekuensi. Keputusan dari kajian tersebut, terdapat tiga penemuan utama yang diperolehi. Pertamanya, cirri-ciri bangunan, ekonomi dan kebudayaan merupakan penyumbang utama kepada permasalahan pencapaian atau prestasi sesebuah bangunan. Yang keduanya ciri-ciri yang kritikal dalam criteria prestasi bangunan merupakan kemampuan bangunan mempunyai kepelbagaian fungsi dan fleksibal. Dan yang terakhirnya adalah keseluruhan kepuasan prestasi bangunan adalah pada tahap yang tinggi iaitu.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

The growing global population, demographic shifts, climate change and increasing consumption of natural resources have all brought sustainability to the top of political, social and business agendas. Sustainability presents major challenges and tremendous opportunities for businesses. Consequently, construction industry have realized that by investing in energy-efficiency measures, responding for changing building user requirement patterns and ensuring sustainable practices in project life cycle, it is possible to move toward projects that can build and operate more efficiently and achieve human value in more eco-efficient manner. In this regards, eco efficiency is a strategy to achieve Sustainability. "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth's estimated carrying capacity" (WBSC 2006).

For nearly two decades, the new building definitions such as Low Energy Buildings concept has changed the aspects of building function to provide the human values in building operations sustainable manner. Low Energy Office (LEO) buildings attempt to harness the buildings architecture and physics to provide a high quality working environment with the least possible primary energy consumption.

1.2 Issues and Problem Statement

The rapidly growing world energy use has already raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts (ozone layer depletion, global warming, climate change, etc.). The global contribution from buildings towards energy consumption, both residential and commercial (non residential) , has steadily increased reaching figures between 20% and 40% in developed countries, and has exceeded the other major sectors: industrial and transportation. Growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings, assure the upward trend in energy demand will continue in the future. For this reason, energy efficiency in buildings is today prime objective for energy policy at regional, national and international levels. Among building services, the growth in HVAC systems energy use is particularly significant (50% of building consumption and 20% of total consumption in the USA). This paper analyses available information concerning energy consumption in buildings, and particularly related to HVAC systems. Many questions Arise: Is the necessary information available? Which are the main building types? What end using should be considered in the breakdown?

Comparisons between different countries are presented specially for commercial buildings. The case of offices is analyzed in deeper details.

During the last two decades (1984–2004) primary energy has grown by 49% and CO2 emissions by 43%, with an average annual increase of 2% and 1.8% respectively (Fig. 1.1). Current predictions show that this growing trend will continue. Energy use by nations with emerging economies (Southeast Asia, Middle East, South America and Africa) will grow at an average annual rate of 3.2% and will exceed by 2020 that for the developed countries (North America, Western Europe, Japan, Australia and New Zealand) at an average growing rate of 1.1% (Fig.1.2). The case of China is striking, taking only 20 years to double its energy consumption at an average growing rate of 3.7% (Luis Pe´rez-Lombard et al. 2008).

