A MODEL FOR FORECASTING THE RUNNING COSTS OF COMMERCIAL BUILDINGS IN SRI LANKA

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Degree of Master of Philosophy

Department of Building Economics

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Philosophy

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DEDICATION

I dedicate this thesis to my beloved family…

ACKNOWLEDGEMENT

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ABSTRACT

A model for forecasting the running costs of commercial buildings in Sri Lanka

Conventionally, early-stage investment decisions on buildings were purely based on initial capital costs and simply ignored running costs and total lifecycle cost. This was basically due to the absence of estimating models that yield running costs at the early design stage. Often, when the design of a building, which is responsible for 10 to15% of its total cost, is completed, 80% of the total cost is committed. This study, therefore, aims to develop a model based on building characteristics, which enable an early-stage determinant of running costs of buildings, to predict the running costs of commercial buildings. While positioning this research in a positivist research paradigm, a survey research strategy was adopted along with a questionnaire survey and a documentary review for data collection. The study involved 135 respondents for identifying factors influencing the running costs of commercial buildings and 46 commercial buildings were accessed to collect running costs and building characteristics data. A Pareto analysis, relative significance index (RSI), bivariate correlation analysis, regression modelling, and hedonic price imputation index were performed on collected data. The RSI confirmed, eight categories of running costs factors: environmental, maintenance, managerial, building characteristics, building design and construction defects, social, tenant, and political, respectively. Among 48 sub-factors identified, the study confirmed, natural deterioration, failure to identify the true cause of a defect, lack of preventive maintenance, insufficient fund, building services, building age, occupancy, vandalism by tenants, misuse of property, expectation of tenants have a substantial impact on running costs. According to the Pareto analysis, utilities (39%), services (19%), admin work (14%), and cleaning (8%) are four main cost constituents, responsible for 80% of running costs, which can be represented by highly correlated building characteristics of the number of floors (0.950), building height (0.945), and building size (0.943). Approximately 94% of the variance in annual running costs/GIFA (sq.m) is expressed by variables of net floor area, the number of floors, and working hours/day together with a mean prediction accuracy of -1.6%. The index constructed revealed, there is an increasing trend of running costs of commercial buildings in Sri Lanka, in office and bank buildings particularly, over the last recent years. Further, a noticeable increase in running cost can be observed during the first quarter while there is a slight reduction in the second quarter of each year. Early-stage supportive running costs estimation model proposed by the study would enable construction professionals to benchmark the running costs and thereby optimise the building design. The developed hedonic model illustrated the variance of running costs concerning the changes in characteristics of a building. While facilitating early-stage running costs estimation, the study findings collectively support building owners, designers and constructors, and facilities managers to optimize the in-use phase costs of a commercial building in terms of designing and constructing cost-effective, sustainable facilities by altering building characteristics during its' design stage as well as carefully considering the significant running costs factors during its' in-use phase.

Keywords: Building characteristics, Commercial buildings, Hedonic price imputation index, Regression modelling, Running costs

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Journal article

Geekiyanage, D., and Ramachandra T. (2020). Nexus between running costs and building characteristics of commercial buildings: hedonic regression modelling. Built Environment Project and Asset Management. (10) 3, 389-406. https://doi.org/10.1108/BEPAM-12-2018-0156
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Peer-reviewed conference papers

Geekiyanage, D., & Ramachandra, T. (2018). Estimating the running costs of commercial buildings: Regression vs. Artificial Neural Network. In Proceeding of the 10th International Structural Engineering and Construction (ISEC) Conference, Chicago, USA: ISEC. https://www.isec-society.org/ISEC_PRESS/ISEC_10/pdf/CPM-25.pdf
(Scopus Indexed Conference)

Geekiyanage, D., Ramachandra, T., & Thurairajah, N. (2018). A Model for Early Stage Estimation of Operational Expenses (OPEX) in Commercial Buildings. In C. Gorse, & C. J. Neilson, (Eds), Proceeding of the 34th Annual Association of Researchers in Construction Management (ARCOM) Conference (pp. 627-636). Belfast, UK: ARCOM. http://www.arcom.ac.uk/-docs/proceedings/6254275799660dfa3cde95c534d2a103.pdf
(Scopus Indexed Conference)

Geekiyanage, D., & Ramachandra, T. (2018). Significant Factors Influencing Operations and Maintenance Costs (OPEX) in Commercial Buildings. In Y.G. Sandanayake, S. Gunatilake, & K.G.A.S. Waidyasekara (Eds), Proceeding of the 7th World Construction Symposium, Built Asset Sustainability: Rethinking Design, Construction and Operations (pp. 477-487). Colombo, Sri Lanka: Ceylon Institute of Builders (CIOB) Sri Lanka. https://www.researchgate.net/publication/326622075_Significant_Factors_Influencing_Operational_and_Maintenance_OM_Costs_of_Commercial_Buildings
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LIST OF ABBREVIATIONS

AECO	:	Architecture, Engineering, Construction and Owner-operated
ANN	:	Artificial Neural Network
ANOVA	:	Analysis of variance
BCIS	:	Building Cost Information Service
BIM	:	Building Information Modelling
BOMA	:	Building Owners and Managers Association
BREEAM	:	Building Research Establishment Environmental Assessment Methodology
BS-ISO	:	British Standards - International Standards Organization
CA	:	Circulation Area
CAPEX	:	Capital Expenses
CIDA	:	Construction Industry Development Authority
CMC	:	Colombo Municipal Council
CRC	:	Corporative Research Centre
DTI	:	Department of Trade and Industry
GIFA	:	Gross Internal Floor Area
IBM	:	International Business Machines Corporation
ICTAD	:	Institute of Construction Training and Development
LCC	:	Life Cycle Cost / Costing
LEED	:	Leadership in Energy and Environmental Design
LKR	:	Sri Lankan rupee
NFA	:	Net Floor Area
NRM	:	New Rules of Measurement
O&M	:	Operation and maintenance
ONS	:	Office for National Statistics
OPEX	:	Operating Expenses
PIOC	:	Price Index of Operating Costs
R&D	:	Research & Development
RIBA	:	Royal Institute of British Architects

RICS	:	Royal Institution of Chartered Surveyors
RII	:	Relative Important Index
RSI	:	Relative Significance Index
SAE	:	Society of Automotive Engineers
SPSS	:	Statistical Package for the Social Sciences
TPISH	:	Tender Price Index for Social Housing
VIF	:	Variation Impact Factor
WFR	:	Wall-to-Floor-Ratio
WLC	:	Whole Life Cost / Cycle
WLCC	:	Whole Life Cycle Costing
WWR	:	Window-to-Wall-Ratio

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Until the mid-1960s numerous conventional cost-accounting frameworks decided upon venture choices principally by bearing in mind capital expenses (CAPEX) (Cole & Sterner, 2000). Beyond doubt, there were numerous reasons behind this. Most of the time, the investors who committed the capital were not in charge of ensuing running costs (also known as building operation and maintenance costs) and the demolition costs of a building. Therefore, the need was to construct facilities at least utilising CAPEX, with the expectation that the cash would be found later to fund any out of the ordinary running costs as it may arise. In this manner, next to no thought was given to the operating expenses (OPEX) or to the proprietorship expenses of keeping up, and dealing with, the facility after it was built (Cole & Sterner, 2000; Kirkham, 2014).

According to the New Rules of Measurement (NRM) 2: Detailed Measurement for Building Works, the life cycle costing (LCC) exercise for a building will incorporate an assessment of the construction costs (C); renewal costs (R); operation and occupancy costs (O); maintenance costs (M); and environmental and/or end of life costs (E) (Royal Institution of Chartered Surveyors [RICS], 2012). On another note, Flanagan and Jewel (2005) have indicated that the cost incurred during the in-use phase of a building is much greater than its construction or acquisition cost. Among the many varieties of building types, commercial buildings are prominent and incur significant running costs, and consequently contributing to a higher percentage of its total life cycle cost (LCC) (Goh & Sun, 2016; Lai & Yik, 2008). Similarly, Wang, Wei, and Sun (2014) in their study recorded that the commercial buildings are in the first rank in terms of running costs as compared to other types of buildings, accounting for over 69% of the total LCC. According to Evans, Haryott, Haste, and Jones (1998, cited in Hughes, Ancell, Gruneberg, & Hirst, 2004; Ive, 2006), the ratio of construction costs to building operating costs over their lifetime is 1:5 for commercial office buildings. Moreover, Wong, Perera, and Eames (2010) indicated that the running costs of an office building vary between 72% to 81% of its total LCC in the UK. On a similar note, a recent study conducted by Building Owners and Managers Association (BOMA) International (2016) contended that the running costs of a typical commercial building is approximately 82% and a comparison of the United States of America's private-sector office buildings' running costs' figures indicate a 35% increase in running costs from 2009 to 2016 (BOMA, 2016). The foregoing review indicates that the running costs of a typical commercial building varies between 70-85% of the total LCC. Despite the significant contribution of building running costs to their total LCC structure, building owners/investors and construction industry professionals base their building investment, and design and construction decisions solely based on its initial cost.

Currently, LCC is concerned with the 'cost of ownership' instead of just the cost of buildings (Glucha & Baumannb, 2004). This implies that the client must assess all the expenses incurred from the time of acquisition of the asset to the time of discarding it. However, it should be stressed that although LCC has been practised since the 1970s, it is yet to be executed as per a standard practice (Cole & Sterner, 2000; Opoku, 2013; Schaude, 2011). Although there were various scholarly papers and course readings on the theme of LCC in a decade after 1990, there is plenty of evidence that LCC did not move from theory into reality during that phase (Higham, Fortune, & James, 2015; Olubodun, Kangwa, Oladapo, & Thompson, 2010; Perera, Morton, & Perfrement, 2009). This was mostly due to various obstructions including the absence of accurate and historical running costs' data, complex and time-consuming calculations, a lack of standardisation and guidance documents for collecting and estimating building running costs data and, additionally, construction clients were not requesting LCC (Cole & Sterner, 2000; Hunter, Hari, & Kelly, 2005; Opoku, 2013: Sterner, 2000). Furthermore, Cole and Sterner (2000) and Perera et al. (2009) had illustrated that there was a limitation in applying conventional LCC calculation methods and models as a significant number of the variables included were difficult to foresee and difficult to fit into mathematical analyses. Consequently, the quality and precision of LCC data, especially the cost data of buildings' operation and maintenance, and the life-cycle performance of building materials, components and systems would often be predicted on presumptions that were more theoretical than certain.

Previous studies, which have focused on LCC modelling, have revealed that both the construction costs and the running costs of buildings are greatly determined by their physical characteristics in addition to a few other determinants such as environmental factors, maintenance factors, design and construction defects, managerial factors, tenants' factors, political factors, and social factors (Ali, 2009; El-Haram & Horner, 2002; Kerama, 2013; Omari, 2015). Ibrahim (2007) was of the opinion that building size, envelope, circulation spaces, perimeter details, and frames are important building design variables that define the cost of buildings. However, only very few studies have taken the effort to model the running costs of buildings based on whole building physical characteristics. For example, Kirkham, Boussabaine, Grew, and Sinclair (1999) have developed an energy cost model for sports centres which is based on only two building characteristics, namely the number of users and the floor area. Furthermore, some of the LCC models (i.e., Al-Hajj & Horner, 1998; El-Haram, Marenjak, & Horner, 2002; Kirkham, Boussabaine, & Awwad, 2002) developed to date are purely based on cost variables, thus, the application of these models is limited to the later stages of the Royal Institute of British Architects' (RIBA) Plan of Work 2013. Additionally, Krstić and Marenjak (2017) argued that these models are based neither an adequate amount of building characteristics nor historical cost data. These authors further highlighted the fact that the cost calculation models that are based on cost variables do not facilitate an early-stage cost estimation due to the unavailability of reliable historical cost data. Further, most of these studies have primarily focused on maintenance costs (i.e., renewal costs + maintain costs) and less focused on the operation and occupancy costs and the total running costs of built facilities.

Academic research published in this area, as evident from the foregoing review, has primarily focused on developing models for forecasting, or predicting changes in the general construction price level. In spite of several standards and guidelines (e.g., the British Standard International Organization for Standardization (BS ISO) 15686-5:2008 standards and the RICS NRM 3) which provide consistent rules for the quantification and measurement of building operation and maintenance work items, a few research studies have taken the effort to develop indices for the running costs of buildings. For instance, Building Running Cost Indices Online, which is developed by the Building Cost Information Service (BCIS) in the UK, assists quantity surveyors and facilities managers to benchmark, plan, forecast, estimate, and thereby control the costs of building operation and maintenance. Similarly, the New York City Rent Guidelines Board (2017) has developed a Price Index of Operating Costs (PIOC) to measure the changes in the cost of goods and services utilised during the in-use phase of apartment buildings in New York City. Furthermore, Goh and Sun (2016) have designed a whole life building cost index for non-residential, green-rated buildings in Singapore. However, these indices seem to have applications to the respective localities and economies, fails to provide an indication on the running costs and its trends in developing countries like Sri Lanka, where there is a significant difference in terms of economy, environment, and social aspects, which can affect the running costs of commercial buildings in developing countries as compared to developed states. This accentuates the need for regional/locational cost indices for running costs of buildings to enhance the estimation of the running costs in the design and construction stages of a building. Addressing the discussed gaps in cost modelling will extend the construction industry stakeholders' consideration into the optimization of the running costs of buddings while promoting the LCC within the architecture, engineering, construction and owner-operated (AECO) industry in Sri Lanka.

1.2 Justification for the study

Broadly, life cycle costs are those associated directly with constructing and operating the building; while whole life costs include other costs such as land, income from the building and support costs associated with the activity within the building. The expertise of the construction industry is best placed to deliver life cycle costs, which its clients can then use to calculate whole life costs. As discussed in the background, the running costs of a typical commercial building varies between 70-85% of the total LCC. Often, a 10 to 15% of the total cost of a building project has been spent when the design of a building is finished while 80% of its total cost has been committed (Kehily, 2010). The previous studies, which focused on LCC modelling have revealed that both initial cost and running costs of a building are highly influenced by its building characteristics, besides few other factors such as environmental, maintenance, design and construction defects, managerial, tenants' factors, political, and social (Ali, 2009; El-haram, & Horner, 2002; Kerama, 2013; Omari, 2015). Despite, most of the running costs estimation models developed to date (e.g., Al-Hajj and Horner (1998), Kirkham et al. (2002), and El-Haram et al. (2002)) are purely based an extensive set of cost variables which are not available at the early design stage of building construction. Therefore, these LCC models do not facilitate early-stage cost estimation due to unavailability of reliable, historical cost data. Even though few attempts, i.e., such as Kirkham, Boussabaine, Grew and Sinclair (1999) energy costs model based on two building characteristics: number of users and floor area, have been taken to model the running costs based on building characteristics Krstić and Marenjak (2017) stressed the point that this model incorporated neither a sufficient number of building characteristics nor significant cost determinants such as building age, location, and the number of occupants also. In addition, most of the studies carried out to date have primarily focused on maintenance cost (i.e. renewal costs + maintain costs), with a very little focus on operation costs and the total running costs of built facilities.

In another point of view, most of the developing countries have neither a standard for running costs estimation of buildings nor running costs indices, which are developed considering countries' native economic, environmental, and social factors. For example, Sri Lanka has construction costs indices maintaining by the Construction Industry Development Authority (CIDA), but no presence of cost indices to forecast the trends in running costs of buildings. Further, Sri Lanka does not have a specific standard to understand the running costs elements specific to its tropical climate. The absence of a country-specific standard for running cost estimation makes the construction and facilities management industry professionals unable to forecast/estimate the running costs of a new building beginning of its construction by comparing to the running costs available from existing buildings. This situation can be evidenced in many developing countries, particularly in the south Asian region.

This study, therefore, aims to enhance the application of LCC within the built environment at early design stages of a building project by addressing the key issues associated with estimating building running costs. Accordingly, the study aims to develop a cost model which can explicitly quantify the running costs of commercial buildings and which is applicable in all phases defined in the RIBA Plan of Work 2013. Furthermore, with regard to the requirement of numerous cost data, as a key constraint of LCC application, the proposed direction for the current research is extended to construct a quarterly index for the running costs of commercial buildings in Sri Lanka in order to enhance the quality and availability of cost data associated with the in-use phase of commercial facilities. Thus, the proposed model could be presented as a piece of new knowledge to the LCC theory, building cost modelling in particular, whereby the index constructed will serve as a tool for forecasting building running costs.

1.3 Research question

The foregoing review provides the motivation to address why the significant contribution of running costs to a building's total LCC was not taken on board as a part of the standard building cost management service. For example, very less amount of research have been dedicated to investigating the key elemental running costs contributing to the running costs of a buildings, developing countries particularly. It is worth to identify the key factors contributing these running costs and to identify any difference to these factors in different setting such as various climatic conditions and social characteristics. Furthermore, the literature emphasise the need of conducting proper investigation on developing LCC estimation tools, particularly for running costs, which can be equally applied during all phases of a building to produce more cost effective and economically sustainable commercial building, as commercial building constructions are blooming all over the world. Pertaining to all these knowledge gaps exist within the current LCC literature, this study investigated the research question of "how to facilitate the estimation of running costs in different phases of a building life cycle, early-design stages particularly, to enhance the LCC application?".

1.4 Aim and objectives

This study aims to develop a cost model which enables to predict the running costs (operation and maintenance costs) of a commercial building during early design stages.

To achieve the above aim, the following objectives are outlined.

1. To identify the significant cost components which constitute the running costs of commercial buildings in Sri Lanka;
2. To identify the significant factors influencing the running costs of commercial buildings in Sri Lanka;
3. To establish the nexus between the building characteristics and running costs of commercial buildings;
4. To develop and validate a building characteristic based model for the estimation of running costs of commercial buildings; and
5. To construct a running costs index for commercial buildings in Sri Lanka.

1.5 Research methodology outline

From a broad perspective, research methodology comprises of methods and technical practices used to establish the research questions, collection and analysis of data, presentation of findings, and the conceptual and philosophical assumptions that justify the use of particular methods (Creswell, 2014; Dainty, 2007)

Chapter three provides a comprehensive explanation of the research methodology adopted for the current study. In brief, this research employs a positivism research philosophy followed by a deductive approach in theory development as this study intends to explain causal relationships between concepts and variables, to measure concepts quantitatively, and to generalise the research findings to a certain extent (Bhattacherjee, 2012; Creswell, 2014). A quantitative research approach together with a survey strategy was employed to align with the philosophical stance of the study.

In terms of the data collection, a questionnaire survey consists of closed-ended questions was administered among a sample of 135 industry practitioners, which include Chief Engineer, Facility Engineers, Electrical Engineer, Quantity Surveyors, Manager Admin, Facility Manager, Manager Operations, Maintenance Managers, and Service Managers to collect respondents' views on factors influencing the operations and maintenance costs of commercial buildings. Subsequently, another survey into 46 commercial buildings which comprises of offices, banks, institutions, retails, and multi-purpose buildings located in the Colombo Municipal Council (CMC) in Sri Lanka was carried out to collect building characteristics and the running costs data.

For data analysis, initially, a data preparation exercise was performed with missing value analysis and univariate analysis and presented the frequency distribution, the central tendency, and the dispersion of the data collected. Next, a Pareto analysis was conducted to identify the significant running cost elements contributing to the running costs of a typical commercial building in Sri Lanka. Followed by this, a relative significance index (RSI) analysis was conducted to determine the relative importance of the factors which influence the operation and maintenance costs of commercial buildings in Sri Lanka. Subsequently, a bivariate correlation analysis was conducted to establish the relationship between the building characteristics and the running costs of commercial buildings in Sri Lanka. Based on this, a stepwise, multiple linear regression analysis and a hedonic price imputation approach were adopted to develop the running costs estimation model together with a running costs index for commercial buildings in Sri Lanka.

Finally, the running costs' estimation model developed was validated with a new set of data to evaluate the prediction accuracy or the reliability of the model.

A simplified graphical representation of the entire research process employed for the study is illustrated in Figure 1.1.

