ENERGY CONSUMPTION BEHAVIOUR ASSESSMENT MODEL FOR STUDENT ACCOMMODATIONS IN MALAYSIAN PUBLIC UNIVERSITIES

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All praises and thanks be to Allah (S.W.T), who has guided us to this, never could we have found guidance, were it not that Allah had guided us!(Q7:43)

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ABSTRACT

In achieving towards sustainable campus of higher education institutions (HEIs), energy consumption behaviour assessment is one of the several issues that require attention by the facilities manager. Information on energy consumption behaviour is needed to determine potential energy savings. However, issues on the information of energy consumption behaviour such as 'direct' and 'indirect' data, pattern segregation, factors influence and modeling subsequently has inhibited the energy consumption behaviour assessment agenda. The purpose of this study is to assess energy consumption behaviour for student accommodations in Malaysian public universities. This study has two main objectives, first, to determine energy consumption patterns and analyse the factors that influence the pattern. Second, is to develop energy consumption behavioural models (ECBM) and assess the potential energy savings. The 'energy culture' framework consolidated with 'centrographic' approach and econometric analysis used to strengthen the development of ECBM. A self-administrated survey carried out involving 1,400 respondents in selected public HEIs. There are three types of energy use among students in public HEIs namely, 'high', 'low', and 'conserve'. The 'device', 'activities' and 'building regulation' are the influence factors on the pattern of energy use. The energy consumption behaviour model (ECBM) was developed at the final stage of the study. Through the model's application, there is a potential energy savings of 52 to 66 percent among the students. It is capable of assessing the energy consumption behaviour and potential energy savings.

ABSTRAK

Kearah kelestarian institusi pengajian tinggi (IPT), penilaian tingkah laku penggunaan tenaga adalah salah satu daripada beberapa isu yang memerlukan perhatian oleh pengurus fasiliti. Maklumat mengenai tingkah laku penggunaan tenaga adalah diperlukan untuk mengenalpasti potensi penjimatan tenaga. Walau bagaimanapun, isu berkaitan maklumat tingkah laku penggunaan tenaga yang merangkumi data 'langsung' dan 'tidak langsung', pembahagian corak, faktor yang mempengaruhi dan pembangunan model telah merencatkan agenda penilaian tingkah laku penggunaan tenaga. Tujuan kajian ini adalah untuk menilai tingkah laku penggunaan tenaga untuk kediaman pelajar di universiti awam Malaysia. Kajian ini mempunyai dua objektif utama, pertama, untuk menentukan corak penggunaan tenaga dan menganalisis faktor-faktor yang mempengaruhi corak tersebut. Kedua, adalah untuk membangunkan model tingkah laku penggunaan tenaga (ECBM) dan menilai potensi penjimatan tenaga. Rangka kerja 'budaya tenaga' digabungkan dengan pendekatan 'sentrografik' dan analisis ekonometrik untuk mengukuhkan proses pembangunan ECBM. Tinjauan tadbir sendiri dijalankan membabitkan 1,400 responden di IPT awam (IPTA) terpilih. Terdapat tiga jenis penggunaan tenaga di kalangan pelajar di IPTA iaitu 'tinggi', 'rendah' dan 'pemulihara'. 'Alatan', 'aktiviti' dan 'peraturan bangunan' adalah faktor-faktor mempengaruhi corak penggunaan tenaga. 'Model tingkah laku penggunaan tenaga' (ECBM) dibangunkan di peringkat akhir kajian. Melalui aplikasi model ini, terdapat potensi penjimatan tenaga sebanyak 52 hingga 66 peratus di kalangan pelajar. Model ini mampu menilai tingkah laku penggunaan tenaga dan potensi penjimatan tenaga.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Electricity is a form of energy that is very important and highly useful in daily life even in the smallest and simplest form, such as batteries. It is fast, silent, cheap and easily converted, divided or combined. Entering the 21st century, high dependence on electricity has created numerous issues, some of the most well-known and serious aspects being the associated environmental problems (e.g. global warming) (O'Callaghan, 1993).