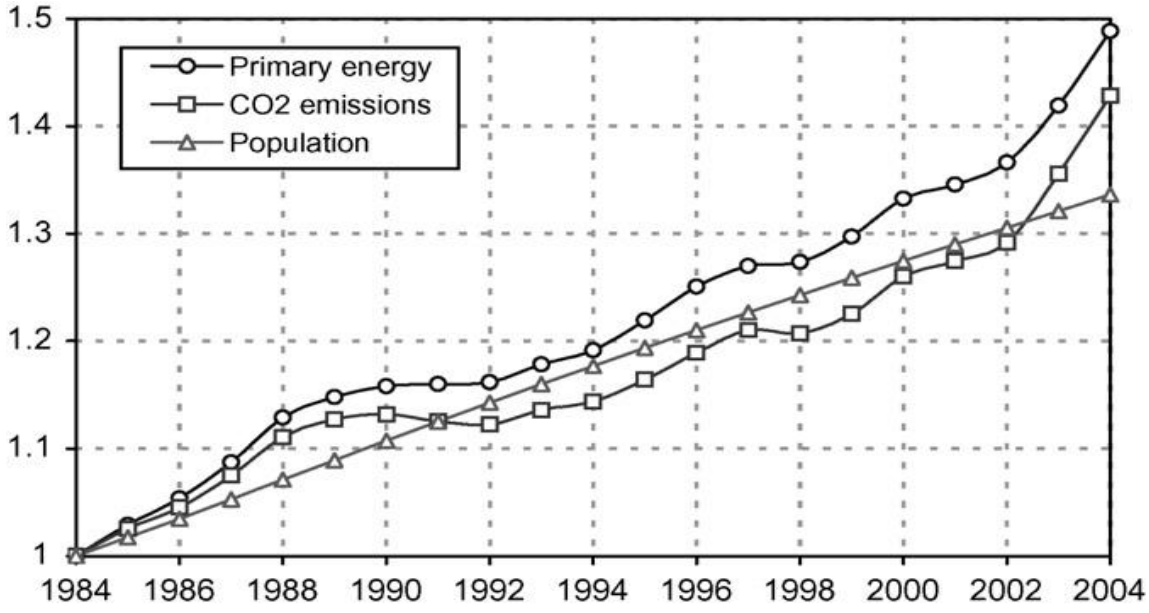

Figure 1.1 Primary energy consumption, CO2 emissions and world population. Reference year 1984.
Source: International Energy Agency (IEA).

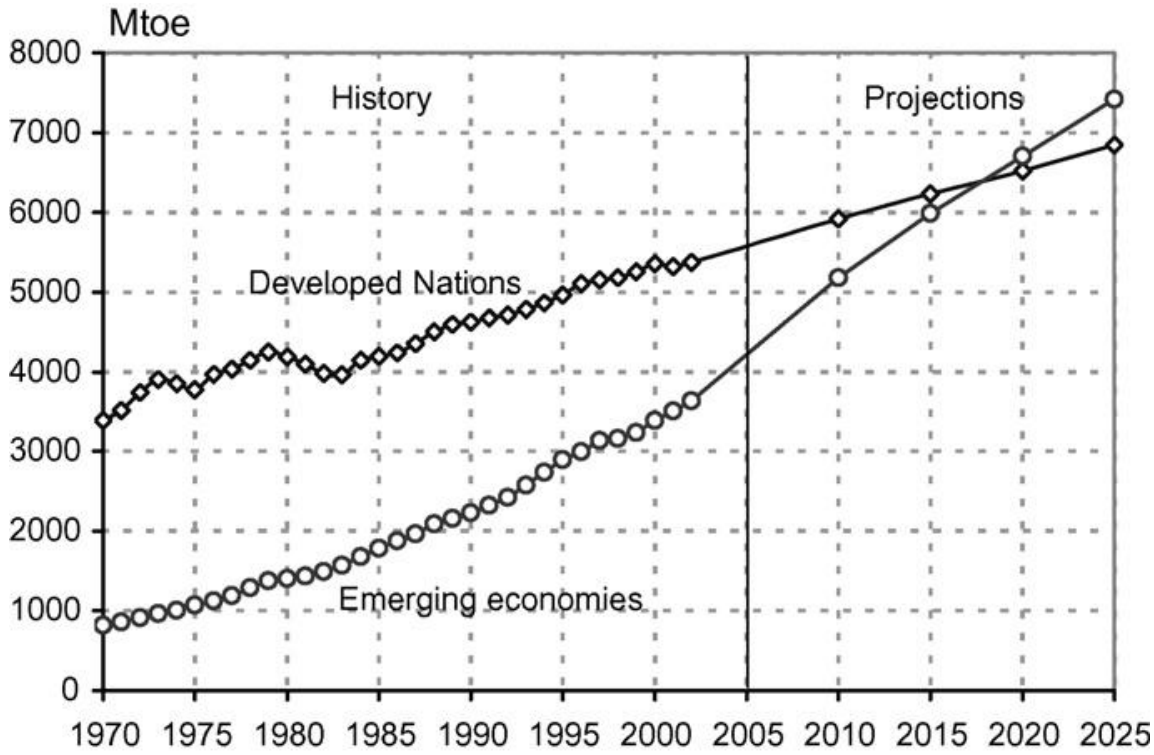

Figure 1.2 World energy use by region.

Source: Energy Information Administration (EIA)

According to information above to reduce the energy consumption the engineers designed new building with low energy consumption. Nowadays, there are several kinds of low energy buildings such as LEO, GEO, ZEO, GB, IB and etc. Low Energy Office (LEO) buildings are one of the most important buildings that we focus on in this project.