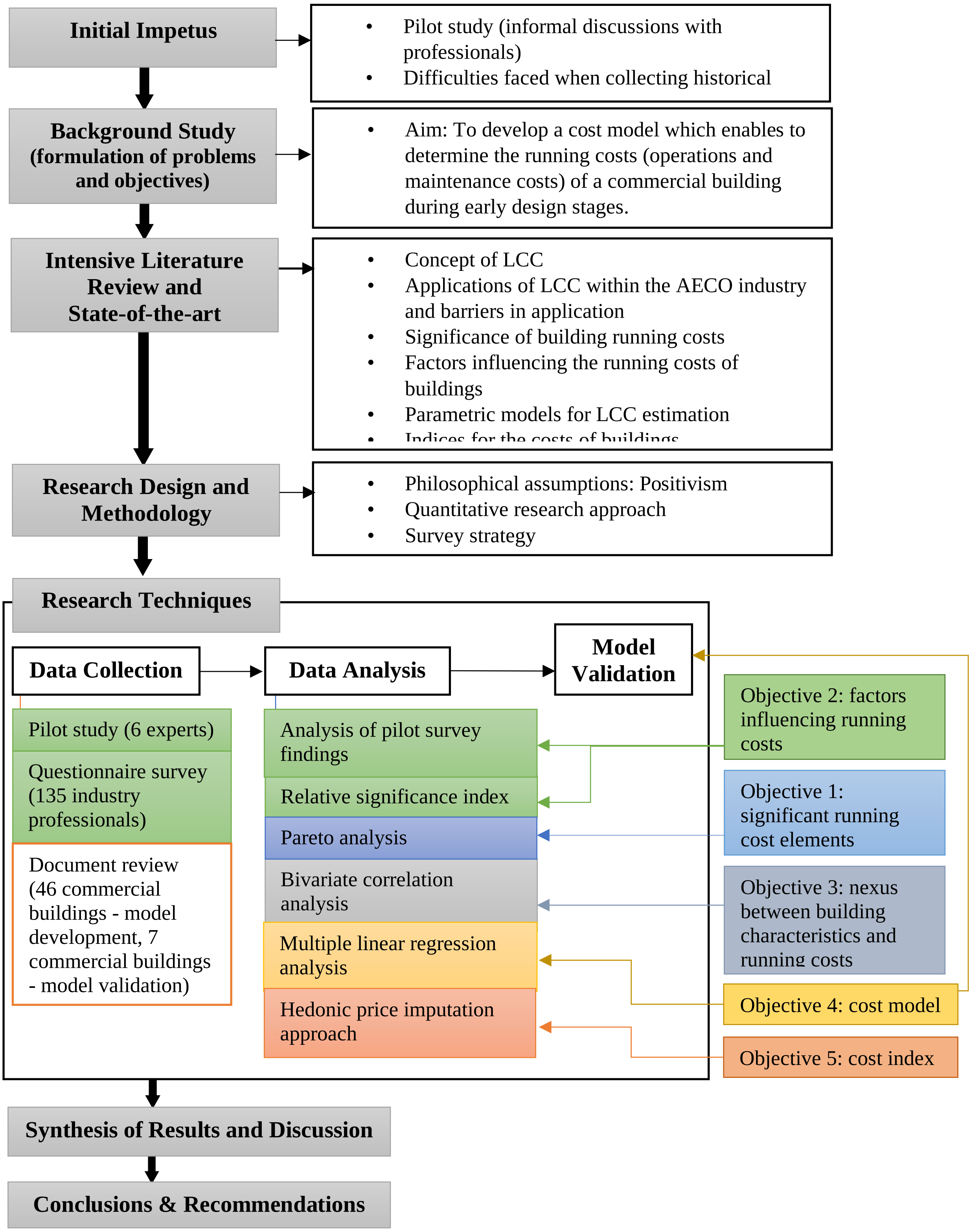


Figure 1. 1: Research process employed for the current study

1.6 Scope and limitations

The solution proposed in this research is an early-stage supportive running costs' estimation model together with running costs' indices. The research is focused on the commercial building stock in Sri Lanka and an especial consideration was given to the CMC as it has a high density of commercial buildings. Among different types of buildings, the commercial building sector was focused upon due to its growing running costs and its lack of historical cost data to control the prevailing situation of high operation and maintenance costs, which can be only controlled through pre-construction stages' of LCC estimation. Commercial buildings (or commercial property or commercial premises) typically refer to buildings operate for profit making activities. These include a vast array of purposes supporting public and private sector business and services, such as government, service industries, education, healthcare, manufacturing, telecommunications and other civil infrastructure. In this study, offices, banks, retails, and institutional buildings were mainly approached for the data collection as these were known as principal sectors within commercial property (RICS, 2012) and due to their existence of sufficient amount of useful of cost data.

However, one could argue for a difference in the running costs in different types of commercial buildings due to their business nature. Even though there are difference in business nature, there are no observed differences in terms of building characteristics. Further, the study carefully selected a fair sample buildings which the individual building design variables are within a range covering all types of commercial buildings in Sri Lanka and checked for any abnormality. Therefore, the developed mathematical equation can be used to estimate the running costs of commercial buildings located in tropical climates. Unfortunately, the running costs involved in the study did not include the operational carbon cost due to the unavailability of carbon cost data within the Sri Lankan commercial building sector. Furthermore, other factors which cannot be measured (e.g. human behaviour and socio-demographic factors, etc.) were not considered within the formation of the cost model as there is no possibility to quantify the impact of those qualitative factors upon the running costs. However, this limitation has been resolved by the data analysis method and the hedonic regression modelling, adopted for the model development, as it enables the estimation of the cost of a product purely based on its structural and locational characteristics. Accordingly, the running costs of commercial buildings were modelled based on building characteristics, whereby the locational characteristics are constant as the sample extracted for the study is in CMC, Sri Lanka. Furthermore, the application of the running costs index that is constructed will be limited to the local context as all the cost data were collected from commercial buildings based in Sri Lanka and subjected to regional locational characteristics.

1.7 Chapter breakdown

This thesis is divided into six chapters. The following provides the purpose of the contents of each chapter and the basis for its structure.

In **Chapter One**, the **Background** of the research is presented along with the justification for the study, the research question, the aims and objectives of the research, and an outline of the research methodology. The scope of the work is discussed and is supported by the justification and significance of the research. Finally, the structure of the thesis is presented.

Chapter Two deals with assessing the state-of-the-art of subject area of the research and is presented as a comprehensive and critical **Literature Review** on the scope of the research. This chapter establishes a research gap within the existing research contributions which warrants further investigation. The chapter deals with the state-of-the-art as to how LCC concept has developed and presents its applications in the AECO industry, the barriers to the wide-spread application of LCC into practice, the significance of building running costs and their influential factors, and existing LCC calculation models and indices.

In **Chapter Three**, the **Research Methodology** adopted to conduct this research is discussed along with the justification for each method selected. The chapter provides a logical sequence of philosophical stances, the research approach, the research strategy, and data collection and analysis techniques employed towards accomplishing the objectives formed for the study. A summary of this chapter is outlined in section 1.4.

Chapter Four describes the **Data Analysis and Findings** of the study. The chapter presents the analysis of the factors influencing running costs, the significant running cost elements, correlations between the building characteristics and running costs, the developed running costs estimation model and the running costs index for commercial buildings in Sri Lanka.

Chapter Five builds the **Discussion** of the research study conducted. There is a separate section for each research finding which outlines the key findings from the data analysed in comparison to the literature findings and discusses the significance and novelty of this research study within the building economics context.

Chapter Six presents the **Conclusions** drawn from chapter four. The chapter highlights the contribution of knowledge to theory and practice, proposes recommendations, outlines the limitations, and discusses potential future research in the subject area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter, initially, distinguishes the concepts of LCC and WLCC and thereby outlines the importance and applications of LCC within the AECO industry. Several barriers that prevent LCC being widely applied are presented along with the current methods and models available for calculating LCC. In addition, the literature extensively reviews the factors that influence the operation and maintenance costs of buildings and the existing cost indices together with the methods available for index construction. The above reviews are presented in seven (7) main sections in this chapter.

2.2 Definitions and costs components of building life cycle costing

It is necessary to understand the definitions and meanings of the study related terms such as LCC, Whole Life Cycle Costing (WLCC), and running costs. Several definitions exist for these cost types and some of the well-established definitions are presented in Table 2.1.

Table 2. 1: Definitions of LCC and WLCC

Term	Definition	Source
LCC	"methodology for the systematic economic consideration of life cycle costs and benefits over a period of analysis, as defined in the agreed scope"	International Standards Organization (BS-ISO, 2008, p. 2)
	"a technique to estimate the total cost of ownership"	Office of Government Commerce (OGC, 2003)
WLCC	"all significant and relevant initial and future costs and benefits of an asset, throughout its life cycle, while fulfilling the performance requirements"	(BS-ISO, 2008, p. 3)
	"the costs of acquiring the facility (including consultancy, design and construction costs, and equipment), the costs of operating it and the costs of maintaining it over its whole life through to its disposal – that is, the total ownership costs"	OGC (2007)

Running costs	“an ongoing cost for running a product, business, or system”	Maguire, Smith, & Kouyoumjian (2008)
	“the running costs of a facility consist of a number of key cost components including operation and occupancy costs, and maintenance costs (renewal costs + maintain costs)”	BS-ISO 15686-5 (2017)
Operation and occupancy costs	“the cost, relating to the occupation of the building, incurred by the occupant – such as rent, taxes, insurances on buildings and contents, depreciation and amortisation expenses”	The British Standards Organization (BSI, 2013)
Maintenance costs	“the total cost of necessary labour, materials, plant and equipment and other related costs incurred to retain a building or its parts in a state in which it can perform its required functions”	BSI (2013)

Though the definitions of WLCC and LCC use different terminologies, the meaning is quite similar and these entail a monetary evaluation of not just the initial construction cost but the owning costs associated with a building’s operation, occupation, the renewing of its components and the maintenance of its assets also (BS-ISO, 2008). Even these definitions do not clearly describe ‘what exactly is the difference between LCC and WLCC?’. To answer this, BS-ISO 15686-5 (2008) provides the hierarchical breakdown structure of WLCC, as shown in Figure 2.1.

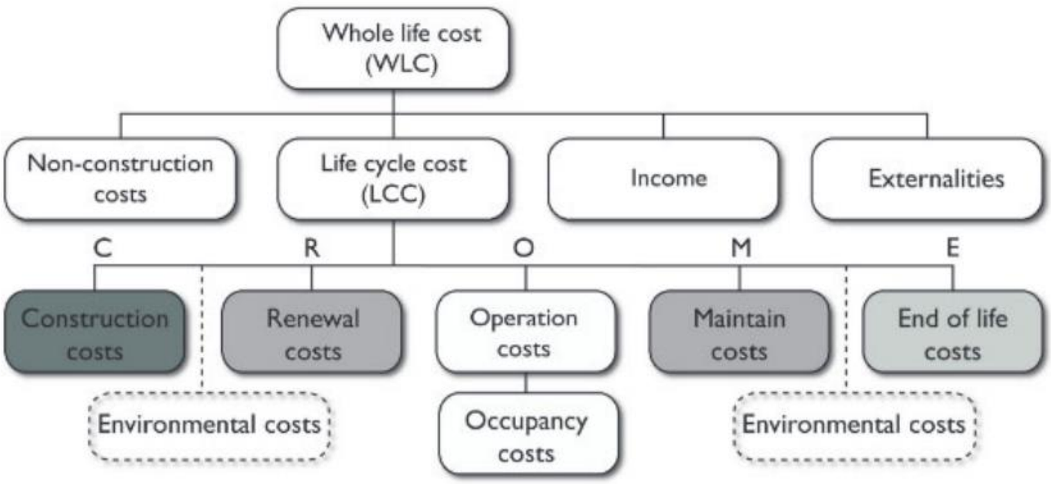


Figure 2. 1: Key cost categories of WLC and LCC

Source: (BS-ISO 15686-5, 2008)

According to Figure 2.1, WLCC comprises a broader economic matrix, about not only LCC, but non-construction costs also (e.g. site purchase, letting or selling agent fees, procurement costs, and the cost of finance), income from the built asset, and any defined external costs. For instance, business staffing, productivity and user costs.

LCC, which is a sub-component of whole life costs (WLC), is broken into several categories which are identified by the acronym ‘CROME’ (Green & Benge, 2014). CROME represents,

1. Construction costs (C): Cost incurred during the design and construction phase of a project, which mainly includes cost for materials, labour, plant, and transportation.
2. Renewal costs (R): Planned major repairs, refurbishing, replacements, redecorations – plus specific improvements and upgrade work.
3. Operation and occupancy costs (O): Operation costs are often referred to as soft facilities management costs; commonly interpreted to mean all costs incurred in the running and managing of a facility whereas occupancy costs include the costs relating to the occupation of the building, incurred by the occupant. The cost items to be considered in this phase include insurance, utility costs (gas, electricity, fuel, water, effluent and drainage charges), administrative costs (i.e. service attendants, laundry, security, waste disposal, property management), taxes (BS ISO 15686-5:2017, 2017).
4. Maintenance costs (M): Planned, reactive, and proactive maintenance costs (including on costs and employer costs). As listed in BS ISO 15686-5:2017 (2017), maintenance includes the cost of external and internal decorations, fabric (i.e. external walls, roof structure, other), fitting and fixtures (i.e. vandalism, built-in furniture, signs, ironmongery, key issues), internal finishes (i.e. wall, floor, ceiling), services (i.e. plumbing and internal drainage, heating and ventilation, lift and escalator, fire detection and protection system, electric power and lighting, other mechanical and electrical services), telecommunication and data, cleaning, external works (i.e. repair and decorations, landscaping, ground maintenance), maintenance management, and repair and replacement of minor components/small areas.
5. End of life costs (E): Includes disposal and demolition costs where the end of life incomes also presents sometimes.

One of the significant changes in this recent LCC classification in NRM Part 3 is that the maintenance costs are classified as renewal costs and maintenance costs, as indicated in Figure 2.1 above, and this division is reflected in BS 8544. Also, the occupancy costs which previously stood as a separate cost category have now been gathered under the operation costs.

Besides, Langdon (2007), a proactive researcher in LLC, has developed an LCC breakdown structure as shown in Table 2.2. Presenting different LCC structures including cost elements come under the building operation and maintenance costs, this study adopted a running costs structure from the BS-ISO 15686-5 (2008) cost structure for running costs of buildings for the data collection, is annexed in Appendix 04.

Table 2. 2: LCC breakdown structure

Acquisition – non-construction costs	**Acquisition – design and construction**	**Operation**	**Maintenance**	**Rehabilitation**	**End of life/ disposal/hand-back**	**Income**
Site (lease/purchase of land and/or existing building(s) /asset(s), including related fees and local taxes)	Professional services (project management, architecture, structural/ civil/environmental engineering, cost and value management)	Facilities management (cleaning, security, waste management)	Maintenance management (inspections, contract management)	Adaptation (evacuation, works, re-commissioning, fit-out)	Final condition inspection including fees	Sales of land, interests in assets, salvaged materials
Finance (interest or cost of money; wider economic impacts)	Site clearance, temporary works	Rates/local taxes, land charges	Minor repairs/ replacements/ renewals	Major replacement/ renewal/refurbishment (evacuation, works, re-commissioning, fit-out)	Restoration/ reinstatement (as required by lease/contract)	Grants, tax allowances
Client's in-house resources (property/ project management, administration/overheads)	Construction (infrastructure, structure, envelope, services, fitting out, commissioning, handover)	Regulatory costs (fire, access inspections)	Loss of facility/ business opportunity costs during downtime	Loss of facility/ business opportunity costs during downtime	De-commissioning	Third party income (rents, service charges)
Professional advice (planning, legal, preparing brief, sustainability)	Fixtures, fittings, furnishings	Energy (heating, cooling, small power, lighting, internal transport (lifts))	Grounds' maintenance		Demolition, disposal, site clean-up	
	Landscaping, external works	Utilities (water, sewerage, telephone)	Redecoration			
		Rent	Cleaning			
		Insurances				

Source: (Langdon, 2007)

2.2.1 Sources of LCC data

Use of cost data and other information extracted from reliable and updated sources enhances the precision of the LCC calculated. Boussabaine and Kirkham (2005) listed three major data sources for LCC and these are presented below.

1. Data from manufacturers, suppliers, contractors, and testing specialists
    - Material and product suppliers and manufacturers;
    - Government testing bodies; and
    - Institutions such as Building Research Establishment (BRE), American Society of Civil Engineers.
2. Forecasting models
    - In the absence of required and adequate data, mathematical models can be developed to estimate costs. As there is a high potentiality to occur any uncertainties, there are numerous statistical techniques to addresses those.
3. Historical cost data

In the United Kingdom, the BCIS of RICS is a well-established source which provides comprehensive, accurate, and independent cost data and price information to the construction industry stakeholders. There seems no similar, globally accepted as well as updated source is available in other developed and developing countries including Sri Lanka.

2.3 Application of LCC within the AECO industry

One of the key applications of LCC is to compare alternative design possibilities from a number of competing proposals. The use of LCC in the evaluation of project proposals has been identified as one of the drivers for change for construction (Winch & Courtney, 2001). Kirkham (2005) recommended using LCC to support design decisions making during the design stage and to reassure clients, as it helps to boost the overall building performance. As an illustration, Wong et al. (2010) demonstrated the effectiveness of the use of LCC in the evaluation of building components wherein the economic feasibility of office buildings with conventional and transparent insulation systems (TI-Facades) were evaluated.

In present, clients have been increasingly demanding the application of investment appraisal techniques to their projects during the early design stages as these techniques help to look at the cost of a building in terms of a whole life approach and to evaluate the environmental and economic sustainability of the construction (Cole & Sterner, 2000; Kelly & Hunter, 2009). For example, LCC is commonly applying in evaluating the energy efficiency of buildings as the energy costs of a building during its in-use phase is influenced by several factors including orientation, thermal efficiency, and airtightness (Cole & Sterner, 2000; Gluch & Baumann, 2004). Green building construction is one of the key areas in LCC application as the green constructions are very much into energy-efficient and sustainable products, where these are guided by green building rating systems such as the Building Research Establishment Environmental Assessment Methodology (BREEAM) and the Leadership in Energy and Environmental Design (LEED).

From a facilities management point of view, LCC can also be used to estimate the operation and maintenance costs of a facility over a period. Early-stage running costs information can inform design decisions on facilities management aspects such as maintenance, cleaning, energy efficiency, and water efficiency (BS-ISO, 2008). Further, cost consultants can prepare sophisticated maintenance plans and running costs profiles, preferably consulting with Facilities Managers, to formulate a life cycle approach (BS-ISO, 2008; Kehily, 2011). This essentially provides benchmarks for running costs while providing a budget and a template for cost control during the in-use phase of a building (Churcher, 2008; El-Haram et al., 2002; Kirkham, 2005). To facilitate LCC practice in facilities management, BS 8544:2013 has introduced guidance for carrying out LCC during facilities management and in doing so, it provides a framework to collect real cost data during the in-use phase (BSI, 2013).

Kehily (2010) states that the absence of an accurate tool or method to profile the future running costs, especially maintenance and replacement costs, during the tender evaluation phase will make a tenderer over-bid mistakenly, even it is a competitive bid. Therefore, the use of LCC inspires contractors to prepare, and investors to evaluate, a tender in a form of reduced maintenance and operation costs to be incurred of a built-facility (Dragos & Neamtu, 2013; Kirkham, 2012). In addition, Meng and Harshaw (2013) opined, even though the LCC is being used in private finance initiatives (PFI), it is constrained by traditional barriers associated with LCC.