The rapid increase in electricity use has destroyed living ecosystems, so controlling consumption is one of the options for creating a more livable society (O'Callaghan, 1993). However, this is very difficult to implement in practice. Two energy saving options were studied in the literature: the physical installation of energy efficiency appliances and the behavioural approach (Young, 1993). The cheapest option is to understand and change individual behaviour about energy use. This approach has many advantages; however, the complexity of its variables has left many gaps and required further exploration (Stephenson et al., 2010).

In higher education institutions (HEI), students are the main group responsible for wasting energy (Galis and Gyberg, 2010). Use of energy (electricity) and lifestyle are key factors contributing to the increase in energy consumption. Towards energy saving in HEIs, one option is to assess the students' perspective through their behaviour. However, lack of knowledge about behaviours related to energy consumption has become an obstacle to this goal. It leads to the unspecified behavioural pattern and uncertainty of potential energy savings that can obtain through behavioral aspects. Therefore, the assessment of energy consumption behaviour is necessary.

'Energy consumption behaviour' studies have not typically focused on HEIs but have instead tended to focus on the housing sector and industry (Sheinbaum and Dutt, 1996; Lo et al., 2012). This is supported by Bansal and Gao, (2006); Lo et al., (2012); and Hafizal Ishak et al., (2012) citing the lack of discussion about energy consumption behaviour in large organisations. Knowledge about energy consumption behaviour is particularly important for HEIs facilities manager. It enables the university to have the correct approach on developing strategies and programs towards energy saving.

Lutzenhiser (1992; 1993) suggested that energy consumption embedded in cultural processes. Hence, in order to assess the lifestyle aspect and its relation to energy consumption, the cultural dimension must be the mainframe (Baranzini and Giovannini, 1995). Therefore, this study suggests an energy consumption behavioural assessment model of Malaysian HEI students through an 'energy culture' framework. It is an approach; that behaviour is seen as an amalgam of 'material culture', 'cognitive norms', and 'energy practice'. The components interact together to produce a self-reinforcing system that becomes characterized by strong habits. It combined with the ‘Centrographic’ approach in order to calculate ‘Standard Deviation Ellipses’ (SDE) for identifying energy consumption patterns and the factors that influence them (details in Chapter 4, p. 70-74). In addition, the study also emphasizes the development of energy consumption behavioural models in order to assess the potential energy savings. The models are developed econometrically using

the multiple regression analysis (MRA) and multinomial logistic regression (MNL) (details in Chapter 4, p. 75-84).

This chapter presents the background and overview of the research approach. Therefore, this chapter contains the statement of the research problem, research questions, research objectives, scopes, limitation and methodology. The outline of the thesis structure also provided.

1.2 Problem Statement

Previous researchers have concentrated on 'direct' data (energy consumption data) (e.g. electricity bills, growth rate). It is used to analyse the pattern of energy consumption (Botsaris and Prebezanos, 2004; Haji-Sapar and Lee, 2005; Stuart et al., 2007; Jamaludin et al., 2013). These data describe only the general pattern of energy consumption without taking into consideration the 'indirect' aspect (internal behaviour of individuals). It supported by earlier studies by Sheinbaum and Dutt (1996) in which the end-use data is not fully exploited by the other researchers, creating an obstacle to the analysis of individual energy consumption.

There are several advantages to consolidating the direct and indirect aspect of individual energy consumption. This approach is not only able to explain the relevant energy consumption pattern, but also the factors that affect energy consumption. This has been done by some researchers that include 'indirect' aspect in their assessment of the energy consumption behaviour pattern (Papakostas and Sotiropoulos, 1997; Tso and Yau, 2003; Al-Mumin et al., 2003; Armstrong et al., 2009; Almeida et al., 2011; Verma et al., 2012). Although it is a good method, previous researchers rarely test a range of behavioural factors together but tend to focus on a few factors only, such as demographics and energy practice. Despite this focus on demographic factors

and energy practice, there are still no consistent analytical results. Other factors that influence energy consumption behaviour, such as building regulations, comfort, education, environmental concerns and social aspirations, and cannot be best explained by previous studies. It is difficult to find researchers who can produce results that replicate those of previous researchers. It resulted in weaknesses in the knowledge and information on the energy consumption behaviour and the factors influencing it.