Furthermore, an overall objective of energy policy in buildings is to save energy consumption without compromising comfort, health and productivity levels. In other words, consuming less energy while providing equal or improved building services, that is, being more energy efficient. Regulatory bodies (Government, energy agencies, local authorities, etc.) have three basic instruments available for encouraging savings and maximizing energy

efficiency in buildings: regulations, auditing and certification. One of the most important parts of energy certification is classification. Classification of energy includes three methods: benchmarking, rating and labeling (Fig.1.3). By these methods the energy consumption of new buildings can be certified as mentioned above (Adopted from Luis et al. 2009).

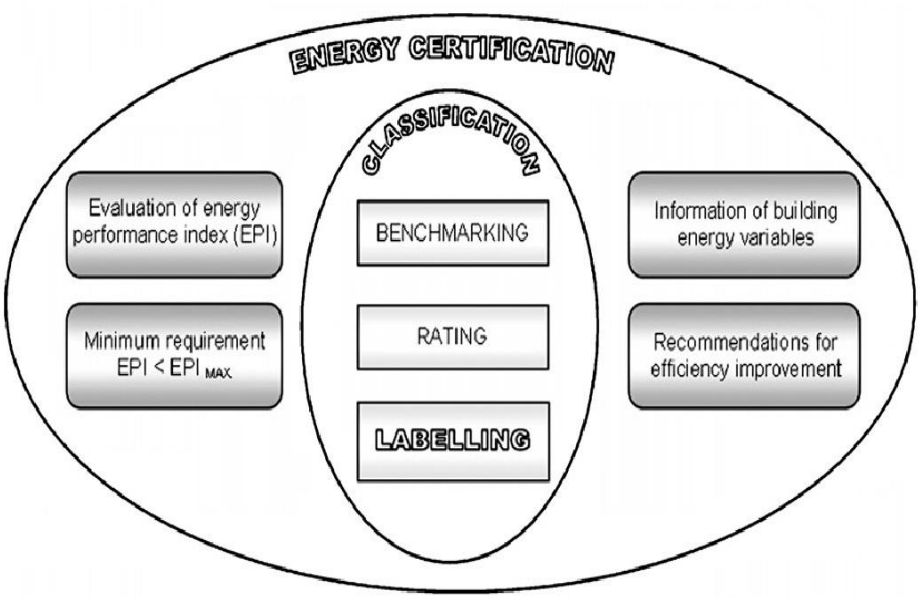

Figure 1.3 Scope of the new European building energy certification scheme
Source: Adopted from Luis et al., 2009

As a matter of fact, the growing global population, demographic shifts, climate change and increasing consumption of natural resources have all brought sustainability to the top of political, social and business agendas. Sustainability presents major challenges and tremendous opportunities for businesses. Consequently, construction industry have realized that by investing in energy-efficiency measures, responding to changing building user requirement patterns and ensuring sustainable practices in project life cycle, it is possible to move towards projects that can be built and operated more efficiently and achieve human.

1.2.1 Problem Statement

There are two ways for perusing problems. First, finding gaps in research focus on theoretical area and second in real practical areas which is the way it is going to be explained here.

1.2.1.1 Gap in research

Many similar studies have also been conducted attempting to measure the level of intelligence (LEO, GEO,ZEO, GB, IB, etc) that a building exhibited and to set up criteria for selection of the best intelligent building developed the 'post-occupancy evaluation process model (POE)' in order to determine the intelligence level of intelligent buildings. The POE process model is generally executed in three stages. First, to develop compatible data collection instructions in the conceptual phase; second, to apply and pilot testing of evaluation instruments in field studies on intelligent office building and third, to carry out comparative analysis of data collected and development of recommendations and guidelines for the utilization of the data-gathering instruments worldwide. There are several assessment methods for Buildings performance with low energy consumption according to review paper in 2004 by Wong (table 1.1). The title is intelligent building research: a review. These methods are all methods that exist for assessment of building performance but these methods are not comprehensive (Wong et al 2004).