Having outlined the state-of-the-art in the application of LCC/WLC within the AECO industry, the central benefit of LCC/WLC is that it enables a whole cost approach to the acquisition of a capital asset, giving the client a total cost view of the project rather than only considering the initial CAPEX. It is asserted that only 10% to 15% of the total cost has been spent during a building construction where 80% of the cost has been committed (Kehily, 2010). Therefore, the investors increasingly demanding buildings with low running costs, thus, there is driving demand for tools and techniques that model a building's running costs. Even though the LCC perspective has proved to be most meaningful during the design phase (where the possibilities of cutting down the costs relating to the in-use phase of buildings are high) (Sterner, 2000), it has not yet been significantly used in early-stage running costs estimation (Cole & Sterner, 2000; Flanagan & Jewel, 2005). The literature evidences many good reasons behind this. Accordingly, the following section describes why the application of LCC, or the early stage estimation of the costs to be incurred during the in-use phase of a building, is limited.

2.4 Barriers in the application of LCC

The literature has extensively stressed the problems and difficulties often associated with the use of LCC methods to estimate the costs that will be incurred during the in-use phase of buildings. They are as follows.

1. Unavailability of, and limited access to, reliable historical running costs' data

Obtaining accurate, appropriate, and sufficient cost information to use in LCC studies is one of most commonly cited barrier to LCC (Chiurugwi et al., 2010; Cole & Sterner, 2000; Opoku, 2013). Flanagan and Jewel (2005) and Kelly and Hunter (2009) commented that the key reasons for less reliable historical cost data is that it is often incomplete, outdated and misinterpreted. An extensive amount of data required and inconsistencies across the data, further, makes collecting historical cost data problematic (Opoku, 2013); consequently, this makes the data unreliable for cost consultants to analyse and adapt to a new project. In addition, Kirkham (2005) stated that another common problem with access to LCC data is the absence of a standard method or framework to report or extract LCC information, especially within the in-use phase of facilities.

2. Lack of L CC standardisation (methodology) across the construction industry

One of the main reasons that LCC has not been widely applied is a lack of standardisation in carrying out and presenting LCC (Chiurugwi et al., 2010; Cole & Sterner, 2000; Opoku, 2013). However, over the last two decades, there have been a number of publications addressing the various barriers to its adoption and presenting an internationally accepted standard method of measurement for LCC. For example, (1) the BS ISO 15686-5:2008: Buildings and constructed assets - Service life planning - Part 5: Life-cycle costing, which has been recently replaced by the ISO 15686-5:2017 in conjunction with its supplement from the BSI/BCIS (2008), (2) RICS Elemental Form of Property Cost Analysis (4th edition) NRM, and (3) Cost Analysis and Benchmarking (1st edition) RICS guidance note 86/2011 (Perera, Morton, & Perfrement, 2009). Besides, RICS NRM 3 has been introduced as a guide to cost estimating and cost planning for building maintenance works (however not covering operation and occupancy costs' standardisation). However, Dragos and Neamtu (2013) and Hourigan (2012) have stressed that none of these standards offers a full solution or methodology for carrying out LCC and producing LCC estimates, especially in the building running costs' modelling and forecasting.

3. LCC is not requested by clients

The most significant barrier in adopting LCC into construction is that the clients are not requesting LCC estimates for their projects (Oduyemi et al., 2014; Opoku, 2013). This is basically due to the additional cost that they have to spend on this service, and they presume that the ultimate LCC value is just an estimate and it does not have any implications (Chiurugwi et al., 2010). Many clients have this misunderstanding about the LCC process as they are not well informed about the benefits of applying LCC (Oduyemi et al., 2014; Olubodun et al., 2010). This is reflected in the lack of ‘contractual incentives’ or ‘fiscal encouragement’ for carrying out LCC, as there is no additional fee for doing so (Chiurugwi et al., 2010; Opoku, 2013; Pelzeter, 2007).

4. Complex process and calculations

The main issue for cost consultants including quantity surveyors is that they do not have proper understanding or expertise to perform LCC exercises (Chiurugwi et al., 2010; Olubodun et al., 2010). Insufficient time for carrying out LCC calculations, complex nature of formulas and perceived lack of confidence in the results are few other related barriers to this less adaption of LCC (Olubodun et al., 2010; Opoku, 2013). In addition, the application of traditional LCC procedures is limited as it highly based on assumptions and difficult to fit into statistical scrutinises.

Although there are ample practical illustrations and scientific publications which continuously discuss the barriers and limitations in the application of LCC into the cost estimation of the operation phase of buildings, several efforts have been taken to model the LCC of buildings. These exercises of running cost modelling are discussed in section 2.7. and 2.8 with example methods, models and indices.

2.5 Significance of building running costs

According to RIBA (2013), a building has a clearly defined lifecycle that consists of eight stages: strategic definition, preparation and brief, concept design, developed design, technical design, construction, handover and closeout, and in use. Of these, the design and construction phases of an average building with a life span of 50 years account for only one to three years and are responsible for 20%-25% of the total expenditure expected to be spent on the building (Lai et al., 2008). On a different note, Wong et al. (2010) indicated that more than 70% of the total LCC of a building incurs during its in-use phase. A recent study conducted by BOMA (2016) contended that 82% of the running costs of a typical commercial building based in the USA is contributed by utilities (25%), repairs and maintenance (23%), cleaning (17%), and administrative work (17%). Furthermore, Lai et al. (2008) introduced some useful benchmarks for the running costs of luxury hotels in terms of major costs’ elements such as electricity (34%), capital projects (23%), repair and maintenance (19%), operation and maintenance staff (13%), town gas (5%), diesel oil (4%) and water (2%).

Accordingly, the overall utility costs mentioned in this study are approximately 45% of the total running costs. Another study has indicated that a breakdown of energy costs of a typical commercial building consists of energy for air conditioning (43%), lighting (34%), office equipment (17%), and lifts and escalators (6%) (Philip & Chow, 2001). The forgoing review indicates that the electricity cost and the building repair and maintenance costs account for a large percentage of the total running costs of commercial buildings.

In the Sri Lankan context, the running costs are viewed with a limited focus, where an emphasis on the reduction of energy costs receives the highest priority (Sri Lanka Sustainable Energy Authority [SLSEA], 2014; Weddikkara, 2001). As commented upon by Korpi and Ala-Risku (2008), potential tenants would least prefer to pay a higher rental unless it is guaranteed that a reduction in running costs would offset the increased rental value. Therefore, concerns for running costs need to arise at the outset of a building's design and the higher capital costs should reflect a likely reduction in running costs.

2.6 Factors influencing the operation and maintenance costs of buildings

The literature provides a thorough account of the factors which affect the running costs of different types of built facilities such as housing, apartments, public buildings, commercial buildings, and educational institutes.

In terms of operation costs, Ungar (2003) indicated that increasing security requirements and budget scorekeeping requirements are two key factors influencing the CAPEX and OPEX of state buildings. Construction costs lead to increasing due to often lease of buildings and renovating them to fit into state requirements while operating expenses are increasing by high-security requirements of those leased properties. The third factor presented by Ungar (2003) is the geographical location of a building. This comprises three aspects: the exact location, whether the building site is in a central business area or a rural or non-central area (i.e. buildings in a central area may result in higher lease costs than a rural setting), and the specific site selected. Another factor is implementing government mandates that encourage environmentfriendly construction and renovation methods which may result in higher initial construction costs but lead to lower operating costs (Ungar, 2003). For instance, the Architectural Barriers Act of 1968 establishes the standards on the accessibility of federal buildings for physically disabled persons, and the Energy Policy and Conservation Act requires federal agencies to implement programmes that reduce energy consumption in federal facilities. Finally, failure to adequately maintain a building may also affect its operating costs (Ungar, 2003).

The cost incurred by maintenance work is affected by numerous factors, and it is vital to identify and rank these cost determinants in order to minimise the respected costs. El-Haram and Horner (2002) classified the factors affecting maintenance costs of buildings into four categories of variables such as building characteristics, political, technical, and administrative factors. Building characteristics comprise building height, size, age, function, type of structure, finishes, building materials and components. The authors further identified poor workmanship and the poor quality of spare parts as technical factors, and poor maintenance management, budget constraints and failure to execute maintenance at the right time are administrative factors which influence the cost of building maintenance. There are other factors such as third-party vandalism and poor, or lack of, training that can affect building maintenance costs (El-Haram and Horner, 2002). Afterwards, Ali (2009) demanded the same classification for factors influencing the maintenance costs of buildings.

In line with Ali (2009), El-Haram and Horner (2002), and Faremi, Adenuga, Dada, and John (2014) ranked the aforementioned factors according to their impact on the maintenance costs of tertiary educational institutions in Nigeria. From the analysis, the age, size, vandalism by users, faulty design and poor incorporation of building services resulted as the top five factors that influence the maintenance costs. The result further implied that the costs of maintenance increases as building ages. Furthermore, the study performed by Talib, Ahmad, Zakaria, and Sulieman (2014) revealed 10 factors influencing the maintenance costs of public buildings in Malaysia. From the relative importance analysis, a lack of preventive maintenance, insufficient funds, a lack of understanding of the importance of maintenance work, non-responses to maintenance requests, and the unavailability of skilled maintenance personnel, respectively, were revealed as the most significant factors contributing to the maintenance costs of public buildings. Contrarily, a recent study has revealed that the expectation of tenants, a building's characteristics, and building defects are the most influencing factors on the maintenance cost of stratified buildings in Malaysia (Che-Ghani, Myeda, & Ali, 2016).

Moreover, Kerama's (2013) and Omari's (2015) studies conducted in Kenya, classified the determinants of the maintenance costs of buildings into five categories: technical defects, environmental factors, management factors, financial factors, and social factors. Technical defects are critical and cover expensive reworks during the operation phase of a building (such as design problems, faulty maintenance, construction defects, and building characteristics). Barrett and Baldry (2009) argue that facilities managers or maintenance staff are responsible for faulty maintenance as they do not often operate the buildings complying with building maintenance guideline. This is likely to result in increased maintenance being required at some point and thereby incur more maintenance costs. Building characteristics include building materials, building age, and building morphology. Building materials used in buildings dictate the rate of wear and tear, therefore, materials that have a short lifespan are likely to increase the maintenance costs of buildings due to frequent replacements being required. Building age refers to the life span of a building. Over time, buildings are likely to require maintenance and could, further, require extensive maintenance for various building components. For instance, higher maintenance costs and remedial costs could be incurred for the maintenance of aged plumbing and drainage systems in buildings due to corrosion problems (Ali & Kamaruzzaman, 2010). Building morphology refers to the physical characteristics of a building such as height, number of floors and gross floor area (Pessenlehner & Mahdavi, 2003). According to Robinson, Symonds, Gilbertson, and Ilozor (2015), the height of a building could have an impact on its maintenance costs as it can consume an additional cost for equipment (for instance, scaffolding which would be needed to carry out maintenance tasks such as external decoration, and window repairs). In addition, poor quality control, a lack of use of LCC techniques, low concern with regard to future maintenance, failures to identify the true causes of defects, new maintenance techniques and tools have been identified as technical factors influencing the maintenance costs of buildings (Omari, 2015).

Omari (2015) further stated that there is a possibility that maintenance costs can increase due to harsh climatic conditions and site conditions (i.e. environmental concerns). Atmospheric pollution associated with rain causes a rapid deterioration of some materials. Accordingly, designers should be familiar with buildings' sites' conditions such as the soil conditions. Ignoring variations in soil conditions will cause cracking of the structural elements and ultimately incur excessive maintenance expenses.

The aspect of management is crucial in maintenance works. Proper management is significant when carrying out maintenance works and, as a result, affects the maintenance costs of commercial buildings. Managerial factors, which have a direct bearing on building maintenance costs constitute the unavailability of skilled labourers; uneducated labourers; the poor quality of spare parts and materials used in building components, elements, services; the unavailability of required spare parts, tools, materials to perform maintenance tasks; poor management by maintenance units; poor communication structures; a lack of building maintenance manuals; unqualified and the unavailability of maintenance contractors, inadequate standards and specifications, and not using the building after the completion (Omari, 2015). The absence of proper maintenance management plan will lead to a cumbersome, time consuming and, most likely, failing maintenance work. There can often be an overlap in managerial roles which can result in maintenance being neglected or certain operations being done twice when not needed which can raise the costs of maintenance (Mahmoud, 1994). Ali, Kamaruzzaman, Sulaiman, and Peng (2010) further stated that poor maintenance management practices are neither cost-effective nor optimum and often cause a lot of problems such as defective buildings and poor building functionality. According to Al-khatam (2003), a proper communication channel between maintenance managers and clients ensures that the contractors are going to perform the work according to the stated conditions and specifications in the contract documents. Similarly, an absence of maintenance manuals, contracts, specifications, and standards will lose a common system of maintenance. It is likely that the non-use of a building after completion would mean that the owner will not give sufficient attention to the building's maintenance work. If no maintenance has been performed on mostly idle components and items, they may require emergency maintenance which will incur an additional cost and potentially require more manpower. Hence, if facilities are not in use, they should be maintained in order to avoid future unplanned costly maintenance.

With regard to financial factors (which influence the costs of building maintenance), an absence of required financial support for on-going maintenance work will, obviously, incur unavoidable costs during the building's lifetime. According to El-Haram et al. (2002), failure to execute maintenance at the right time is often due to insufficient budget allocation. Consequently, further implications occur such as excessive damage, wear and tear, and building defects (Narayan, 2003). Ali et al. (2010) stated that additional costs, which are not allocated in the budget, will then be required for such maintenance and repair works. Furthermore, labour productivity, material availability, materials' waste, good and effective maintenance methods, using effective tools and equipment, and good maintenance planning should be financially controlled on-site (Al-Juwairah, 1997). Maintenance management should be aware of these factors in order to achieve better financial control on-site and, consequently, reducing the maintenance costs.

According to Saghatforoush, Trigunarsyah, and Too (2012), social factors involve increasing maintenance costs. An early response to building failures is necessary in order to reduce maintenance costs. According to El-Haram and Horner (2002), an early response to building defects or failures cannot be undertaken if there are delays and failures in reporting the problems. An inability to gain access to the property is one of the major factors that affects maintenance costs. Other factors are a lack of user understanding of the importance of maintenance work, misuse of buildings, execution of maintenance works only when it becomes a matter of urgency, and cultural practices. There are many problems faced by the maintenance management team when maintaining and operating a building due to the influence of cultural practices. For instance, improper use of toilet bowls due to customs influenced by culture can make maintenance work more difficult. Destructive behaviours that are influenced by cultural practices (e.g. urinating idly) can cause high maintenance costs.

Additionally, Ofori1, Duodu, and Bonney (2015) concluded that the misuse of buildings after the completion of the construction; faulty design; unavailability of skilled workers; less financial assistance for maintenance work, and absence of preventive maintenance are key factors that influence the maintenance costs of private housing units.

Olayinka and Owolabi (2015) investigated factors influencing housing maintenance in Nigeria. A relative important index (RII) is used to identify significant factors affecting housing maintenance costs. In this study, design and proper workmanship (0.933), material specifications (0.847), construction supervision (0.827), the detailing of working drawings (0.813), and cash flow analysis (0.72) came out as the foremost factors. Even though this study has focused on residential sector, this study has analysed the relative significance of these factors over the running costs and the factors discussed seem relevant to the commercial building sector also. Thus, it is worth to see any difference in the relative significance of same factors upon the running costs of commercial properties.

In a recent study, Waziri (2016) found several design and construction defects account for increasing maintenance costs of residential buildings in Nigeria. Amongst them, architectural design defects, poor supervision, and ignoring buildability and maintainability in the design are relatively significant.

In Sri Lanka, Perera, Illankoon, and Perera (2016) have carried out a study investigating the determinants of running costs of condominiums. The authors of the study concluded that building characteristics, maintenance factors, tenant factors, regulatory and economic factors, and other factors (e.g. the lack of competencies of the workers, poor management decision systems, interdepartmental boundaries, third party vandalism, building energy management systems, warranty and after-sales services, and changes in climatic conditions), respectively, influence both the operation and maintenance costs of condominiums in Sri Lanka.

In addition, researchers such as Ashworth (2004), Ayyad (2011), Catalina, Virgone, and Iordache (2011), Ferry and Brandon (1991), Krem (2012), Smith and Jaggar (2007), and Yang, Liu, Shu, Mmereki, Hossain, and Zhan (2015) have conducted studies to understand the relationship between some individual building characteristic with the running costs of buildings. A summary of their findings is presented in Table 2.3.

Table 2. 3: The impact of building characteristics on running costs of buildings

Design variable	**Literature findings**
Number of floors	Heating costs are likely to fall as the number of stories increases (Catalina et al., 2011)
Building shape	Shape of a building has an important effect on its running costs (Krem, 2012)
window area / Window-to-wall-ratio (WWR)	Costs of energy increase with the increase of WWR (Catalina et al., 2011; Yang et al., 2015)
Wall-to-floor-ratio (WFR)	Costs of energy decrease with the increase of WFR (Ayyad, 2011)
	Rooms with reduced perimeter/floor area ratio result in a subsequent reduction in maintenance and heating costs, but these saving may offset the increased lighting costs (Catalina et al., 2011)
Grouping of buildings	Grouping of buildings can have a significant influence on total costs (Ferry & Brandon, 1991)
	Grouping of buildings produces lower costs in using and maintaining buildings (Ashworth, 2004)
	Grouping of buildings reduces service costs (Smith & Jaggar, 2007)

As shown from the table, most of these studies are predominantly focused on energy costs and no detailed inspection conducted focusing the running costs.

Based on the foregoing review, the factors influencing the operation costs of buildings can be discussed under four major determinants; these are building characteristics, maintenance factors, managerial factors, and political factors/regulatory requirements. Including above factors, maintenance costs of buildings is influenced by an extensive set of eight determinants (including environmental factors, tenant factors, design and construction defects, and social factors). Each determinant mentioned above has a list of sub-factors which responsible for the growing costs of operating and maintaining buildings as illustrated in Table 2.5.

Table 2. 4: Factors influencing the operation and maintenance costs of buildings

Main and sub-factors		Sources									
		Operation cost	**Maintenance cost**							**Running costs (O&M)**	
		1	2	3	4	5	6	7	8	9	10
D1	**Building characteristics (BC)**										
1	Function		X	X							
2	Location	X									X
3	Building age		X	X	X	X	X	X			X
4	Building size		X	X		X		X			X
5	Building height		X	X			X	X			X
6	Type of structure		X	X			X	X			
7	Building materials and components		X	X		X	X	X	X	X	X
8	Building services					X		X			X
9	Finishes		X	X							X
D2	**Maintenance factors (MTF)**										
10	Failure to identify the true cause of a defect	X					X				
11	Lack of preventive maintenance	X				X			X		
12	Poor workmanship	X	X	X		X		X			X
13	Faulty maintenance	X				X	X				
14	Low concern for future maintenance	X				X	X		X		
15	Failure to execute maintenance at the right time	X	X	X		X					X
D3	**Managerial factors (MNF)**										
16	Budget constraints	X	X	X	X	X	X	X	X		X
17	Lack of building maintenance manuals, standards, and specifications					X	X		X	X	
18	Poor quality of spare parts and materials		X	X		X	X	X			X
19	Unavailability of the required spare parts, tools, and materials						X				
20	Poor financial control when executing maintenance work			X		X	X	X			X
21	Poor or lack of training		X	X		X	X	X			X
22	Poor management by maintenance units		X	X			X	X			X
23	Unqualified and unavailability of maintenance contractors						X		X	X	

24	Unavailability of skilled and educated labours		X				X		X	X	
25	Failure reporting procedure			X		X					X
D4	**Design and construction defects (DCD)**										
26	Poor supervision									X	
27	Architectural design defects					X	X		X	X	X
28	Poor quality control on site					X	X			X	
29	Defective construction materials									X	
30	Poor structural design					X	X		X	X	X
31	Lack of proper reinforcement in concrete									X	
32	Site defects						X		X	X	
D5	**Tenant factors (TF)**										
33	Vandalism by tenants		X	X		X	X	X			X
34	Misuse of property			X			X	X	X		X
35	Expectation of tenants			X				X			X
36	Ignorance about maintenance works						X		X		
37	Accessibility to the property			X				X			X
38	Right to buy policy			X				X			
D6	**Environmental factors (EF)**										
39	Natural deterioration										
40	Harsh climatic conditions						X				X
D7	**Political factors (PF)**										
41	Changes in legislation (new H&S regulations)	X		X	X			X			X
42	Changes in O&M standards	X									X
43	Price inflation	X									X
44	Changes in taxes and utility tariffs	X									X
D8	**Social factors (SF)**										
45	Cultural practices						X				
46	Third-party vandalism			X		X					X

Source: (Adapted from 1-Ungar, 2003; 2-Olayinka and Owolabi, 2015; 3-El-Haram and Horner, 2002; 4-Ali, 2009; 5-Faremi et al., 2014; 6-Omari, 2015; 7-Kerama, 2013; 8-Ofori1 et al., 2015; 9-Waziri, 2016; 10- Perera et al., 2016)

The foregoing review provides a thorough account on the factors influencing running costs of different types of buildings located in different climatic and economic conditions. Nonetheless, a very few studies have been focused on operation costs and running costs of buildings when investigating their determinants. Further, even though few studies have been conducted in the developing countries such as Nigeria, Malaysia, and Kenya, which has a tropical climate, none of these studies has considered both the operation and maintenance costs. In another point of view, the literature has been focused on different types of buildings such as federal buildings, educational institutes, and offices but an account of commercial buildings is still missing in this regard. Considering the unique characteristics of commercial building operation and maintenance, it is vital to identify the factors affecting the running costs of commercial facilities, especially in a developing, tropical country. Any difference of these identified factors to different types of buildings, climatic conditions, and economies remains to identify. Furthermore, the level of significance of these influential factors of running costs is an understudied area, thus demands a proper investigation.