Another particular aspect of the research on energy consumption behaviour is found to be less emphasized. Researchers who use billing data or index tend to present patterns of energy consumption in the form of trends and charts (e.g: the cumulative percentage compared to the level of energy consumption) (Haji-Sapar and Lee, 2005; Stuart et al., 2007; Jamaluddin et al., 2013). On the other hand, researchers using individual data tend to segregate energy consumption behaviour patterns either by using percentage/cumulative consumption (kWh) presented in the form of charts (Papakostas and Sotiropoulos, 1997; Tso and Yau, 2003: Al-Mumin et al., 2003; Armstrong et al., 2009; Almeida et al., 2011; Verma et al., 2012). However, the approach cannot segregate the energy consumption pattern in the exact number. It has never been reported before the actual minimum and maximum amount of energy consumption for each behaviour pattern. Furthermore, the current method cannot explain the normal energy consumption.

Exact figures or numbers are important for facilities manager, especially when outlining potential energy savings. It is important in developing a good energy management strategy in the higher education sector. Thus, the econometric model is suitable for implementation. Previous studies have shown econometric model can combine aspects of direct and indirect energy consumption behaviour in a single model. However, as mentioned, the factors that influence energy consumption behaviour, are not as well tested. Previous researchers have focused less on certain aspects of econometric models, especially in terms of a combination of direct and indirect factors. Previous research has focused on the conceptual model, which describes the behavioural intentions (Van Raaij and Verhallen, 1983a; Hitchcock,

1993; Wilk, 2002; Barr and Gilg, 2007; Wilson and Maxwell, 2007). The models tend to suggest behavioural change as a strategy for saving energy. However, it is difficult for this model to show the cumulative amount (kWh/$) of potential savings expected to result from behavioural change. The econometric models not only help to predict energy consumption and behaviour patterns, but can be used as a tool to assess the potential for energy savings.

Issues on 'direct' and 'indirect' data; factors that influence energy consumption behaviour; pattern segregation and modeling subsequently leads to a knowledge gap of the energy consumption behaviour assessment. For facilities manager, the information on the types of behavioural pattern, factors influencing the patterns, energy consumption prediction, normal energy consumption and potential energy saving are valuable. The information helps on energy management process in the HEIs.

1.3 Research Questions

This research has five key questions:

a. What are the energy consumption patterns among Malaysian HEI students?
b. What are the factors that influence energy consumption behaviour patterns?
c. What is a systematic method to assess the energy consumption behaviour patterns?
d. What are the tools that can use for the purpose of developing the energy consumption behaviour model?
e. How the model can be used to assess the potential for energy savings?

1.4 Objectives

This research has two main objectives:

a. To determine the energy consumption pattern and analyze the factors that influence the pattern.
b. To develop energy consumption behavioural model and assess the potential for energy savings through the model.

1.5 Scope

This research has three main scopes:

a. The scope of this study focuses on student accommodation buildings at selected universities: Universiti Teknologi Malaysia (UTM), Universiti Sains Malaysia (USM), Universiti Malaya (UM) and Universiti Putra Malaysia (UPM).
b. It focuses on the use of electricity (e.g. electrical equipment) to determine the energy consumption.
c. Factors such as building regulations (BulReg), comfort (Comf), education (Edu), environmental concerns (ECon), social marketing (SocMar) and social aspirations (SocAsp), device (Dev) and activity (Act) selected from the 'Energy Culture' framework are used to assess energy consumption behaviour patterns and develop the model (details in Chapter 3).

1.6 Limitations

This research has several limitations:

a. It will only collect information from student accommodation.
b. It did not attempt to determine changes in behaviour, but to assess the potential for energy savings among university students through their behaviour.
c. It did not attempt to develop energy management strategies or policies for university students.

1.7 Methodology

This research has three stages methodology. The first stage is the process of collecting data through field research among Malaysian HEI students. Stage two focuses on determining the energy consumption patterns and analyzing factors that influence the patterns, and the third stage focuses on the development of energy consumption behaviour models and determines potential energy savings. The overall methodology explained in Figure 1.1 (details in Chapter 5).