Table1.1: Intelligent building performance assessment methods (adapted from Refs. [19,27,85]) **,**Source: Wong et al. 2004

Year	Research agency	Details of assessment methods
1983	DEGW	Orbit 1: multi-client study (building use studies)
1985	DEGW	Orbit 2: degree of matching between the building, the organizations occupying it and IT (using nine key organizations issues and eight key IT issues)
1988	Camegie Mellon University	Measures of quality, satisfaction and efficiency (using six performance criteria and five system integration criteria)
1991	Kuala Lumpur City Hall	Guidelines specifying features of office buildings based on location, design, systems and services (six-star, five-star and four-star).
1992	Intelligent Building Research Group	Building IQ rating method: considering needs (10 for individual user, 15 for organizational, 6 for local environmental and 5 for global environmental). Project was not completed
1992	Intelligent Building in Europe Project	Intelligent building rating: key questions based on building shell characteristics, services and applications (not published)
1992–1994	Holland, New Zealand and Canada	Development of three evaluation methodologies to evaluate the quality of buildings and the suitability for different tenant types: real estate norm, building quality assessment, and serviceability tools and methods
1995	DEGW	Building rating method: involving five sections (A–E) including namely (A) building site/location (7 items), (B) building shell issues (14 items), (C) building skin issues (3 items), (D) organizational and work process issues (11 items), and (E) building services and technology (12 items) where the result is an overall score by combination of all items
1997	Arkin and Paciuk	Magnitude of systems' integration: to determine the level of systems' integration in intelligent buildings. "MSI" was used to evaluate as objective index that quantifies and summarizes the various aspects of integration (Eq. (1)). A simple cumulative index is obtained by summing all the ratings (R_i) attributed to the integration features of various systems in the building, and then dividing the sum by the number of available systems; $$\mathrm{MSI} = \frac{\sum_{i=1}^{\mathrm{NS}} R_i}{\mathrm{NS}} \quad (1)$$
1998	Harrison et al.	Building rating method (results matrix): based on the building rating method constructed by DEGW (1995) and demonstrated its use in evaluations through the two plots of the categories (A–B/C, D–E). The categories are each dimensioned as percent and the four quadrants of each plot are considered to indicate the building's performance
2002	Preiser and Schramm	Post-occupancy evaluation process model (POE): three phases of process model include: ■ First phase: planning POE involves liaison with client, performance criteria and planning the data collection process; ■ Second phase: conducting POE involves methods and instruments—initiating data collection, monitoring data collection and analyzing data; ■ Third phase: applying POE involves reporting findings, recommending actions and reviewing outcomes
2002	So and Wong (AIIB)	Intelligent building index (IBI): quantitative assessment methods for IB which was originated from the nine 'Quality Environment Modules' (M1–M9)

Another review paper just focused on technical methods and a comprehensive assessment method was not mention. As the research was about building performance evaluation only building energy and thermal performance evaluation and solar irradiation were studied. As a result, a good and comprehensive method is going to be found to assess the problem (Zhenjun Ma, Shengwei Wang 2009).

Comprehensive POE is our goal as method. As we researched about the items, we understood other researcher studied about 15 items such as Health, Safety, Security, Functionality, Efficiency, Social, Environmental, Psychology, Aesthetic, Operations, Comfort, Durability, Economics, Flexibility and Accessibility but nobody has covered all these items completely so we need a method to cover all the items.

According to Steve 2009 report, the current operation of LEO building has faced some problems, starting from diverse cultural issues up to the knowledge sufficiency of the staff to operate and maintain the building. In this situation, as MECM LEO Building in Malaysia reported a need to benchmarking 2014 guidelines for LEO in Malaysia, it is needed to establish a strategic plan. Therefore, this research aims to establish some findings for the 2014 guidelines.

Besides, as for Malaysian perspective, in order to achieve an eco-efficient living environment; motivating the society to follow sustainable agendas as well as optimizing energy consumption is concerned (Institute of Environmental and Water Resource Management (IPASA) 2009). The electricity consumption growth during 1984-2004 was estimated to be 3 billion kilo-watt hours each year, and the main consumer is the commercial and public

services which are followed by residential sectors (Energy Information Agency (EIA) 2009). Furthermore, in 1996, Koomey reported that the highest wattage of energy consumption in a building is for lighting, cooling; ventilation and heating which are all factors of enhancing user physical comfort.

In this situation for LEO, some guidelines have been benchmarked in 2004 and 2008 by Ministry of Energy Water and Communications Malaysia (Steve 2009).