2.7 Current scientific methods for LCC estimation

Cost modelling is a vital task that should be carried out all over the life cycle of a building (Zhiliang, Zhenhua, Wu, & Zhe, 2011). Mathematical LCC models generally aid design-team decision making in conjunction with analyses of alternatives at the initial stages (Al-Hajj & Horner, 1998). Early implementation of cost estimation models is, therefore, essential as it delivers accounts on the relationships between the cost and design variables (Durairaj, Ong, Nee, & Tan, 2002). These models further contribute to cost reduction by identifying high-cost contributors. The literature (Datta & Roy, 2010; Huang, Newnes, & Parry, 2012; Niazi, Dai, Balabani, & Seneviratne, 2006) provide evidence on seven different methods for evaluating LCC of assets. They are:

1. Intuitive method/Heuristic models/Expert opinions: based on the experience of the cost consultant. Thus, the outcome is mostly depending on the estimator’s knowledge
2. Conceptual methods/Rule of thumb: based on usual deterministic cost relationships

3. Analogical/Comparative method: uses historical data from comparable developments as a basis for the cost estimation
4. Parametric method: uses statistical modelling to develop a cost estimate
5. Analytical method: evaluation of the cost of a product from a decomposition of the work required into elementary tasks
6. Bayesian: deals with the modification of existing cost models with available new data and information
7. Engineering: costs are assigned to each element at the lowest level of the design detail and then combined into a total for the product/system

Besides, there are non-parametric machine learning approaches such as artificial neural networks (ANN) which can be used to model costs. ANNs are originally inspired by the study of processes in the human brain (Günaydin & Doğan, 2004). Although the ANN approach shows its potentialities in obtaining fairly accurate cost models, this approach mostly deals with big data analysis where it requires an extensive amount of data and involves three data input stages namely, model development, model training and validation (Matel, Vahdatikhaki, Hosseinyalamdary, Evers, & Voordijk, 2019). Thus, ANN says difficult in applying for contexts with less data.

One can choose a preferred approach to estimate the total cost of a product, considering its whole life cycle, but these choices may influence by the inherent features of each method. Amongst the aforementioned methods for cost estimation, the intuitive and conceptual methods do not have mathematical/statistical behaviour in their models, thus are not guaranteed to produce optimum solutions (Datta & Roy, 2010; Niazi et al., 2006). Table 2.5 presents an evaluation of the statistical LCC estimation methods, along with their applications, advantages, and limitations.

Table 2. 5: An evaluation of statistical LCC estimation methods

Method	Application	Advantages	Limitations
Analogical method	• During feasibility, definition, development stages and after-sales service of a product • Use with group technology • Where less information is available • Use to solve complications when there is no trade knowledge exists	• Ability to propose a solution very rapidly • Functions in a transparent manner • User can edit the results • If good analogy found, it allows for a lower level of detail • Ability to combine several methods in the adaption phase	• Difficult to find good analogy and requires engineering judgement
Parametric method	• During the feasibility and definition stages of a product • "Black box" scenario: where it is complicated to understand the significant elements of the manufacturer and to unable to justify the results • Where less information is available • Use technical and physical characteristics to evaluate the cost • Hedonistic regression analysis	• Captures major portion of an estimate quickly with limited information • Meets the criteria of precision • Rapidity of execution • Based on objective inputs • Ease of use • Versatility • Sensitivity • No results' justification is necessary	• Requires a considerable amount of data to calibrate accurately • The designer will have to estimate the missing parameter, which causes uncertainty in the results • Does not provide low-level visibility • Subtle changes in sub-element cannot be reflected in the estimate easily
Analytical method	• During development, production, utilisation stages and after-sales services of a product	• Results meet demand perfectly	• Comparatively slow method
Engineering	• Use when detailed design data is available on the product/system • During the production/construction and use phase • Use for proposal/execution estimates	• Most detailed of all the techniques • A greater level of confidence	• Most costly to implement • Need for detailed data • Time-consuming process
Bayesian	• To upgrade an existing estimation model with newly available data/information	• Allows old and new data sets to be combined to give the most probable outcome	-

As shown in Table 2.5, some of these methods are better than others depending on the context. The parametric cost estimation approach is preferred in most situations as it essentially correlates cost and product/system parameters describing the items to be costed (Caplehorn, 2012; Kirkham, 2002).

2.7.1 Parametric models for the estimation of costs of buildings

Parametric estimation entails the analysis of cost, physical, and technical data towards identifying the cost drivers and developing the cost models. The approach essentially correlates cost and product/system parameters describing the item to be costed. A mathematical model for the cost of buildings contains mathematical equations that can be explicitly applied to quantifying the cost of a building. Following provides an account on different cost models developed for buildings.

LCC models

A basic set of LCC estimation models has been developed by Raheja (1991). This set is as follows:

$$LCC = Non\ recurring\ costs + recurring\ costs \quad (1)$$

$$LCC = Initial\ price + Warranty\ costs + Repair, maintenance, and\ operating\ costs\ to\ end\ users \quad (2)$$

$$LCC = Manufacturer's\ cost + Maintenance\ costs\ and\ downtime\ costs\ to\ end\ users \quad (3)$$

In equation 1, LCC is presented as a sum of non-recurring costs (e.g. construction costs) and recurring costs (e.g. running costs). In equation 2 and 3, non-recurring costs have been replaced by initial costs and manufacturer's costs, respectively.

The Society of Automotive Engineers (SAE, 1993) also developed an LCC model directed towards a manufacturing environment.

$$LCC = Acqusition\ costs + operating\ costs + scheduled\ maintenance + unsheduled\ maintenance + \frac{conversion}{decommission} \quad (4)$$

Except LCC estimation models developed which are common to each type of building, Bromilow and Pawsey (1998) have developed a simple model for computing the LCC of university buildings. All costs are divided into two types such as regular costs which incur annually (e.g. maintenance, cleaning, energy, and security) and irregular costs including repainting or replacement of building components, which incur occasionally.

$$NPV = C_{0i} + \sum_{i=1}^{n}\sum_{t=1}^{T} c_{it}\,(1 + r_{jt})^{-t} + \sum_{j=1}^{m}\sum_{t=1}^{T} c_{jt}\,(1 + r_{jt})^{-t} - d(1 + r_d)^{-T} \tag{5}$$

where, C_0 - the procurement cost at time t = 0 including construction costs; c_{it} - the annual cost at time t of support function i including maintenance and energy costs; c_{jt} - the cost at time t of discontinuous support function j; r_{it} and r_{jt} - the discount rates applicable to support functions i and j, respectively; d - the value of asset on disposal; and r_d - the discount rate applicable to asset disposal over period 0 to T.

Similarly, Kirkham et al. (2002) proposed the following stochastic model for calculating the LCC of hospital buildings.

$$WLCC = \sum_{n=1}^{i} \frac{FM_c + E_c + M_c + F_c + R_c}{(1+r)^i} \tag{6}$$

where WLCC - whole life cycle costs; FMc - facilities management costs; Ec - energy costs; Mc - maintenance costs; Fc - financial costs; Rc - residual costs; r - discount rate; and i - number of years (time).

Furthermore, Marenjak, El-Haram, and Horner (2003) developed a model for calculating LCC according to the following equations.

$$UTP_p = Ti_p + Tfm_p + Tr_p \tag{7}$$

$$Tfm_p = \sum_{i=1}^{e} Tfm_e + \sum_{i=1}^{z} Tfm_z \tag{8}$$

$$Ti_p = \sum_{i=1}^{e} Ti_e + \sum_{i=1}^{z} Ti_z \tag{9}$$

where, UTP_p - whole life cycle costs (e.g. hospitals, schools, etc.); Ti_p- initial (capital) project costs; Tiz - other initial costs (e.g. land, design etc.); Tfm_e - facility management costs at the project level; Tfm_z - facility management costs associated with building elements (e.g. insurance costs, cost of electricity, etc.); and Tr_p - disposal costs at the project level. Marenjak et al. (2002) further explained that, according to the data structure of the model and the analysis of the total project costs, this model enables the generation of various project alternatives, thus minimises risks of financial and technical.

In place of the estimation of WLC for an entire building, El-Haram et al. (2002) developed a model for estimating the WLC of each building element for each alternative.

$$WLCC = Cc + (\sum_{i=1}^{n}(\sum_{j=1}^{m} Oc_j) + \sum_{i=1}^{n}(\sum_{j=1}^{m} Mc_j) + \sum_{i=1}^{k} Rc_i) \pm Dc \ldots\ldots \quad (10)$$

where, WLC - whole life cycle costs; Cc - construction cost; Oc - operating cost; Mc - maintenance cost (reactive and preventive); Rc - replacement cost; Dc - disposal cost; n - number of years (expected life of the project or period of analysis); m - number of operating and maintenance tasks; and k - number of replacements.

Running costs estimation models

Unlike the above-discussed models, there are models which are exclusively focused on the running costs of buildings. For example, the study conducted by Al-Hajj and Horner (1991) on the running costs of institutional buildings over a period of 18 years, concluded that the significant cost items can be determined by identifying the cost elements which are above average. The authors further mentioned that approximately 15% of all the cost elements are only contributed to an average of 85% of the total maintenance costs. This study, therefore, presented a model for monitoring and predicting the maintenance costs of buildings using the historical cost data, as expressed below.

$$R_c = \frac{1}{CMF}\sum_{i=1}^{n}[(c_1 + c_2) + (e_1 + e_2 + e_3) + (a_1 + a_2) + (o_1 + o_2) + (m_1 + m_2)] \quad (11)$$

where, R_c - total running cost; CMF - cost model factor (0.87); n - time in years; c_i - c_1 expenditure on internal cleaning expenditure, c_2 laundry expenditure; e_i - e_1 gas, e_2 electricity, e_3 fuel oil; o_i - o_1 rates, o_2 insurance; a_i - a_1 management fees, a_2 security; and m_i - m_1 internal decoration, ft2 roof repair. Subsequently, this model was evaluated by Young (1992, cited in Krstić and Marenjak, 2012) and stated that the accuracy of this model lies outside the expected range due to three reasons: (1) the cost data reporting system differs from one case building to another which used in the model development, (2) the models do not consider the impact of different materials or components used in the case buildings, and (3) the occurrence of occasional high-cost items.

However, Dhillon (2010) explained that there are still a great many reasons for not having a generally accepted model including user preference, the existence of numerous cost data reporting systems, and different types of equipment, appliance or systems. Furthermore, Liu, Gopalkrishnan, Quynh, and Ng, (2009) opined that there are two basic flaws in existing LCC models: the low prediction accuracy of the costs and the restrictions associated with the different stages of buildings' life cycles. For example, the application of the Kirkham et al. (2002), El-Haram et al. (2002), and the Al-Hajj and Horner (1998) models are restricted to the later stages of the building life cycle as these are purely based on historical cost records.

Regardless of these shortcomings, Weerasinghe, Ramachandra and Rotimi (2016) proposed a basic model for forecasting the running cost of office buildings considering two building characteristics as predictor variables.

$$Running\ cost = -4964009161 + 3607150.063(Average\ Floor\ Area) + 161567613(Number\ of\ floors) \ldots\ldots\ldots \quad (12)$$

However, the model accuracy is argued by having a large standard error of the estimate (587201089.6).

Considering the rapid increase in cooling energy demands, Kirkham et al. (1999) computed a regression model to predict the energy costs of sports centres by taking only two independent variables: building size (area) and the number of users. The model includes two basic mathematical equations for calculating the energy costs (CE) and these are presented as,

$$CE = 1.203 + o.97 * AREA \ldots\ldots\ldots \quad (13)$$

$$CE = 1.217 + 0.642 * AREA + 0.206 * USERS \ldots\ldots\ldots \quad (14)$$

Similarly, Geekiyanage, Ramachandra, and Rotimi (2017) introduced a morphology-based model for forecasting the cooling energy demand of condominiums.

$$\begin{aligned} Cooling\ energy\ demand\ (Kwh/y) \\ = -194913.837 + 19160.987\ (Number\ of\ floors) \\ + 4339.533\ (WWR) \end{aligned} \tag{15}$$

However, the application of the models developed by Kirkham et al. (1999), Weerasinghe et al., (2016), and Geekiyanage et al. (2017) are limited to sports centres, offices, and condominium buildings, respectively.

A graphical representation of the analysis of the aforementioned existing models for the LCC estimation of buildings is depicted in Figure 2.3. The model formula number here indicates the number assigned to each model equation discussed above.

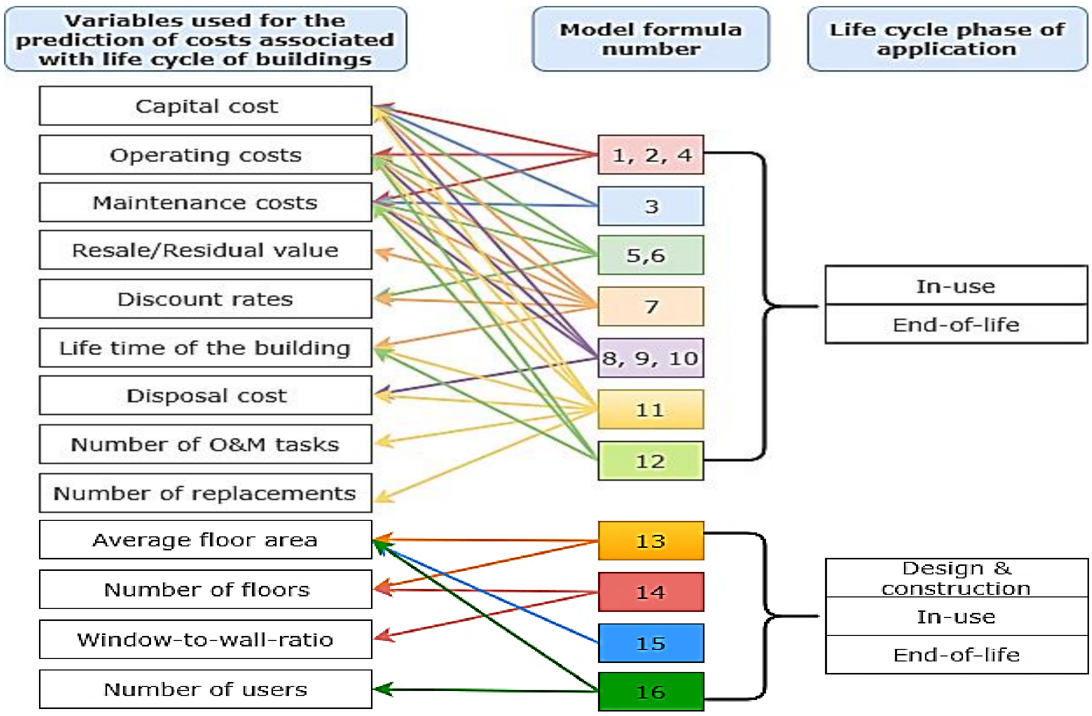


Figure 2. 2: Analyses of current building LCC estimation models

As shown in Figure 2.2, the LCC models developed so far can be classified into two categories based on their predictor variables: cost items and building characteristics. Models from one (01) to 11 in the Figure have taken cost items as their variables (i.e. capital costs, operation costs, maintenance costs, disposal costs, and resale/residual value) whereas the rest of the models (12 to 15) have been developed using building characteristics (i.e. floor area, number of floors, window-to-wall-ratio (WWR) and occupancy) as independent variables to predict the LCC. Accordingly, the LCC estimation models which are based on building characteristics are only capable of predicting the LCC of buildings at the design and construction stages of their life cycle.

However, Krstić and Marenjak (2017) argued that these models are usually not based on adequate historical cost records and are developed based on the available cost structure, rather than on the standard cost structure. The authors further opined that no adequate databases are containing running cost data that could be used for forthcoming research to bring up to date or upgrade the prevailing models. Moreover, they stated that the models developed so far ignore some important factors such as the age, location, level of occupancy, and standards of operation (Krstić and Marenjak 2017). The authors further stressed that there is no simple model for predicting running costs based on building attributes, operational arrangements, and user characteristics. Given the limitations of the existing models and the limited application of parametric models, this study aims to develop a reliable and simple model for forecasting the running costs of commercial buildings which is equally applicable throughout the building life cycle especially in the early design and construction stages.

2.8 Indices for the cost of buildings

The bulk of the literature has signalled that the absence of reliable and historical cost data, particularly in the in-use phase of buildings, leads to the limited applicability of the LCC concept within the building construction industry (Ashworth, 1996; Cole & Sterner, 2000; Hunter, Hari, & Kelly, 2005; Opoku, 2013). However, a few studies have taken the effort to solve this critical issue throughout the years. For instance, Goh, Kumaraswamy, and Liyanage (2016) designed a whole life building cost index for non-residential, green-rated buildings in Singapore. The Paasche price index method was used to produce the weighted composite index. However, the authors opined that the developed index may not necessarily be appropriate for sole application as the index is developed based on a combination of commercial, industrial, and institutional buildings.

In another light, construction industries in developed nations (such as the UK, USA and Australia) have been promoting WLC practices, over the years, and have established comprehensive guidelines and standards to apply the tools and techniques for managing the cost of buildings. Furthermore, since the 1990s, the universally recognised BCIS, in the UK, has been developing and maintaining a cost database relating to building construction costs. Similarly, in Singapore, there is a national ‘Building Tender Price Index’ series to guide industry stakeholders on tender prices of public and private sector building projects. Besides the aforementioned indices, there is a separate set of construction price indices in Sri Lanka which were developed and maintained by the CIDA in collaboration with the Institute of Construction Training and Development (ICTAD). In brief, they have published construction price indices for construction materials, labour wages, and dry hire rates for the plant, equipment and fuel. Furthermore, there are several cost indices developed for different types of constructions and all construction. However, there is still a lack of a body of knowledge (in terms of a centralised database) concerning WLC, specifically the costs of running a building.

“An index number is a statistical device for measuring relative changes in the magnitude of a group of related variables over time” (Pillai, 2008). The information provided by an LCC index can be particularly useful to commercial developers in helping them to be informed when to implement improvements like achieving higher energy savings in their properties. Having a ‘WLC Index’ essentially creates a body of knowledge in respect of how to manage the total costs of a typical building which must encompass operation and maintenance costs, which has a significant contribution on a building’s total LCC. In other words, a WLCC index allows prospective clients to appraise the total costs of building ownership while it allows present owners to monitor and predict the cost efficiency levels of their buildings.

Most of the literature relating to WLC indices highlight the importance of having construction cost indices although the running costs of a typical building is five times greater than its construction costs. Compared to current construction cost indices, there are very few indices exist to show the trends in the running costs of buildings. For example, the New York City Rent Guidelines Board (2017) developed a PIOC in 2017.