1.7.1 Stage One

Data collection is conducted in four selected universities in Malaysia, Universiti Malaya, Universiti Putra Malaysia, Universiti Sains Malaysia and Universiti Teknologi Malaysia, involving 1,400 respondents. A quantitative approach

using a questionnaire is employed to obtain information about their energy consumption behaviour. The 'continuous rating scale' and 'energy audits' are used as research instruments.

1.7.2 Stage Two

The second stage focuses on determining energy consumption patterns and factors that influence these patterns among Malaysian students. Based on the data obtained in the first stage, the first step is to calculate total energy consumption among the respondents.

Calculated total energy consumption was plotted on a graph along with the duration of use (hours vs. kWh). Using the same idea as plotting the map (x, y coordinates), the output will show a pattern of energy consumption as a whole. The standard deviation ellipses (SDE) are used to determine the centre point of the graph. From this analysis, segregation is made for the differential pattern of energy consumption. The centre point is determined from the analysis of the SDE to create boundaries for each pattern of energy consumption. Energy consumption patterns that identified, analyzed through multiple regressions (MRA) to determine the factors that influence each pattern.

1.7.3 Stage Three

Stage three will focus on developing behavioural models for energy consumption and assess potential energy savings based on the pattern of behaviour

that has determined in the second stage. Two models developed at this stage; the first model relates to behaviour that can predict energy consumption. The model developed through multiple regression analysis (MRA).

Second, the energy consumption behaviour pattern model was built. The model developed with the use of multinomial logistic regression (MNL). This model has the objective of determining the energy consumption behaviour patterns of individuals. Through this model, individuals can be sorted according to patterns of energy consumption behaviour.

Finally, potential energy savings were determined. Here, MRA and MNL models were tested using holdout samples. Calculating the difference between the observed data, predictions energy consumption and normal energy consumption will determine the amount of potential energy savings.

1.7.4 Research Approach and Tools

This study used a quantitative approach to collect data and various types of analysis to achieve the goal of this research. The research tools used are described in Table 1.1 below. Data collection involved Malaysian HEI. There are twenty universities under government supervision; however, for this study, only four universities were selected as a representative sample.

Table 1.1: Research methods and tools

Objectives	Method	Variables	Tools	Expected Outcome
Objective One	a. Quantitative (Questionnaire - 4 selected universities - 1,400 students)	Energy Culture Framework: a) Material: Device. Building Regulation. b) Energy Practice: Activities, Social marketing c) Cognitive norm: Social aspiration, Environmental concern, Comfort, Education.	a. Descriptive statistic. b. Standard deviation ellipse (SDE). c. Multiple regression analysis (MRA)	a. Observed energy consumption b. Energy consumption pattern c. Normal energy consumption c. Factors influence
Objective Two	a. Quantitative (Data from objective one)		a. Multiple regression analysis (MRA). b. Multinomial Logistic regression (MNL) c. Descriptive statistic.	a. Energy consumption behaviour model (ECBM) b. Energy consumption behaviour pattern model (ECBPM)
	b. Holdout sample		a. Energy consumption behaviour model (ECBM) b. Energy consumption behaviour pattern model (ECBPM) c. Different on observed, predicted, and normal energy consumption.	c. Potential energy saving

(Details in Chapter 5)