In accordance to Steve 2009 report, the current operation of LEO building has faced on some problems, starting from diverse cultural issues up to the knowledge sufficiency of the staff to operate and maintain the building. In this situation, as MECM LEO Building in Malaysia reported a need to benchmarking 2014 guidelines for LEO in Malaysia is needed to establish a strategic plan.

In accordance to the following problems, the research questions are planned as follow:
"What would be the strategic plan for improving LEO practices in Malaysia?"

1.3 Aims and Objective of the Study

The aim of this study is introducing future directions of improving LEO Building practices in Malaysia.
To achieve this aim the following objective were identified.

Objective 1: To investigate the problems related to the building performance criteria parameters in the Low Energy office practices.

Objective 2: To establish the influence of building performance criteria parameters in terms of cost in the Low Energy Office practices.

Objective 3: To establish critical user satisfaction of building performance criteria parameters in the Low Energy office practices.

1.4 Scope of the study

The scope of study include case study, Method of data gathering, sampling and validation. As the looking for finding a suitable choice as a case study has done there are not many Low Energy Office buildings in Malaysia but, a few buildings in Putra Jaya have been constructed under the scope of LEO Building. Therefore, the study was focused on three buildings in Putra Jaya as research case studies and after that for some special reason the Ministry of Energy, water and communication (MEWC) was chosen as a case study. Post Occupacy Evaluation (POE) was chosen as the method of data gathering scope and it is suitable for LEO because this method is for buildings after occupancy. Scope of date gathering was Interview with LEO's technical staff. In the close group discussion with the professional person such as building facility management and building technology the data was validated.

1.5 Significance of the Study

The importance of the study divided to three directions as follow:

- The findings of the first objective are useful to conduct POE in LEO building practices in Malaysia.
- The findings of the second objective are useful to align the development of future LEO in Malaysia.
- The findings of third objective will help to improve the designer awareness of the building to design the building based on satisfaction of the users in the future buildings.

1.6 Brief Research Methodology

An essential stage of methodology was conducted to achieve the objectives of this study as shown in Flow chart 1.4. The major processes include two phases as follows:

1.6.1 Phase 1: As a preliminary study, a literature review has been conducted and aim of study identified. After proposal writing, focused on aggregating building performance criteria in Post Occupancy Evaluation (POE) methods. Thus a content analysis was done on previous project reports, books, articles, journals, conference papers, internet data etc. In this stage the finding was concluded within fifteen parameters. The data analysis (validating) was the last stage of methodology in this phase. So, in a close group discussion with the professionals discussed about the relevant description of building performance criteria parameters related to Low Energy Office (LEO) building for data. Finally ten criteria have been confirmed to be evaluated in LEO.

1.6.2 Phase 2: In this phase preliminary study was done on some cases studies to find the appropriate case among some LEO buildings in Putra Jaya as the scope of the study. Low Energy Office (LEO) Building of the Ministry of Energy, Water and Communications (MEWC) in Putra Jaya was chosen as the case study due to the number of technical staff. In the second stage of this phase data collection has been done. So the result was from appropriate questionnaire survey to cover and achieve the objectives of this study by asking the building performance criteria parameters performance in the specific Low Energy Office Building. All the data collected was scheduled and analyzed using appropriate statistical methods such as ranking using Likert Scale, rating using Average Index Scale and Frequency Analysis.

In such the building performance criteria parameters in terms of problem, cost and user satisfactions were ranked. The methodology of this study is highlighted in Figure1.4.