The PIOC measures fluctuations in seven (7) running cost components: taxes, labour costs, fuel, utilities, maintenance, administrative costs, and insurance costs, of purchasing a specified set of goods and services used in the operation and maintenance of rent stabilised apartment buildings in New York City. Apart from that the BCIS has developed online running cost indices which provide a central location for those who involved in facilities management. However, there is no indication available on the methodology followed for the construction of these index values. Therefore, it seems that, so far, very little attention has been paid for developing cost indices to predict the costs to be incurred during the in-use phase of a building.

2.8.1 Methods of constructing index numbers

Constructing a cost index is a complex task which involves several alternatives and possibilities that affect the reliability and quality of the results. The main problems associated with index compilation methods are the choice of a theoretical framework, the availability of the data, the selection of more representative indicators, and their treatment in order to compare and aggregate them. Methods of constructing index numbers can be basically categorised into simple or unweighted index numbers and weighted index numbers as depicted in Figure 2.3.

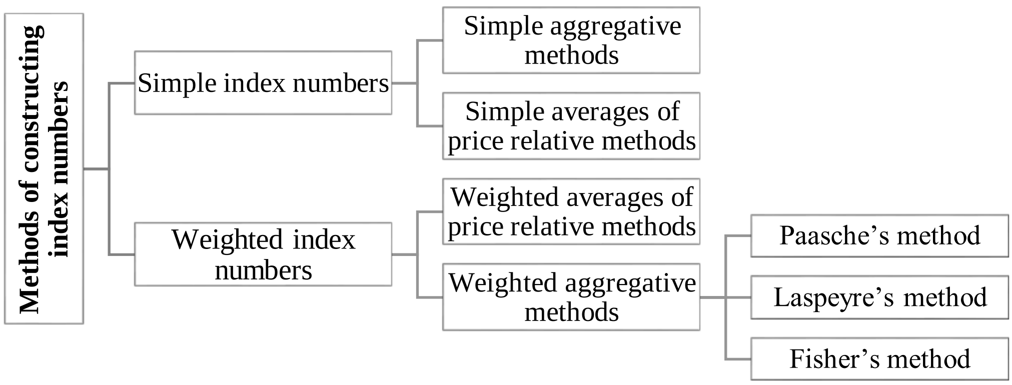


Figure 2. 3: Methods of constructing index numbers

The simple/unweighted index number method gives equal importance to all items in the series and as shown in Figure 2.3, this method is classified into two: the simple aggregative method and the simple average of price relative method. In the simple aggregative method, the aggregate price of commodities in the current year is divided by the aggregate price of these commodities in the base year and expressed in a percentage. The equation followed by the simple aggregative method is as follows:

$$P = \sum P_1 / \sum P_0 * 100$$

where, P – price index of the current year, $\sum P_1$ – sum of prices of commodities in the current year and $\sum P_0$ – sum of prices of commodities in the base year.

In the simple average of price relative method, the first price relative of the current year is calculated considering the price relative as the price for the current years expressed as a percentage of the period of the base year. This is expressed as:

$$P = \sum (\frac{P_1}{P_0} * 100)/N \quad or \quad P = \sum PR\,/N$$

where, P – price index of the current year, P_1 – current year prices, P_0 – base year prices, N – number of commodities and $\sum PR$ – price relative.

Weighted index numbers are more advanced compared to the compilation of simple index numbers. As shown in Figure 2.3, weighted index numbers can be divided into two: weighted average of price relative methods and weighted aggregative methods. In the weighted average of price relative method, the price relatives of the current year are calculated on the basis of the base year prices. The index formula of the weighted average of price relative method is as follows:

$$P = \frac{\sum RW}{\sum W} \ ; \ R = \frac{P_1}{P_0} * 100 \ and \ W = P_0 Q_0$$

where, P – price index of the current year, P_1 – current year prices, P_0 – base year prices and Q_0 – quantity of the base year.

The second weighted index number is the weighted aggregative method. In this method, the weights are assigned to various items to reflect their relative importance in the series and, therefore, the weighted aggregate of prices is calculated instead of simple aggregates. There are 3 techniques used for assigning weights to items (pilot survey findings), namely:

1. Paasche’s method
2. Laspeyres’ method

3. Fisher's method

These are the common and most reliable methods used for the development of price indices worldwide. Table 2.7 presents a review of these three methods together with their formula, advantages, and limitations.

Table 2. 6: A comparison of the methods used to develop weighted aggregate price indices

Method	Formula	Weighted average	Advantages	Limitations
Paasche's method	$P_i = \frac{\sum P_1 Q_1}{\sum P_0 Q_1} * 100$	Based on quantities of the current year	• Requires quantity data only from the current year • Reflects current buying habit	• Tends to under-estimate the general price level • Requires prices to be recomputed each year
Laspeyre's method	$P_i = \frac{\sum P_1 Q_0}{\sum P_0 Q_0} * 100$	Based on quantities of the base year	• Requires quantity data only from the base year • More meaningful comparison over time • The changes in the index can be attributed to changes in the price • Relatively easy to get timely figures	• Tends to over-estimate the general price level • Does not reflect buying patterns over time
Fisher's method	$P_i = \sqrt{\frac{\sum P_1 Q_0}{\sum P_0 Q_0} * \frac{\sum P_1 Q_1}{\sum P_0 Q_1}} * 100$ Or $P_i = \sqrt{L * P}$ where, L - Laspeyre's method and P - Paasche's method	Based on quantities of the current and base year	• More appropriate when dealing with percentage changes • Corrects positive bias inherent in the Laspeyre's index and negative bias inherent in the Paasche index. • Satisfies time reversal test and factor reversal test	-

Source: (Pilot study findings)

The Paasche price index is a formula designed to measure the price growth of a basket of goods and services that is consumed in the current period (Anghelache, Marinescu, Gheorghe, Bichir, & Nan, 2012). The output value of this index answers the question of how much a basket that consumers buy in the current period would have cost in the base period. Hence, it is also defined as a 'fixed-weight', or 'fixed-basket', index, or a 'current weighted index' as it uses the basket of goods and services and their weights from the current period (Anghelache et al., 2012).

In contrast, the price development of a basket of goods and services consumed in the base period can be measured using the Laspeyres price index formula (Anghelache et al., 2012). This answers the question of how much a basket that consumers bought in the base period would cost in the current period, which the vice versa of the Paasche index answered. It is also defined as a 'fixed-weight', or 'fixed-basket', but 'base-weighted index' as it uses the basket of goods and services and their weights from the base period (Anghelache et al., 2012).

Taking the effect of both the Paasche and Laspeyres indices, the Fisher-price index is developed to measure the price growth of goods and services based on baskets from both the base period and the current period (Anghelache et al., 2012). It is, therefore, introduced as the geometric mean of the Laspeyres and Paasche price indices.

The data availability plays a significant role in making choices among these price index formula for a particular case (Anghelache et al., 2012). The Fisher-price index requires more data than both the others and, consequently, may often be impracticable. Unlike other formulas, the Laspeyres index does not require information on the basket of the current period. Therefore, in practice, the Laspeyres formula is usually preferred for the calculation of consumer price indices which are typically compiled and released rapidly before consumption or production information for the current period could have been collected.

Although the Laspeyre's and Paasche's index formulas are commonly used for constructing indices, they do not consider the consumers' typical fluctuation on the purchasing quantity as a result of price changes (Anghelache et al., 2012). The issue related to Laspeyres and Paasche index value formulas is that, although they are equally plausible, usually, they are giving different outcomes. Accordingly, Paasche's index systematically understates inflation, while Laspeyres' index overstates it (Anghelache et al., 2012). Giving possible solutions to the aforementioned shortcomings (i.e. the reliability of index numbers and requiring more data), the hedonic index method has been introduced in the present era. A detailed review of the hedonic price imputation approach for index numbers is presented in the following section.

2.8.2 The hedonic price imputation approach

Hedonic prices are defined as *"the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them"* (Rosen, 1974, p. 34). In the construction of the hedonic price indices, the implicit prices are estimated by the first step regression analysis (product price regressed on characteristics) (Rosen, 1974). In general, the hedonic regression technique is developed to correct the heterogeneities among products rather than adapt to the quality improvements over time. According to the hedonic regression technique, heterogeneous goods/products can be defined by their attributes or characteristics (The European Commission [Eurostat], 2013).

In the context of a building, these characteristics may encompass both the structural and locational attributes of a property. For example, the 12 attributes used for the construction of the US Census Bureau's hedonic model for a single-family house are as the size of the house, geographic location, metropolitan area location, number of bedrooms, number of bathrooms, number of fireplaces, type of parking facility, type of foundation, presence of a deck, construction method, primary exterior wall material, and heating system and central air-conditioning (Ive, 2008). Similarly, the hedonic residential building price series in the US, constructed by Somerville (1999), took the model types of the houses, the unit size, bedrooms, bathrooms, and location as independent variables and found that the published construction cost indices are biased to the US context. The Tender Price Index for Social Housing (TPISH) published by the Department of Trade and Industry (DTI) has also applied the hedonic technique to control the variations in the project specifications (Yu and Ive, 2008). This method has been further accepted by the Office for National Statistics (ONS) in the UK for compiling their price indices (Yu and Ive, 2008).

The key advantages of the hedonic regression methods are:

- The hedonic methods can be adjusted for both the sample mix changes and the quality changes of the individual properties if the list of available property characteristics is adequate.
- This method can be adjusted to make the most out of the available data.
- The imputation variant of the hedonic regression method is analogous to the matched model methodology that is widely used in order to construct price indices.

Besides the above-mentioned advantages, there are a few disadvantages that arise from the hedonic regression method. They are:

- The outcome is hard to generalise to a different region if the property prices and price trend are varying across regions. However, hedonic regressions along with a stratified approach will help to solve this problem to some extent.
- The method requires extensive property characteristics data from all applicable cases, and therefore relatively expensive to implement.
- The method is fairly complicated to execute and understand as it requires sound statistical knowledge.
- The outcomes are strongly based on the model requirement.

In terms of constructing hedonic indices for costs of building constructions and operations, Meikle (2001) suggested hedonic construction price indices as an area for further research. Very importantly, Yu and Ive (2008) elaborated upon the necessity of developing a hedonic index of mechanical and electrical services as it will capture a greater percentage of the most significant cost components of buildings unmeasured by existing methods, which have been examined in this study. However, the application of the hedonic price imputation approach for the modelling of LCC of buildings is not yet been into the study; therefore, this further emphasises the significance of this study.

2.9 Summary

The purpose of this chapter is to present the state-of-the-art and to reveal the knowledge gaps in the focus area. The chapter begins with a brief introduction to the chapter. Thereafter, the chapter reviews the literature on the applications of LCC, and the importance of, and barriers to, implementing LCC. Furthermore, a critical review of the literature has been undertaken on the factors affecting the running costs, on the available LCC estimation models together with their limitations, and on the existing LCC indices with methods of development.

The literature highlights that a thorough account on significant running costs elements is mostly lack in developing countries like Sri Lanka where their investigations are mostly focused on increasing energy costs instead of a total running costs approach. Furthermore, a very few studies have been focused on both operation and maintenance costs of buildings when investigating their determinants, especially an account of commercial buildings is still missing in this regard. Moreover, the level of significance of these influential factors of running costs is an understudied area, thus demands a proper investigation. The literature further revealed that LCC predictions on building facilities have been mainly limited due to a lack of reliable, historical cost data, especially during the in-use phase of buildings. Thus far developed models also observed with limitations in practical application, for instance, solely based on costs variables which are unknown at building design stages. Therefore, the development of reliable running costs models and indices is still an area worthy of research, especially for a country like Sri Lanka for two main reasons: (1) absence of a building running cost information database and (2) no proper standard or a mechanism to collect, store and estimate the running costs of buildings.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

Having established the theoretical background to the area of study in the previous chapter, this chapter presents the research methodology adopted for this study. It begins with a detailed explanation of the research process adopted for this research and then further develops the research approach, the research strategy, and the research techniques. The latter part of the chapter presents the sampling techniques, the data collection and the analysis techniques, and the model validation techniques used to achieve the formulated research objectives. The chapter concludes with a summary which states the highlights of the chapter.

3.2 Research process

The path to finding the answers to the research problem is constituted by the research process (Kumar, 2011). The research process looks into two main aspects of the study such as the research problem (i.e. the research study wants to find answers) and how to find the answers to the research problem. According to Saunders, Lewis, and Thornhill (2016), the research process can be represented as an onion, which is depicted in Figure 3.1.

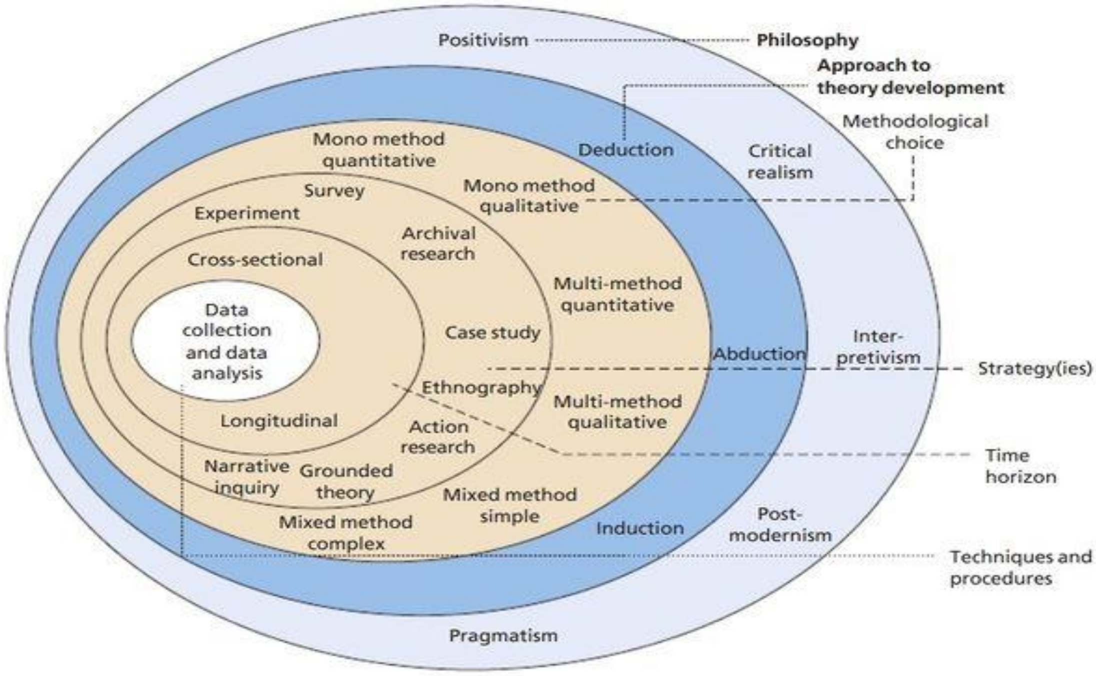


Figure 3. 1: Research onion

Source: (Saunders et al., 2016)

The following subsections explain the contents of the onion: the philosophies, approaches, strategies, choice, and techniques and procedures in general, and relating to the current study.

3.3 Research philosophy and paradigms

Research philosophy is the first layer of the research onion and is the most crucial one. According to Saunders et al. (2016), the research philosophy is a belief or an idea about the collection, interpretation, and analysis of data collected. Simply, it provides a framework to the researcher(s) to develop knowledge within a particular subject area. Indeed, a researcher's specific view and opinion of the association between knowledge and the process by which it is developed is one of the main considerations influencing the choice of a specific philosophy (Saunders, Lewis, and Thornhill, 2009). There are two main research philosophies, namely Positivism and Interpretivism which can be placed at the two extreme ends of a research continuum (Easterby-Smith, Thorpe & Lowe, 2002). Three assumptions can be identified within these philosophical stances which are ontology, epistemology, and axiology. The ontology seeks to identify the nature of the reality; epistemology shows how to acquire and accept knowledge about the world; and axiology indicates the nature of the values the researcher places on the study (Easterby-Smith et al, 2002; Collis and Hussey, 2003). Figure 3.2 depicts how positivism and interpretivism are characterized by ontological, epistemological, and axiological assumptions.

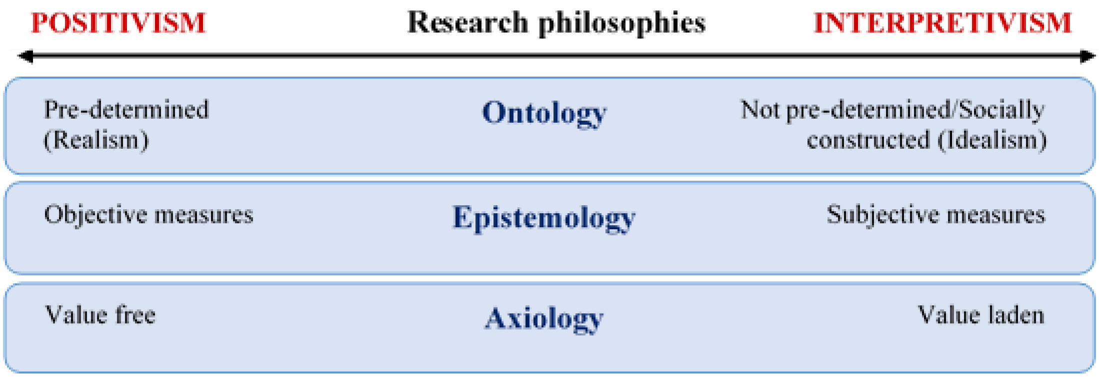


Figure 3. 2: The philosophical stance of a study against the research philosophical continuum

Source: (Adapted from Kulatunga, Amaratunga, & Haigh, 2007)

Ontology is defined by (Crotty: 2003:10) as "the study of being". It is concerned with "what kind of world we are investigating, with the nature of existence, with the structure of reality as such". Guba and Lincolin (1989:83) state that the ontological assumptions are those that respond to the question 'what is there that can be known?' or 'what is the nature of reality?' Considering above definition of ontology and the research question of 'how to enhance the estimation of running costs of buildings at its early design stages?' articulated for the current study, this study uses a realistic ontology which believes 'whatever happens, there is a structured way of doing it'. In this study, the researcher is going to measure the significance of running costs and thereby develop possible scientific tools to estimate the running costs of commercial buildings with the use of different statistical approaches. The study mainly deals with numbers which the research outcomes may not be influenced or biased by inner thoughts and believes of individuals.

Epistemology is 'a way of understanding and explaining how we know what we know' (Crotty, 2003). Epistemology is also 'concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate' (Maynard, 1994:10). Epistemology considered different routes of approaching research and could be either inductive or deductive (Holden & Lynch, 2004). In this study, the researcher is attempting to test a theory which is already built in the context that is 'the statistical significance of running costs and its statical relation to building design variables' with objective measures. This takes a deductive approach where it initially explores the global scenarios and then narrowing down it to a specific context and test the particular theory within that particular context.

Axiology concerns about how researcher is judging value. Some researchers want to use their own experience which is Value Laden, and some researchers may not include their previous experience within the study which is value free (Saunders et al. 2012). According to Orlikowski and Baroudi (1991), realistic view or deductive approach is objective, which is free from values. As the current study does not intend to collect any subjective perspectives on the research focus, the study outcomes are free from biasness, therefore axiological position for this research is value neutral.

With all above justifications, the most relevant philosophical view for the current study is positivism. In positivism, the researcher is responsible for measuring the gap between the actual knowledge and the accepted knowledge (Saunders et al., 2009). The researcher can frame the research questions and can test them in the actual and natural environment. The positivism research philosophy deals with the top-most layer of truth and reality by testing the hypothesis in the real world. The role of statistical analysis is huge in the positivism research philosophy (Saunders et al., 2009) and, therefore, is fit for the current study.

3.4 Research approach and methodological choice

The research approach enables researchers to determine the research design to be employed considering the type of data to be gathered, data sources, and the techniques to be utilised to collect and analyse data (Easterby-Smith et al., 2002). Saunders et al. (2009) presented two streams of research approaches: deductive and inductive.