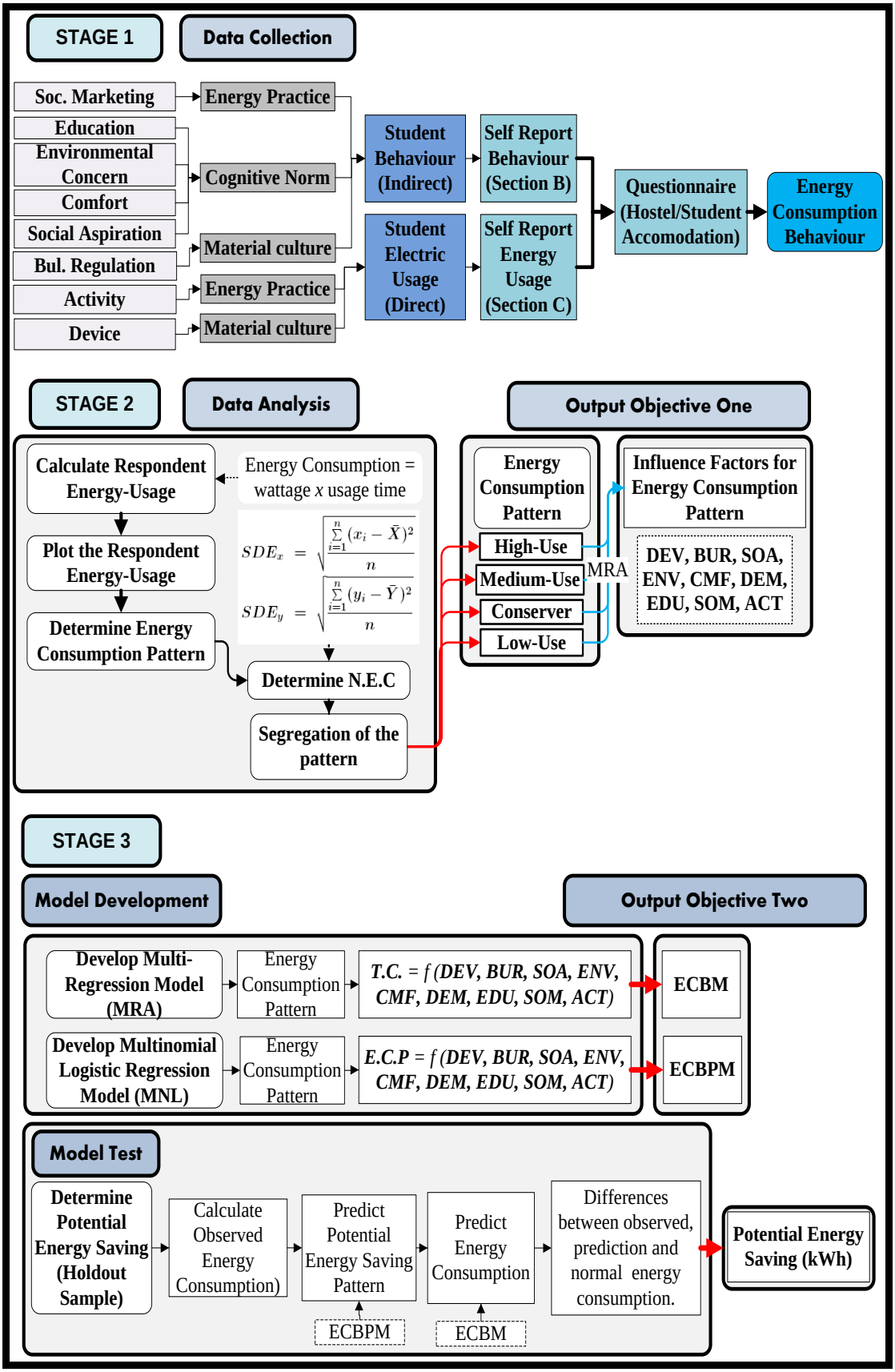

Figure 1.1: Research methodology

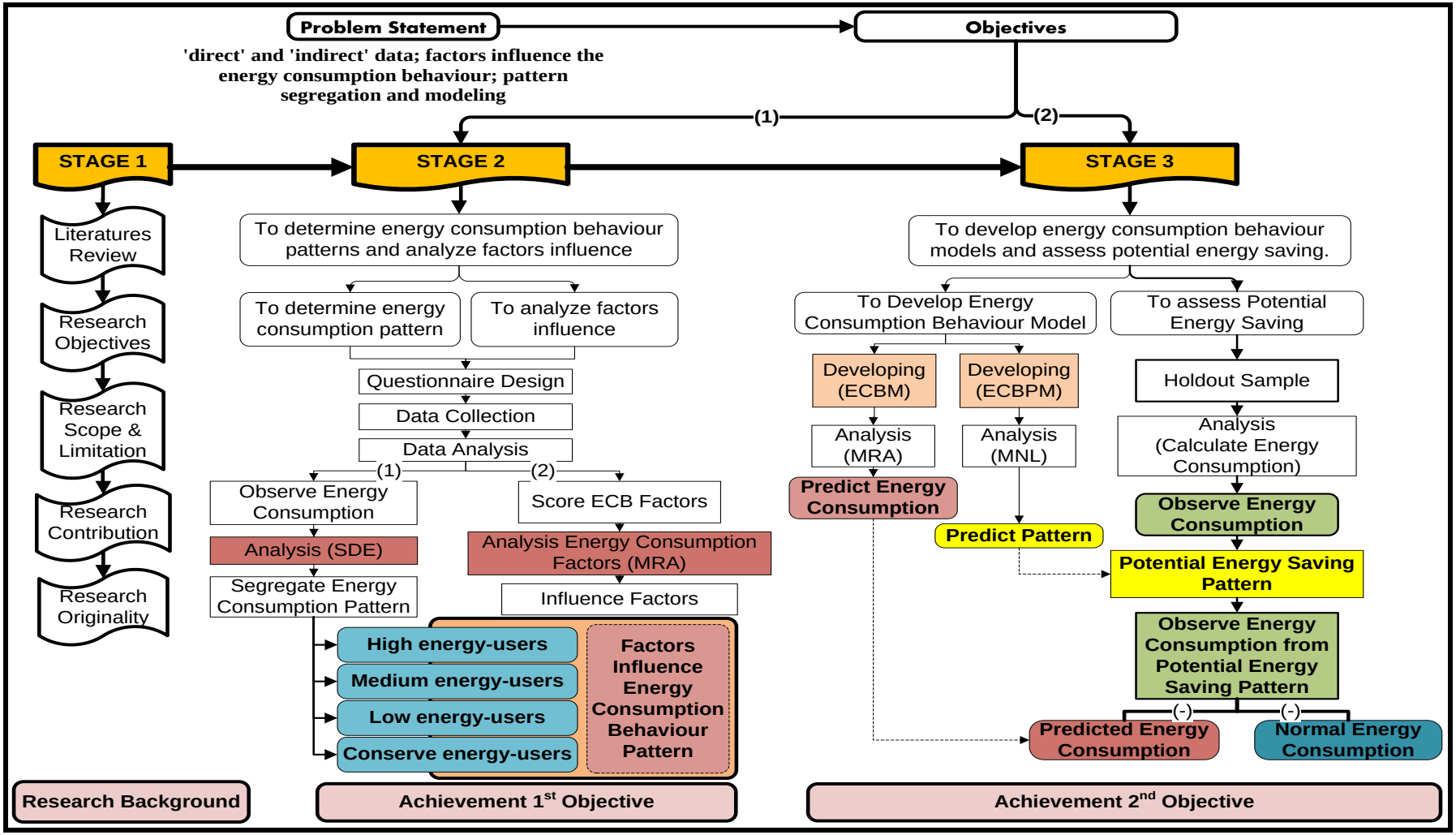

Figure 1.2: Research flow

1.8 Thesis Structure

Chapter 1: This chapter introduces the research topic of the thesis. It presents the study's problem statement, research objectives, research methodology, scope and limitations.

Chapter 2: This chapter presents a state-of-the-art literature review on topics related to energy consumption behaviour. It also presents theories relevant to this study and related to facilities management (FM).

Chapter 3: This chapter presents the behavioural factors of energy consumption used in the study.

Chapter 4: This chapter presents the 'Centrographic' approach, and multiple regression analysis (MRA) and multinomial logistic regression (MNL) used to develop ECBM and ECBPM. The discussion also touches on aspects of potential energy savings.

Chapter 5: This chapter describes the methods that used in the study. It shows how the study conducted, including a discussion of research approaches and tools.

Chapter 6: This chapter describes the analysis of 'energy consumption behaviour patterns' and the factors that influence them. The analysis is for achieving the first objective that is to determine the energy consumption pattern and analyze the factors that influence the pattern.

Chapter 7: This chapter describes the analysis that contributed to the development of the behavioural model of energy consumption (ECBM and ECBPM). The model tested through the holdout sample to assess the potential for energy savings. The analysis is for achieving the second objective that is to develop an energy consumption behavioural model and assess the potential for energy savings through the model.

Chapter 8: This chapter discusses the main conclusions and contributions of this research. In addition, it also presents the potential for future exploration.

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