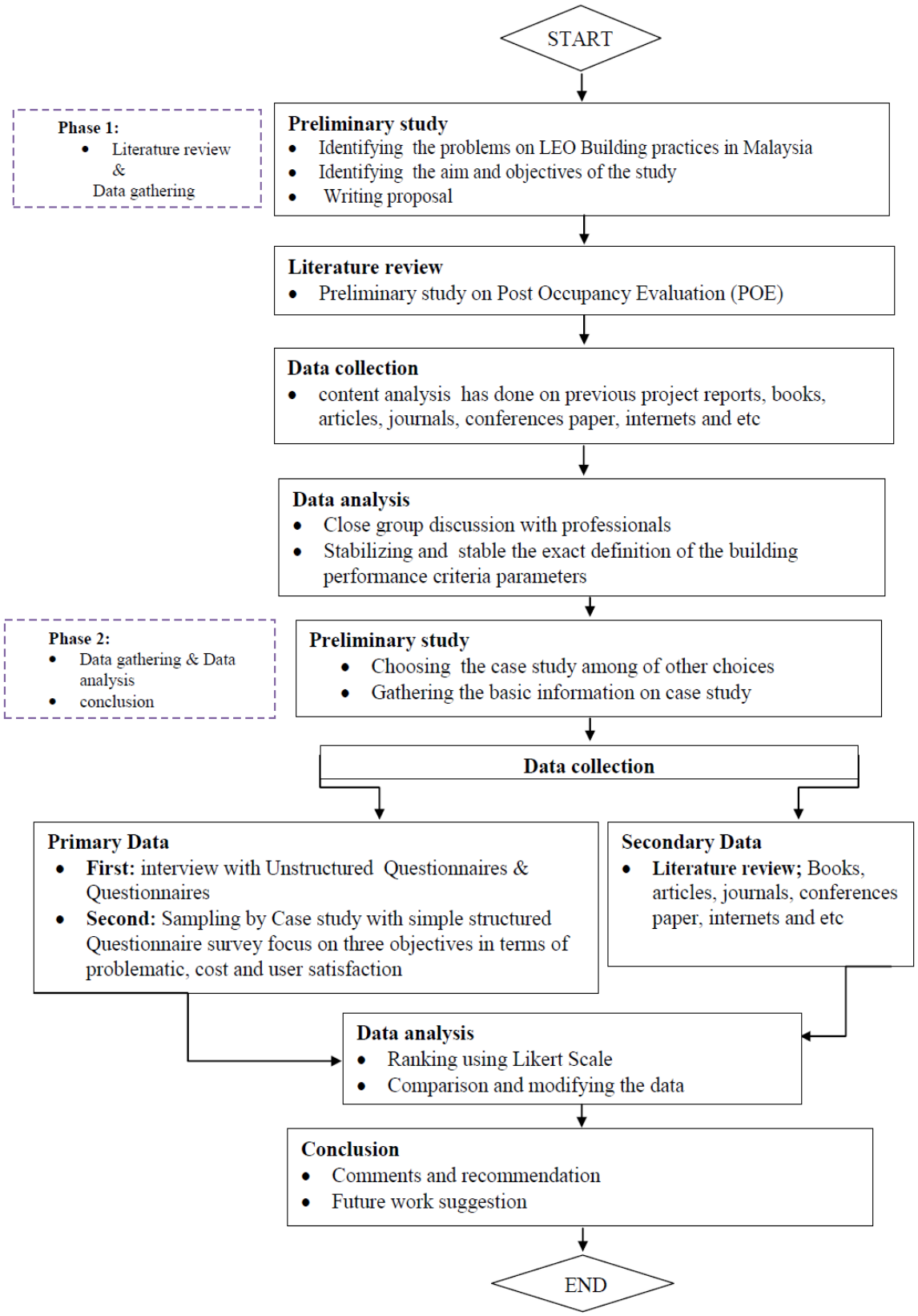

Figure 1.4 Flowchart of Research Methodology

1.7 Organization of the Thesis

The thesis contains five chapters. In Chapter I, introduction, background of the Study, Issues and Problem Statement, aims and objectives of the study, scope of the study, Significance of the Study, brief research methodology are discussed. Additionally, the author explains briefly the overall content of the thesis.

Chapter 2 is a literature review on LEO and POE. It presents the introduction, Post Occupancy Evaluation (POE), Low Energy Office (LEO) and summery of the chapter. Low Energy Office (LEO) consists of significant of energy efficiency in Building, GBI, LEO and performance evaluation on LEO.

Chapter 3 discusses the methodology of this research. This chapter includes introduction, research methodology and summary. The research methodology is divides into 3 main stages. They are preliminary study, data collection, data analysis and report writing.

In Chapter 4 introduction, case study, data analysis, results and summary are the main parts. Data Analysis consists of content analysis, Post Occupancy Evaluation (PEO) analysis. (PEO) analysis in terms of problem, cost and user satisfaction were analyzed and compared then the building performance criteria parameters with all related graphs and ranking of the criteria and parameters are presented.

The title of Chapter 5 is conclusion and recommendation. The main parts of this chapter are introduction, conclusions and recommendations but, Barriers in implementing and future work are also mentioned at the end of this chapter.