The deductive approach concentrates on using the literature to identify theories and ideas that the researcher will test using data (Holden & Lynch, 2004; Saunders et al., 2009). In contrast, the inductive approach involves collecting data and developing a theory based on the results of the data analysis (Holden & Lynch, 2004; Saunders et al., 2009). This study presents a focus on theory testing; thus, this emphasises that the present study is of the deductive orientation.

Research methods followed by the research approach are classified into qualitative, quantitative, and mixed-method approaches (Tashakkori & Teddlie, 2003; Williams, 2007). With reference to the choice of research methods, one can use a single data collection technique with a corresponding data analysis procedure (mono method) or more than one data collection technique with data analysis procedure (multiple methods) (Saunders et al., 2009). A mixed-method approach is where both quantitative and qualitative data collection techniques and analysis procedures are used (Tashakkori & Teddlie, 2003).

The deductive approach, generally, leads to using the quantitative method, while the inductive choice leads to the qualitative method (Saunders et al., 2016; Yin, 2009). With regard to rational objectives, the current study aims to enhance the application of LCC within the built environment by developing a cost model and an index for forecasting the running costs of commercial buildings in Sri Lanka. The current study primarily deals with numbers and, therefore, mainly employs a highly structured form of data collection (i.e. Likert scale data, scale data) and statistical data analysis techniques, where no opinions or views of the parties within the data collection will influence the findings of the study. This evidences that the current study utilises a quantitative research approach. Accordingly, the objectives and the philosophical assumptions, the quantitative data to be collected, and the data analysis procedure all validate employing the multi-method quantitative research approach for this study.

3.5 Research strategy

The selection of appropriate research strategies for a research study is driven by numerous factors such as the research aim and objectives, the philosophical stances, the time taken, and other resources available for data collection (Saunders et al., 2016).

Yin (2009) suggests five research strategies such as experiment, survey, archival analysis, history, and case studies. Saunders et al. (2016) further asserted action research, grounded theory, and ethnography also as research strategies. Table 3.1 outlines these research strategies along with the related factors which facilitate the selection of a proper strategy for any research study.

Table 3. 1: Research strategies and their application

Strategy	Form of research questions	Focuses on behavioural events	Focuses on contemporary events
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
Experiment	How, why?	Yes	Yes
Case study	How, why?	No	Yes
Action	How, why?	Yes	Yes
Grounded theory	How, why?	No	Yes/No
History	How, why?	No	No
Ethnography	How, why?	Yes/No	Yes

Source: (Adapted from Ramachandra, 2013; Saunders et al., 2016; Yin, 2003)

Having outlined the research strategies in general, this research study utilises the survey research strategy. Justifications for the selection of this strategy are as follows. This study involves research questions of what are the significant running cost components?, what are the significant factors influencing running costs of commercial buildings in tropical climates like Sri Lanka?, how the building characteristics correlated with the running costs?, how to model the running costs of commercial buildings in tropics?, which the research aim is primarily in the nature of "what" and "how", thus, the survey design strategy is the ideal strategy as explained by Yin (2003). Also, the study is intended to collect categorical data (i.e. Likert scale data) and scale data (i.e. running costs and building characteristics data) from a substantial sample of respondents and buildings, respectively. The major advantage of the survey method is that it is helpful when a researcher intends to collect a large amount of data or information (Saunders et al., 2016). Furthermore, this research is focused on contemporary events (i.e. actual running costs and building characteristics of currently operating commercial buildings) and no control is needed over behavioural events. Moreover, the nature of the data to be collected and the research approach adopted for the study influences the selection of the survey method as it has a high level of positive contribution in analysing quantitative data and in association with the deductive approach (Saunders et al., 2016). These arguments convinced the researcher to employ the survey strategy to address the above-mentioned research questions.

3.6 Research techniques

As the research primarily employs quantitative methods along with the survey strategy, the research techniques are discussed accordingly. Research techniques can be broadly discussed under the headings: sampling techniques, data collection techniques, and data analysis techniques (Saunders et al., 2016).

3.6.1 Sample and sampling techniques

In all cases, a sample must be drawn from a population. The term ‘sample' means a specimen of the population which is drawn to show what the rest is like (Creswell, 2014). Selecting the research sample is very important and great care must be taken when choosing the type of sample design. Sampling Methods can be classified into two main categories (Creswell, 2014). They are:

- Probability sampling: the sample has a known likelihood of being selected.
- Non-probability sampling: the sample does not have a known probability of being selected (as in convenience or voluntary response surveys).

Simple random sampling, stratified sampling, cluster sampling, systematic sampling and multistage sampling are examples of probability sampling, whereas volunteer sampling and haphazard (convenience) sampling can be illustrated as non-probability sampling techniques. The sample and the sampling technique employed for each data collection technique is comprehensively described in subsequent sections.

3.6.2 Data collection procedure and techniques

Based on the nature of the collected data, either numeric or textual, data collection techniques are categorised as either quantitative or qualitative data collection tools. Furthermore, the survey strategy embraces a variety of evidence such as a questionnaire, document reviews, and interviews (Creswell, 2014; Yin, 2009). The following describes the data collection procedure and techniques used for this study.

1. Pilot study

A pilot study is essential in providing a focus mechanism to establish the research direction more clearly (Van Teijlingen and Hundley, 2001). Such test run surveys are crucial to revealing the methodological thoroughness and precision of a survey (Munn & Drever, 1990). Accordingly, there are three basic purposes of the pilot study conducted in this study.

The first focus was to refine the list of factors influencing the running costs of buildings to the local context as those that were identified through the review of the literature were in a global context. Accordingly, a questionnaire including the list of factors influencing the running costs of buildings which were found through the literature review was distributed among six (06) industry experts who engage in the operation and maintenance of commercial buildings. The experts were asked to comment on the factors that needed to be removed or added in order to proceed with the main survey. Next, an informal discussion was conducted with each expert to check the availability of the running costs' data in commercial buildings (as the second purpose of the pilot study that was conducted). A profile of experts selected for the pilot survey is presented in Table 3.2.

Table 3. 2: Profile of the experts selected to refine the factors influencing running costs of buildings

Expert code	Designation	Work experience (yrs.)	No. of commercial buildings worked for
E01	Chief Engineer	16	03
E02	Chief Engineer	14	04
E03	Facility Engineer	14	03
E04	Maintenance Engineer	12	03
E05	Facility Manager	12	03
E06	Manager Operation	12	02

As observed in Table 3.2, all the experts had more than 10 years of working experience in the field of building construction and facilities management.

The final purpose of the pilot study was to identify currently available and commonly applying index value compilation methodologies in the local context. There are only few institutes established in Sri Lanka to construct building costs indices at national level. These are these government institutes namely, Central Bank of Sri Lanka, CIDA, and Census and Statistics Department, Accordingly, a fair sample of eight (08) experts who are actively involved in the construction of indices were selected form these institutes, and informal discussions were conducted with them. A profile of the experts is presented in Table 3.3.

Table 3. 3: Profile of the experts selected to identify the methods of index construction

Expert code	Organization	Designation	Work experience (yrs.)
E07	Central Bank	Director, Department of Statistics	22
E08	Central Bank	Asst. Director, Department of Statistics	12
E09	Central Bank	Senior Statistician	08
E10	CIDA	Asst. Director (R&D)	11
E11	CIDA	Senior Statistician	07
E12	CIDA	Statistical Officer	04
E13	Census and Statistics Department	Deputy Director	23
E14	Census and Statistics Department	Senior Statistician	08

<u>Sample selection for the pilot survey</u>

The experts were selected using the snowball sampling technique as there are only a small number of experts who are equally involved in both building construction and facilities management and there are only a few organizations and professionals dealing with constructing indices at the country level.

2. Questionnaire survey

Questionnaire survey is one of the most used data collection techniques under the survey strategy. Saunders et al. (2016) suggested that a questionnaire is most appropriate to a situation where most of the questions are standardised and the researcher is confident that the questions will be interpreted in the same way by all respondents. Furthermore, the nature of the research questions, and the data that the researcher needed to collect also influenced the selection of a questionnaire survey for this study.

The questionnaire for this research study was designed by considering both the sample of respondents and the research questions. Basically, the questionnaire consisted of two sections: (1) the details on the respondents including profession (i.e. either engineering or management), designation and years of work experience and (2) a list of factors influencing the running costs of buildings followed by a five-point Likert scale: 1- Insignificant, 2- Little significant, 3- Moderately significant, 4- Very significant, and 5- Extremely significant. Accordingly, the respondents were asked to rank the level of influence of each factor presented on the running costs of commercial buildings in the local context based on their experience in the field of building operation and maintenance. Refer to Appendix 01 and 02 for the questionnaire designed for this study. The questionnaires were disseminated physically and in hard copies as it led to have an increased response rate.

Sample selection for the questionnaire survey

Respondents for the survey were selected using the non-probability sampling technique due to the convenience and time constraints. In quantitative survey design, determining sample size and dealing with nonresponse bias is necessary. According to Cohen, Manion, and Morrison (2000), if the research utilises a survey strategy, the sample size should be more than 30. Similarly, many researchers (for example, Altunisik, Coskun, Bayraktaroglu, & Yildirim, 2004; Ross, 2004; Yildirim & Simsek, 2006) opined that a sample size from 30 to 500 at 5% confidence level is generally adequate for many statistical analyses. Accordingly, a total of 185 questionnaires were administered to the target respondents (i.e. professionals involved in building construction and facilities management in commercial buildings in Sri Lanka) and a total of 143 out of 185 questionnaires were received representing a 77% response rate. However, only 135 out of the143 questionnaires were found to be useful for the analysis due to incomplete data. In line with the above concerns, 135 duly completed questionnaires received satisfied the sample required for a survey research strategy.

3. Document review

Finally, a document review was conducted to collect data relating to running costs and building characteristics as this research aims to develop a running costs' estimation model and an index for commercial buildings in Sri Lanka. Accordingly, the documents looked at included architectural drawings of buildings, utility bills, cost estimates, periodical cost databases, and occupancy reports. The standard cost elements were extracted by referring to three cost structures published by the Standards of BCIS, BS ISO 15686-5:2008, and RICS NRM 3: Order of cost estimating and cost planning for building maintenance works. Accordingly, a list of 13 main running cost elements and 64 sub cost elements covering both operation and maintenance costs were considered for data collection, but only 60 out of 64 sub cost elements together with 13 main running costs elements were utilised for the data analysis. The costs' data relating to porterage, built-in-fittings, emergency lighting, and grounds' maintenance were excluded from the data analysis as these data are not collected and maintained from the buildings considered for the study and, broadly, are not collected and maintained in Sri Lanka. (Refer to Appendix 04 for the elemental breakdown of the running costs considered for the study).

Data relating to 14 building characteristics, namely working days/week, working hours/day, functional years (i.e. years in building operation), Gross Internal Floor Area (GIFA), Net Floor Area (NFA), Circulation Area (CA), building height, number of floors, window area, Wall-to-Floor-Ratio (WFR), number of occupants (this includes only the employees of the facility and the customer/visitors to the facility are not considered due to inconsistency and no data availability), grouping of buildings (this datum was determined by observations and asking from the contacted person of each building), type of structure, and building shape of the selected commercial buildings, were extracted from the detailed architectural drawings and the handed over documentation. Refer to Appendix 03 for the template used for the collection of the building characteristics data.

Sample selection for the document review

According to the pilot survey discussions held with industry experts, it would not be possible to collect running cost data from the entire commercial building stock in Sri Lanka due to time constraints, limited access to cost data and the fact that most of the commercial buildings located in semi-urban and rural areas do not maintain running cost data. Therefore, the research population for this study had to be limited to commercial buildings located within the CMC in Sri Lanka.

The next step was to define the number of buildings which was undertaken to explore the research phenomenon. Accordingly, the sample size for the selection of commercial buildings was calculated using the equation below by (Bartlett, Kotrlik, & Higgins, 2001; Taherdoost, 2017; Taherdoost, 2016).

$$Sample\ size = ((Z^2 \times P(1-P)) \div e^2)/(1 + (Z^2 \times P(1-P) \div e^2 N))$$

where, Z = level of confidence according to the standard normal distribution (for a level of confidence of 95%, z = 1.96, for a level of confidence of 99%, z = 2.575);

P = estimated proportion of the population that presents the characteristic (when unknown we use p = 0.5);

e = tolerated margin of error (for example we want to know the real proportion within 5%); and

N= population size.

Accordingly, the statistically valid sample for this study is calculated as below.

$$Sample\ size = ((1.96^2 \times 0.5(1-0.5)) \div 0.05^2)/(1 + (1.96^2 \times 0.5(1-0.5) \div 0.05^2 \times 117))$$

$$= 90$$

Even though the calculated sample is 90, a sample of 50 out of 117 commercial buildings registered within the CMC, Sri Lanka, was primarily approached using the non-probability sampling technique due to unavailability of running costs data and time constraints. However, the data collected (and used in the analysis) came from only 46 commercial buildings due to unavailability and limited access to cost data but accepted to perform the statistical data analysis techniques (Cohen et al., 2000; Altunisik et al., 2004; Ross, 2004; Yildirim & Simsek, 2006) described in section 3.6.3.

Having outlined the data collection procedures and the techniques adopted for the study, the following sub-sections explain how the techniques were employed to analyse the data collected.

3.6.3 Data analysis techniques

The multi-quantitative choice of the methods and research questions (together with survey strategy) that were employed in the study lead to quantitative data analysis techniques. Therefore, presented below are the data analysis techniques adopted for this study.

1. Analysis of pilot survey findings

The opinions obtained from the informal discussions conducted with the experts were manually analysed. Initially, the conceptual framework of factors influencing the running costs of buildings was developed from both the literature findings and the invaluable opinions of the experts who were working in the field of building operation and maintenance. Experts' opinions were further considered to refine the list of running cost elements extracted from the BS-ISO 15686-5 (2008).

Moreover, the opinions obtained from experts who are specialised in statistics and cost indices were considered in terms of selecting the most appropriate method of constructing the running costs indices, particularly in such situation where there was less availability in the data on running costs.

2. Missing value analysis and missing value imputation

Missing value analysis is used to identify the percentage of missing values included within a data set. Accordingly, three missing value analyses were initially conducted using the Statistical Package for the Social Sciences (SPSS) version 22 software to identify the percentage of missing values within the Likert scale data, running costs data, and building characteristics data collected. Following the percentage outcomes, an appropriate missing value imputation method for each data set was selected.

Missing value imputation is a simulation-based procedure and its purpose is to handle missing data in a way to result in valid statistical inference to minimise compromising the validity and reliability of the output due to unavailability of data (Field, 2009). Basically, there are two imputation methods such as simple and multiple where the missing value imputation is only suggested to perform when there is a missing value percentage greater than 5% (Jakobsen, Wetterslev, Winkel, Lange, & Gluud, 2014).

For the pre-analysis of data, the average value of the annualised elemental running costs for each selected building was calculated and the derived annualised elemental running costs and the average annualised running costs of 46 commercial buildings were normalised by calculating the running costs per square meter of GIFA (Kantardzic, 2011) which is called as the floor area method (Ashworth, 1994; Seeley, 1996).

3. Univariate analysis

Univariate analysis used to describe one characteristic or attribute that varies from observation to observation. To describe how data pertaining to one variable varies, one could use univariate data to find the statistics that represent the center value for particular variable along with how the other values spread from that center value (Ho, 2006). A researcher would want to conduct a univariate analysis for two purposes: (1) to answer a research question that calls for a descriptive study on how one characteristic or attribute varies or (2) to examine how each characteristic or attribute varies before including two variables in a study using bivariate data or more than two variables in a study using multivariate data (Chamberlain, 2013). Therefore, in this study, univariate analyses were conducted for each data set to fulfil both the above purposes. Also, it is used to explain the population and the sample obtained numerically. Univariate statistics include numerical descriptors of the distribution under examination, measures of centrality (means, mode, median), and spread/variability (variance, standard deviation, coefficient of variation, interquartile range, range).

4. Relative Significance Index (RSI)

Relative importance index analysis allows identifying most of the important criteria based on participants' replies and it is also an appropriate tool to prioritise indicators rated on Likert- type scales (Rooshdi, Majid , Sahamir, & Ismail (2018). The statistical tools used for this study include percentage, mean, and RSI (also known as Index of Relative Importance, IRI or RII) for the evaluation of the factors affecting the O&M costs of commercial buildings and, thereby, to rank the identified factors based on the most selected response (mode value) by respondents in the survey. Johnson (2001) gave an equation that could be useful for determining the RSI in prevalence data as:

$$RSI = \sum \mu AN$$

Where μ is the weighting given to each factor by respondents; A is the highest weight (i.e. 5 in this case); N is the total number of respondents.

In detail, for this type of research work where a five-point Likert scale was used, the RSI shall be calculated via the equation:

$$RSI = \frac{5a + 4b + 3c + 4d + 5e}{5N}$$

Where: a = number of respondents stated, ‘highly significant’, b = number of respondents stated ‘significant’, c = number of respondents stated ‘neutral’, d = number of respondents stated ‘insignificant’, e = number of respondents stated ‘highly insignificant, and N = sample size (135).

5. Pareto analysis

The Pareto analysis uses the Pareto principle, also called the 80:20 rule, to analyse and display data. It is a decision-making technique that statistically separates a limited number of input factors as having the greatest impact on an outcome, either desirable or undesirable. For example, quality expert J.M. Juran applied the Pareto principle to quality control and found that 80% of problems stem from 20% of the possible causes (Craft & Leake, 2002). The numbers 80 and 20 are not meant to be absolutes. The main point, as Juran stated, is that we should focus on the “vital few” problems (those in 20% category) rather than on the "trivial many" to make the most significant improvements in product quality (Craft & Leake, 2002). Accordingly, in this study, a Pareto analysis was initially employed to identify the 20% of significant O&M costs elements which constitute the 80% running costs of commercial buildings in Sri Lanka.

6. Bivariate correlation analysis

The bivariate correlation analysis is usually conducted to identify the statistical relationship between any two variables. In this study, a bivariate correlation analysis was conducted using the SPSS to investigate the correlation of running costs with each building characteristic. The results were presented using the Pearson correlation coefficient to interpret the correlations between continuous variables, while the Spearman correlation coefficient was used for categorical variables (Göb, McCollin, & Ramalhoto, 2007). Correlation strength determination followed suggestions made by Bishesh and Banga (2016). Accordingly, the correlation coefficient 'R' is $0 < |R| < 0.3$ - weak correlation; $0.3 < |R| < 0.7$ - moderate correlation; and $|R| > 0.7$ - strong correlation, respectively.

7. Hedonic multiple linear regression modelling

Hedonic models regress the price of a product on a vector of characteristics (Leeuwen, 1995). In this study, the independent variables included 14 building characteristics: working days per week, working hours per day, the grouping of buildings, operated lifetime (yrs), NFA (m^2), circulation space (m^2), building height (m), type of structure, window area (m^2), WFR, occupancy, number of floors, GIFA (m^2), and building shape, where the average annual running costs/GIFA (m^2) served as the dependent variable.

The formula for hedonic multiple regression is presented as:

$$Y = b_0 + b_1 X_1 + b_2 X_2, \ldots b_n X + e$$

where, Y - the predicted value (dependent variable); b_0 - the "Y Intercept"; $b_1, b_2, \ldots b_n$ - the change in Y for each 1 increment change in $X_1, X_2, \ldots X_n$; $X_1, X_2, \ldots X_n$ - independent variables; and e – random error.

In regression analysis, there are several prerequisites to be tested to select the best-fit model (Field, 2009). These are,

1. Both dependent and independent variables should be the continuous form of data;
2. The relationship between the dependent variable and the independent variables as well as among the independent variables need to be linear;
3. The dependent variable should have the same variance for all the values of the independent variable (homoscedasticity);
4. The normal distribution of residual values;
5. The data series should free from significant outliers; and
6. The effect of multicollinearity should be checked after the model formulation.

Although there is no formal criterion for determining the bottom line of the tolerance value or the variation impact factor (VIF), Chatterjee and Hadi (2012) suggested that a tolerance value of less than 0.1 or VIF greater than 10 generally indicates significant multicollinearity. Additionally, the commonly used measure of the goodness of fit of a linear model is R^2 (the coefficient of determination) which ranges between 0 and -1. However, in multiple linear regression modelling, the best model is defined by its highest adjusted R^2, as it is more accurate than R^2. The hedonic multiple linear regression analysis was performed with the aid of the SPSS.

8. Hedonic price imputation for index construction

At its most general, the hedonic approach reorients the measurement problem to one related to characteristics rather than goods, which are bundles of characteristics (Aizcorbe, 2003). simply, it involves the estimation of the implicit, shadow prices of the quality characteristics of a product Hedonic techniques currently offer the most promising approach for explicitly adjusting observed prices to account for changing product quality (Heravi and Silver, 2007).

In this study, the required coefficient values for each quarter were computed via hedonic price imputation approach modelling and the coefficient value of the first quarter of 2014 was replaced with “0” as it was considered as the base quarter. Next, the logarithm exponential value of each coefficient value was computed to construct the index for all commercial buildings and a further two separate indices were developed for the running costs of office and bank facilities in Sri Lanka.

This study is the first to apply these state-of-the-art methods in developing indices for the running costs of commercial properties. This, in itself, is an important contribution, bearing in mind the pervasiveness of the missing-data problem in running costs' data sets.

3.6.4 Model validation

Finally, the model developed was validated using a new sample of commercial buildings. The validation sample has to be limited to seven (7) new buildings mainly due to less availability and difficulty in accessing running costs data. The sample includes three (3) offices and two (2) of banks and retail buildings. One of the commonly used forms of model validation is linear regression which tests whether the actual value equals the model-predicted value (Marcus & Elias, 1998). This has been further identified as a typical form of a goodness-of-fit test in model validation (Gianola et al., 2010).

3.7 Summary

This chapter has presented the research methodology adopted for the current research study along with proper justifications for the selections. The chapter initially positioned the current research in terms of the research philosophy, the approach, and the strategy adopted. Furthermore, the data collection and analysis techniques used in the current study are discussed.

In brief, for this study, a quantitative research approach followed by a survey design strategy was adopted. For the data collection, a pilot study was initially conducted to validate the running costs factors identified from literature and to understand the index compilation methods used in the national level in absence of proper documentation in this regard. Subsequently, a questionnaire survey was administered to a sample of 135 industry professionals to rank the significance of running costs factors towards the running costs of commercial buildings. In parallel, an intensive document review was conducted to extract building running costs data and building characteristics data from a 46 commercial buildings in Sri Lanka. An RSI, a Pareto analysis, a correlation analysis, and a multiple linear regression analysis together with a hedonic price imputation approach for index construction were, respectively, performed for the accomplishment of the set objectives of the study. A graphical illustrations of the flow of data analysis is presented in Figure 3.3.

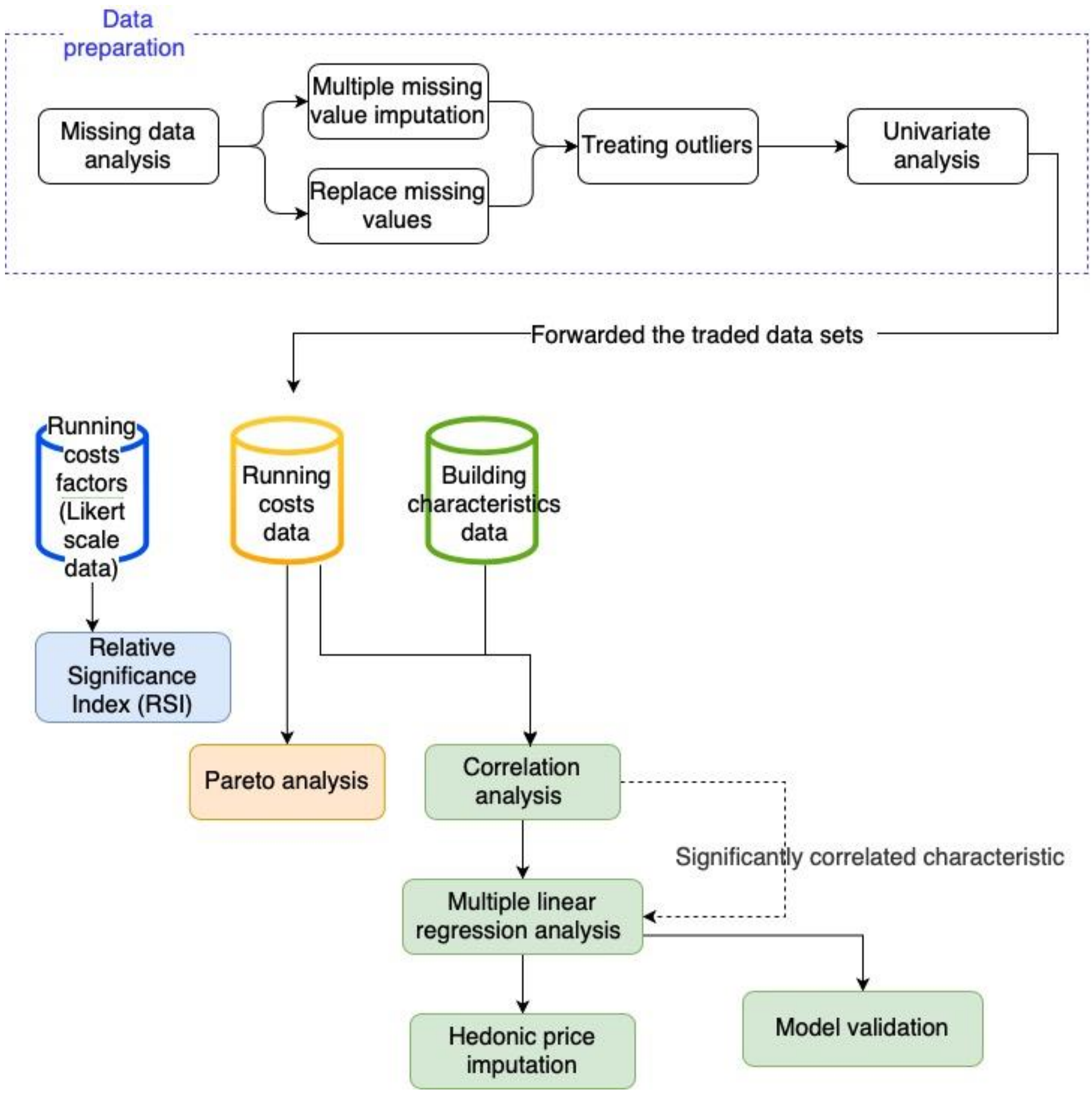


Figure 3. 3: Flow of data analysis

CHAPTER FOUR

4.0 DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter presents the results of the data analysis performed using the data collected as per the techniques discussed in the previous chapter. The analyses are presented in six main sections. Initially, the chapter presents the data preparation. This is followed by presenting the significant running cost elements of commercial buildings in the next section. The subsequent section presents the analysis of factors influencing the running costs of commercial buildings while the next section combined both running costs and building characteristics and present the correlation analysis of them. The early-stage supportive running costs estimation model developed is presented in the next section. The chapter further provides a note on the validation exercise performed for the developed model and this is followed by the running costs indices in the next section. Finally, a summary is presented highlighting the key findings of the data analysis.

4.2 Data Preparation

This section deals with the preparation of data for the analysis. The purpose of this pre-data analysis is to prepare and enhance the quality and accurateness of the data collected prior to the main data analysis. This section presents the results of the missing value analysis, the missing value imputation analysis, and the univariate analysis conducted by the SPSS. Next, the extreme values contain with each data set was checked and treated for outliers.

4.2.1 Missing value analysis

Initially, the data collected from both the questionnaire survey and the document review were converted to a machine-readable, numeric format with the use of a spreadsheet to analyse the data through SPSS. The participants' views on factors influencing the running costs of commercial buildings were collected on a 1-5 Likert scale. Both the running costs data and the building characteristics data extracted from relevant documents. These three data sets were subjected to missing value analysis.

Table 4.1 presents the univariate statistics for Likert scale data collected from 135 respondents on factors influencing the operating and maintenance costs of commercial buildings.

Table 4. 1: Univariate statistics for Likert scale data

Factors influencing running costs	**N**	**Mean**	**Std. Deviation**	**Missing**	
				Count	**Per cent**
1. Function	135	4.71	.455	0	.0
2. Location	135	4.21	1.107	0	.0
3. Building age	135	5.00	.000	0	.0
4. Building size	135	4.83	.466	0	.0
5. Building height	135	4.69	.465	0	.0
6. Type of structure	135	4.55	.709	0	.0
7. Building materials and components	135	4.79	.412	0	.0
8. Building services	135	5.00	.000	0	.0
9. Finishes	120	2.24	1.372	15	11.1
10. Occupancy	135	5.00	.000	0	.0
11. Failure to identify the true cause of defect	135	4.67	1.252	0	.0
12. Lack of preventive maintenance	135	4.44	1.577	0	.0
13. Poor workmanship	133	4.90	.298	2	1.5
14. Faulty maintenance	134	4.89	.400	1	.7
15. Low concern to future maintenance	135	4.68	1.056	0	.0
16. Failure to execute maintenance at the right time	135	4.87	.495	0	.0
17. Budget constraints	135	5.00	.000	0	.0
18. Lack of building maintenance manuals standards	135	4.96	.190	0	.0
19. Poor quality of spare parts and materials	135	4.94	.237	0	.0
20. Unavailability of the required spare parts tools and materials	135	4.84	.364	0	.0
21. Poor financial control when executing maintenance work	135	4.87	.341	0	.0
22. Poor or lack of training	135	4.80	.501	0	.0
23. Poor management by maintenance units	135	4.75	.529	0	.0
24. Unqualified and unavailability of maintenance contractors	135	4.72	.528	0	.0
25. Unavailability of skilled and educated labours	135	4.56	.760	0	.0
26. Poor incorporation of building services	135	4.70	.462	0	.0
27. Failure reporting	135	4.43	1.103	0	.0

28. Poor supervision	135	4.88	.368	0	.0
29. Architectural design defects	135	4.85	.357	0	.0
30. Poor quality control on site	135	4.75	.484	0	.0
31. Defective construction materials	135	4.65	.705	0	.0
32. Poor structural design	135	4.56	.698	0	.0
33. Lack of proper reinforcement	135	4.55	.582	0	.0
34. Site defects	132	3.88	1.027	3	2.2
35. Vandalism by tenants	135	5.00	.000	0	.0
36. Misuse of property	135	5.00	.000	0	.0
37. Expectation of Tenants	135	5.00	.000	0	.0
38. Lack of understanding the importance of maintenance work	135	4.73	.591	0	.0
39. Accessibility to the property	135	3.61	.954	0	.0
40. Existence of buy policy	135	2.77	.930	0	.0
41. Natural deterioration	135	5.00	.000	0	.0
42. Harsh climatic conditions	135	4.95	.223	0	.0
43. Health and safety regulations	135	4.70	.462	0	.0
44. Changes in operating and maintenance standards	135	4.81	.390	0	.0
45. Price inflation	135	3.81	1.288	0	.0
46. Changes in taxes and utility tariffs	135	1.00	.000	0	.0
47. Cultural practices	135	4.01	1.146	0	.0
48. Third party vandalism	130	4.72	.584	5	3.7
Total				26	

The univariate analysis results reveal that four out of forty-eight sub-factors having missing values namely finishes (15), poor workmanship (2), faulty maintenance (1), site defects (3), and third-party vandalism (5). This is 0.4% [26/(135*48)] from the complete Likert scale data collected, which is insignificant. As the potential impact of the missing data is negligible; less than 5%, no missing value imputation was carried out for Likert scale data collected (Jakobsen et al., 2014).

Similarly, the missing data analysis was performed on the running costs as well as building characteristics data collected from 46 commercial buildings in Sri Lanka and the respective univariate statistics are presented in Table 4.2 and 4.3, respectively.

Table 4. 2: Univariate statistics of the building running cost data

Cost element	N	Mean	Std. Deviation	Missing	
				Count	Per cent
Running costs	46	165,315,275.17	227768665.54	0	0.0
Operating costs	46	104,099,132.77	118618037.60	0	0.0
1. Insurance	42	7,757,709.06	14818839.14	4	8.7
2. Utility	45	62,558,760.14	75893962.41	1	2.2
3. Administrative	44	25,257,404.34	40450854.60	2	4.3
4. Taxes	36	14,896,286.94	29336521.23	10	21.7
Maintenance costs	46	61,216,142.40	169924610.44	0	0.0
5. Decoration	21	4,911,170.11	8931424.35	25	54.3
6. Fabric	43	8,494,023.42	15677072.41	3	6.5
7. Fitting and fixtures	27	1,159,684.89	1595941.25	19	41.3
8. Internal finishes	38	2,221,797.26	3205894.64	8	17.4
9. Services	45	34,695,435.48	162106165.22	1	2.2
10. Cleaning	38	15,877,639.76	53000040.94	8	17.4
11. External works	39	737,822.45	954774.23	7	15.2
12. Maintenance management	14	496,933.93	421302.13	32	69.6
13. Repair and replacement	20	1,572,406.25	4419708.37	26	56.5
Total				146	

The results show that the average running costs of a commercial building in Sri Lanka is 165,315,275.17 LKR, where the average operating costs and maintaining costs are 104,099,132.77 LKR (63%) and 61,216,142.40 LKR (37%), respectively. The table further verifies the absence of the running costs data within the industry in Sri Lanka as the missing data ranges from 2% to 70% for key cost elements comes under the operating and maintenance costs. This indicates a 24% [146/(46*13)] missing values in total. The rule of thumb is to accept missing values of less than 5% of the total data set (Jakobsen et al., 2014). Thus, this demands multiple missing value imputation of data prior to performing the main data analysis.

Table 4. 3: Univariate statistics of building characteristic data

Building Characteristics	N	Mean	Std. Deviation	Missing	
				Count	Per cent
1. Working days/week	46	5.73	0.77	0	.0
2. Working hours/day	46	8.73	3.76	0	.0
3. Functional years	46	13.20	13.15	0	.0
4. GIFA (m^2)	44	28312.43	30061.42	2	4.3
5. NIFA (m^2)	44	18765.25	18684.77	2	4.3
6. CA (m^2)	44	8270.66	8172.50	2	4.3
7. Height (m)	45	47.94	32.93	1	2.2
8. Number of floors	46	13.13	8.83	0	.0
9. Window area (m^2)	43	22858.60	29027.24	3	6.5
10. WFR	41	0.38	0.15	5	10.9
11. Number of occupants	41	1080	720.20	5	10.9
12. Shape	46			0	.0
13. Type of structure	46			0	.0
14. Grouping of buildings	46			0	.0
Total				20	

As shown in Table 4.3, 14 buildings characteristic data (i.e. 11 scale variables and 3 categorical variables) were collected from 46 commercial buildings in Sri Lanka. Amongst, the average working days/week is approximately 6 working days with a mean of 9 working hours/day. Considering the number of years, which the building is in operation, it is approximately 13 years on average. In terms of building size, the average GIFA a commercial building selected for the study is 28312.43 m^2, whereas NIFA and CA are 18765.25 m^2 and 8270.66 m^2, respectively. However, there are two missing values in each building size element. The average building height considered for this study is nearly 48 m together with 13 floors on average. Only one value is missing in building height. The window area of the selected buildings is approximately 22,859m^2 and three missing values within the data set. The average WFR of the building selected is 0.38 but contains five missing values. The number of occupants within the sample is around 1080 on average and have five missing values. All these missing values of different elements all together contribute to 3% [20/(46*14)] that is relatively low and acceptable when collecting primary data (Jakobsen et al., 2014). However, these missing values were imputed through a single imputation method as this data is to be subjected to correlation and regression analysis, which require statistically reliable data.

In addition, this study involves three qualitative building characteristics, which were converted to categorical variables by assigning numerical figures. The shape of the selected buildings was classified as regular and irregular where they represent "1" and "2", respectively. Similarly, the type of structure of the selected buildings was classified as 1=steel frame, 2=concrete, and 3=pre-cast panels. Finally, the detached and attached buildings were referred to "1" and "2", respectively. The missing value analysis claims that there are no missing values within these categorical variables.

4.2.2 Missing data imputation

Initially, the Mersenne Twister was set as the random generator and a fixed value of 2000000 was set as the starting point for multiple imputations using the random number generators function in SPSS. Next, missing value imputation analysis was conducted with the use of "Multiple imputation" function in SPSS. The five number of imputations were set in default and the automatic imputation was selected as the method for missing value imputation as this option automatically chooses the best imputation method based on a scan of the data. Finally, the imputation model and the descriptive statistics for the variable with imputed values were selected as the analysis outcomes. Table 4.4 provides the imputation specifications for running costs data imputed.

Table 4. 4: Imputation specifications

Imputation Method	Automatic
Number of Imputations	5
Model for Scale Variables	Linear Regression
Interactions Included in Models	(none)
Maximum Percentage of Missing Values	100.0%
Maximum Number of Parameters in Imputation Model	100
Imputation Method	Fully Conditional Specification
Fully Conditional Specification Method Iterations	10

The important information shown in the table above is that the model for scale variables considered in this analysis is linear regression and the method of imputation is the fully conditional specification.

The "Replace Missing Values" function under the data transformation category in SPSS software was selected and all variables were input to the new variable section. The series method was selected as the imputation method. The analysis created a "SMEAN" variable for each characteristic and this will be considered for the subsequent analysis. The results derived from the simple imputation for building characteristics data are shown in Table 4.5.

Table 4. 5: Result variables

Result Variable		No. of Replaced Missing Values	Case Number of Non-Missing Values		No. of Valid Cases	Creating Function
			First	Last		
1.	Working days/week	0	1	46	46	SMEAN(Working days per week)
2.	Working hours/day	0	1	46	46	SMEAN(Working hours per day)
3.	Functional years	0	1	46	46	SMEAN(Functional yrs)
4.	GIFA (m^2)	2	1	46	46	SMEAN(GIFA)
5.	NIFA (m^2)	2	1	46	46	SMEAN(NIFA)
6.	CA (m^2)	2	1	46	46	SMEAN(CA)
7.	Height (m)	1	1	46	46	SMEAN(Height)
8.	Number of floors	0	1	46	46	SMEAN(Floors)
9.	Window area (m^2)	3	1	46	46	SMEAN(Window area)
10.	WFR	5	1	46	46	SMEAN(WFR)
11.	Number of occupants	5	1	46	46	SMEAN(Occupancy)
12.	Shape	0	1	46	46	SMEAN(Shape)
13.	Type of structure	0	1	46	46	SMEAN(Type of structure)
14.	Grouping of buildings	0	1	46	46	SMEAN(Grouping)

4.2.3 Addressing outliers within the data

After conducting the missing value imputation, it is recommended to test for outliers within the data set. This is a prerequisite in more sophisticated techniques such as correlation, regression, and analysis of variance, to ensure the linearity and homoscedasticity nature of the input data for reliable results, but not required in RSI analysis. Therefore, in this study, the outliers were checked for both the running costs data and building characteristics data.

Accordingly, a descriptive analysis using the SPSS was conducted for each data set and saved the standardized values for each variable. Next, the standardized data variables were checked for any outliers exiting within each data set. A standard cut-off value for finding outliers are Z-scores of +/-4 or further from zero (Bors, 2018; Field, 2009). Accordingly, the standardized values (Z-scores) greater than +4 and lower than -4 were replaced with the highest value in the variable data set. This is called as "Winsorization", a method of replacing a specified number of extreme values with a smaller data value (Bors, 2031; Fernandez, 2010; Mwitondi, 2012).

Accordingly, the data relating to only the main running costs components were subjected to descriptive analysis and checked for outliers. It is to note that these main 13 running costs components were derived by transforming the sub-cost elements identified under each main cost component. Table 4.6 presents a summary of the main running cost elements found with outliers.

Table 4. 6: A summary of outliers found within the running cost data collected

Main running cost elements with outliers	**Outliers**		**Value Replaced (LKR) (Winsorization)**
	Count	**Per cent**	
1. Administrative costs	1	2%	192,553,000.00
2. Taxes	1	2%	142,929,128.00
3. Fabric	1	2%	77,974,000.00
4. Fitting and fixtures	1	2%	7,780,000.00
5. Services	1	2%	1,094,000,000.00
6. Cleaning	1	2%	316,000,000.00
7. Repairs and replacement of minor components/ small areas	1	2%	20,000,000.00
Total	7		

These outliers were resulted from 5 out of 46 selected buildings considered for the running costs data collection and replaced with winsorized value as shown in the table above.

Next, the outliers were checked within the building characteristics data collected from the same sample of 46 commercial buildings in Sri Lanka. Table 4.7 presents a summary of outliers found from building characteristics data.

Table 4. 7: A summary of outliers found within the building characteristics data

Building characteristics with outliers	Outliers		Original value	Value Replaced (Winsorization)
	Count	Per cent		
Working hours per day	3	6%	24	12
GIFA	1	2%	116538.00	76643.52
NIFA	1	2%	76026.00	50000.00
CA	1	2%	40512.00	26643.52
Window area	1	2%	211952.30	124534.19
Occupancy	2	4%	7,800	3250
Total	9			

As shown in Table 4.7, the total count of outliers within the building characteristics data set is 6, represent only a 1.4% from the total data set.

4.2.4 Univariate analysis for imputed data

After data preparation, a univariate analysis was conducted for each imputed data set. The univariate analyses conducted provide frequency distribution, central tendency, and dispersion statistics for each data set.

The central tendency measure of an ordinal scale can present by its median or mode since the mean values are meaningless. Accordingly, Table 4.8 shows the central tendency data derived for factors affecting the running costs of commercial buildings, which are ordinal in the level of measurement.

Table 4. 8: Central tendency data for factors influencing the running costs of commercial buildings

Factors	Median	Mode	Minimum	Maximum
1. Function	5.00	5.00	4.00	5.00
2. Location	5.00	5.00	2.00	5.00
3. Number of years in operation	5.00	5.00	5.00	5.00
4. Size	5.00	5.00	3.00	5.00
5. Height	5.00	5.00	4.00	5.00

6.	Type of structure	5.00	5.00	3.00	5.00
7.	Building materials and components	5.00	5.00	4.00	5.00
8.	Building services	5.00	5.00	5.00	5.00
9.	Finishes	2.00	1.00	2.00	5.00
10.	Occupancy	5.00	5.00	5.00	5.00
11.	Failure to identify the true cause of a defect	5.00	5.00	0.00	5.00
12.	Lack of preventive maintenance	5.00	5.00	0.00	5.00
13.	Poor workmanship	5.00	5.00	4.00	5.00
14.	Faulty maintenance	5.00	5.00	3.00	5.00
15.	Low concern to future maintenance	5.00	5.00	0.00	5.00
16.	Failure to execute maintenance at the right time	5.00	5.00	2.00	5.00
17.	Budget constraints	5.00	5.00	5.00	5.00
18.	Lack of building maintenance manuals standards	5.00	5.00	4.00	5.00
19.	Poor quality of spare parts and materials	5.00	5.00	4.00	5.00
20.	Unavailability of the required spare parts tools and materials	5.00	5.00	4.00	5.00
21.	Poor financial control when executing maintenance work	5.00	5.00	4.00	5.00
22.	Poor or lack of training	5.00	5.00	3.00	5.00
23.	Poor management by maintenance units	5.00	5.00	3.00	5.00
24.	Unqualified and unavailability of maintenance contractors	5.00	5.00	3.00	5.00
25.	Unavailability of skilled and educated labours	5.00	5.00	2.00	5.00
26.	Poor incorporation of building services	5.00	5.00	4.00	5.00
27.	Failure reporting	5.00	5.00	0.00	5.00
28.	Poor supervision	5.00	5.00	3.00	5.00
29.	Architectural design defects	5.00	5.00	4.00	5.00
30.	Poor quality control on site	5.00	5.00	3.00	5.00
31.	Defective construction materials	5.00	5.00	1.00	5.00
32.	Poor structural design	5.00	5.00	3.00	5.00
33.	Lack of proper reinforcement	5.00	5.00	3.00	5.00
34.	Site defects	4.00	4.00	1.00	5.00
35.	Vandalism by tenants	5.00	5.00	5.00	5.00
36.	Misuse of property	5.00	5.00	5.00	5.00
37.	Expectation of Tenants	5.00	5.00	5.00	5.00
38.	Lack of understanding the importance of maintenance work	5.00	5.00	3.00	5.00

39.	Accessibility to the property	4.00	3.00	0.00	5.00
40.	Existence of buy policy	3.00	3.00	0.00	5.00
41.	Natural deterioration	5.00	5.00	5.00	5.00
42.	Harsh climatic conditions	5.00	5.00	4.00	5.00
43.	H&S regulations	5.00	5.00	4.00	5.00
44.	Changes in operation and maintenance standards	5.00	5.00	4.00	5.00
45.	Price inflation	4.00	5.00	0.00	5.00
46.	Changes in taxes and utility tariffs	1.00	1.00	1.00	1.00
47.	Cultural practices	4.00	5.00	1.00	5.00
48.	Third party vandalism	5.00	5.00	3.00	5.56

Allowed central tendency measures for running cost data involved in this study include mean, median, or mode, as the measures of dispersion, such as range and standard deviation. This is presented in Table 4.9.

Table 4. 9: Univariate statistics for running cost data

Running costs of commercial buildings	N	Mean	Range	Std. Deviation
Running costs	46	165315275.18	1122639174.00	227768665.54
Operating costs	46	104099132.78	551685190.44	118618037.60
1. Insurance	46	2053870.61	267765260.31	34403018.35
2. Utility	46	61220619.49	338995709.74	75592753.85
3. Administrative	46	23913111.83	206659974.8	40091879.56
4. Taxes	46	16214169.17	178806473.4	35689582.73
Maintenance costs	46	61216142.40	1097800000	169924610.44
5. Decoration	46	14097162.60	149992614.94	29394284.24
6. Fabric	46	8283301.19	77764100.00	15199676.10
7. Fitting and fixtures	46	10163725.17	166111628.96	27298888.15
8. Internal finishes	46	1581082.68	29822977.77	4164402.93
9. Services	46	33842538.39	1098537831.06	160399208.54
10. Cleaning	46	11936785.94	329981282.02	48871701.30
11. External works	46	3689695.38	115972551.23	17018936.89
12. Maintenance management	46	13912789.74	664831652.51	91782110.39
13. Repair and replacement	46	43142393.43	1447860840.76	222751065.56

The same central tendency measures and dispersion measures are applied to the building characteristics data and the univariate statistics for these are presented in Table 4.10.

Table 4. 10: Univariate statistics for building characteristics data

Building characteristic (SMEAN variable)		N	Minimum	Maximum	Mean		Std. deviation statistic	Range statistics
					Statistic	Std. error		
1.	Working days/week	46	5.0	7.0	5.739	0.117	0.794	5.0
2.	Working hours/day	46	6.0	12.0	8.239	0.310	2.102	6.0
3.	Functional years	46	1	50	14.152	1.922	13.038	1
4.	GIFA (m2)	46	8485.97	76643.52	33969.871	2872.258	19480.599	8485.97
5.	NIFA (m2)	46	5536.00	50000.00	22160.956	1873.777	12708.576	5536.00
6.	CA (m2)	46	2949.97	26643.52	11808.916	998.480	6772.023	2949.97
7.	Height (m)	46	31.48	497.38	162.414	17.952	121.759	31.48
8.	Number of floors	46	3	43	13.630	1.477	10.016	3
9.	Window area (m2)	46	1144.60	124534.19	23724.177	4209.308	28548.915	1144.60
10.	WFR	46	0.03	0.68	0.360	0.023	0.156	0.03
11.	Number of occupants	46	210	3250	1440.370	130.156	882.760	210
12.	Shape	46	1	2	1.609	0.073	0.493	1
13.	Type of structure	46	1	3	1.826	0.100	0.677	1
14.	Grouping of buildings	46	1	2	1.761	0.064	0.431	1

The data prepared and presented in this section were then forwarded for the statistical analyses carried out and the results are presented in subsequent sections.

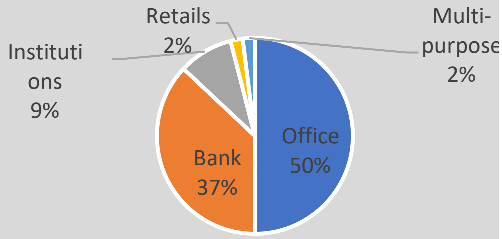
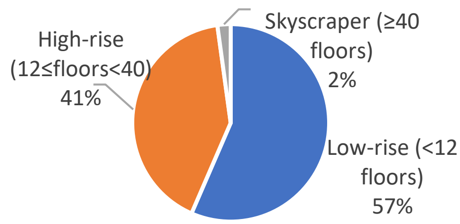
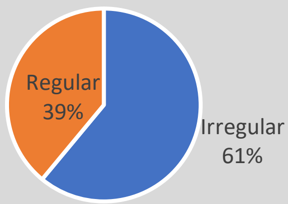
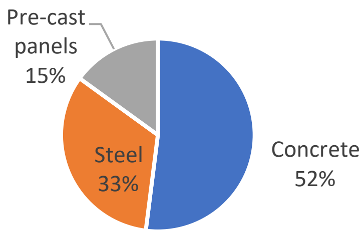
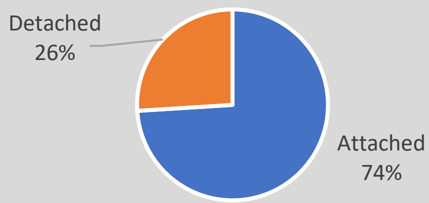
4.3 Significant running cost elements of commercial buildings

This section refers to the analysis of the running costs data to identify the significant running costs elements of commercial buildings in Sri Lanka, which is the first objective of this study. Accordingly, the running costs data collected from the sample of 46 commercial buildings were analysed using Pareto analysis. The Pareto analysis provides the salient running costs elements which contribute to a substantial share of the total running costs.

4.3.1 Profile of commercial buildings surveyed

The second part of the questionnaire survey involved collection of the running costs and building characteristics data from the selected commercial buildings by referring to the documents of architectural drawings of buildings, utility bills, cost estimates, periodical cost databases, and occupancy reports. The list of running costs elements appropriate to the local context was extracted by referring to the Standards of BCIS, BS ISO 15686-5:2008, and RICS NRM 3: Order of cost estimating and cost planning for building maintenance works. Accordingly, 50 commercial buildings based in CMC in Sri Lanka were identified for the data collection. Nevertheless, the data collected from only 46 out of 50 buildings were found to be useful and valid for the analysis due to the absence of running costs data. A detailed profile of the selected commercial buildings is presented in Table 4.11 based on its' physical characteristics.

Table 4. 11: Profile of the commercial buildings

Criteria		Quantity		Pie chart
		No.	Per cent (%)	
Function	Office	23	50	
	Bank	17	37	
	Institutions (Educational)	4	9	
	Retails	1	2	
	Multi-purpose	1	2	
	Total	46		
No. of floors	Low-rise (<12 floors)	26	57	
	High-rise (12≤flr.<39)	19	41	
	Skyscraper (≥40 floors)	1	2	
Building shape	Irregular	28	61	
	Regular	18	39	
Type of structure	Concrete	24	52	
	Steel	15	33	
	Pre-cast panels	7	15	
Grouping of buildings	Attached	34	74	
	Detached	12	26	

The profile of the commercial buildings surveyed for this study is presented as an account of their building characteristics. The profile is presented in terms of building function, the number of floors, building shape, type of structure and the grouping of buildings, which clearly describe building morphology. As shown in Table 4.11, half of the commercial buildings selected for the study are office buildings, while the remaining sample includes 37% of banks, 9% of educational institutes, and 2% of retails and multi-purpose (i.e. hotel + apartment) buildings. Further, a majority of the selected buildings (57%) have 03 to 12 floors, while 41% and 2% have 12 or more but less than 40 and 40 or more floors, respectively. Moreover, over 50% of the buildings are irregular, while the rest of the buildings are taking a regular form. In term of structure, 37% are in steel, 48% are in concrete, and 15% are in pre-cast panels. The sample can be further categorised into detached and attached buildings, representing approximately 26% and 74%, respectively.

The running costs and building characteristics data collected from these buildings were subjected to statistical analyses and the results are presented in subsequent sections.

4.3.2 Significant running cost elements of commercial buildings

The elemental running costs data collected from these buildings were then analysed to understand how the running costs of a commercial building is proportioned among the major components of operation and maintenance costs and their sub cost elements. Accordingly, Table 4.12 presents the minimum, maximum, mean, and standard deviation of the running costs of a total of 46 commercial buildings in Sri Lanka.

Table 4. 12: Descriptive statistics of collected running costs data

Running costs components	N	Minimum (LKR)	Maximum (LKR)	Mean (LKR)	Std. Deviation	Breakdown of elemental running costs as a per cent of operation / maintenance cost
Running costs	46	4,757,500.00	704,691,923.00	135,079,752.58	22210287.41	
Operational costs	46	2,024,809.56	516,546,000.00	102,036,787.08	16721011.19	
Insurance	46	35,000.00	64,000,000.00	7,757,709.06	2286596.52	8%
Utilities	46	1,200,000.00	340,000,000.00	62,558,760.14	11313603.94	61%
Administrative costs	46	42,000.00	155,389,000.00	24,412,767.98	5597242.71	24%
Taxes	46	10,000.00	85,225,225.99	13,293,400.78	3840403.44	13%
Maintenance costs	46	1,550,000.00	188,145,923.00	33,042,965.50	6523842.28	
Decoration	46	225,000.00	35,000,000.00	4,911,170.11	1948996.58	15%
Fabric	46	150,000.00	94,539,000.00	10,049,718.71	3652458.97	30%
Fitting and fixtures	46	25,000.00	3,293,300.00	993,510.81	193192.21	3%
Internal finishes	46	51,980.00	12,780,000.00	2,221,797.26	520064.78	7%
Services	46	100,500.00	65,700,000.00	11,844,324.37	2419127.52	36%
Cleaning	46	209,900.00	53,343,500.00	7,921,221.09	2036796.77	24%
External works	46	50,000.00	3,766,541.20	737,822.45	152886.23	2%
Maintenance management	46	75,000.00	1,200,000.00	496,933.93	112597.73	2%
Repairs and replacement	46	38,000.00	2,912,062.50	718,009.38	222197.20	2%

As observed in Table 4.12, the mean value of the annual running costs of a commercial building based in Sri Lankan tropical climate is nearly 135,079,753 LKR with a minimum cost of 4,757,500.00 LKR and a maximum cost of 704,691,923.00 LKR. Of which, 76% is contributed by operation costs with a mean value of nearly 102,036,787.00 LKR. The maintenance costs is responsible for the remaining 24% where the mean value is 33,042,965.50 LKR. This indicates that the ratio between the average operation costs and maintenance costs of a typical commercial building is 3:1. The operation costs is mainly contributed by utilities (61%), administrative costs (24%), taxes (13%), and insurance (8%), while maintenance costs is constituted by services, fabric, cleaning, decorations, internal finishes, fitting and fixtures, external works, maintenance management, and repairs and replacement with the percentage contribution of 36%, 30%, 24%, 15%, 7%, 3% 2%, 2%, 2%, respectively.

To identify the significant cost elements contributing to running costs of a commercial building, using the cost data presented in Table 4.12, the per-unit cost of each sub-element, its percentage contribution to total running costs, and the cumulative percentage to total running costs were calculated and presented in Table 4.13.

Table 4. 13: Distribution of running costs of commercial buildings in Sri Lanka

Running costs components	**Cost/GIFA (LKR/Sq.m)**	**Per cent**	**Cumulative per cent**
1. Utilities	4,428.67	39%	39%
2. Administrative costs	2,176.06	19%	58%
3. Services	1,636.63	14%	72%
4. Cleaning	917.89	8%	80%
5. Fabric	481.33	4%	84%
6. Taxes	464.04	4%	88%
7. Insurance	455.98	4%	92%
8. Decoration	295.00	3%	95%
9. Internal finishes	273.52	2%	97%
10. External works	118.72	1%	98%
11. Fitting and fixtures	117.56	1%	99%
12. Repairs and replacement of minor components/ small areas	67.50	1%	100%
13. Maintenance management	30.18	0%	100%
Total	11,463.08	100.0%	

As observed in Table 4.13, four (04) cost elements out of 13 have resulted in significant costs incurred during the operation phase of a commercial building and contributing to 80% of the running costs. In a different view, only 30% of the cost elements are contributing to 80% of the running costs in commercial buildings. Accordingly, utility cost is the dominant cost element, which has 39% of contribution to the running costs of a commercial building. Next, the cost incurred for administrative work, maintenance of building services, and cleaning are significantly influencing the running costs by 19%, 14%, and 8%, respectively. The graphical representation of the Pareto analysis is shown in Figure 4.1 below for further interpretations.

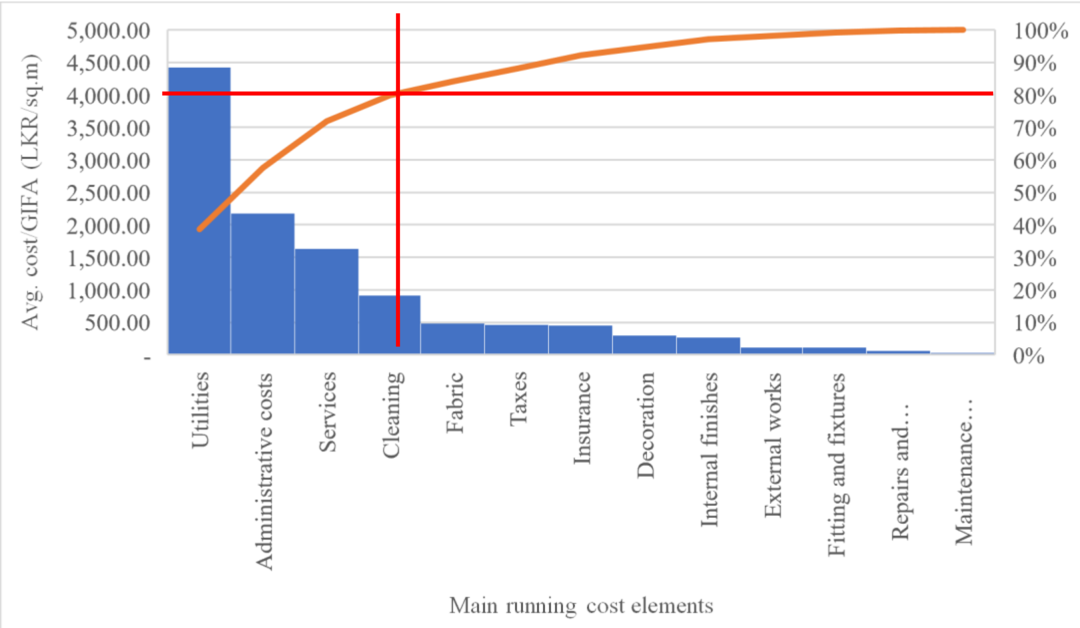


Figure 4. 1: Pareto analysis of running costs of commercial buildings in Sri Lanka

While the findings of the Pareto analysis provide how significant the contribution of these each cost element to the total running costs of a commercial building, it is yet to understand what factors influence the running costs of a commercial building. Therefore, the next section presents the analysis of the factors affecting the running costs of commercial buildings.

4.4 Factors affecting the running cost of commercial buildings

The study intended to identify the main factors as well the sub-factors influencing the running costs of commercial buildings in Sri Lanka. Accordingly, the sub-factors identified from the literature were initially forwarded for a pilot study to refine the identified list of factors according to the local context. Following the pilot study, the finalised list of factors was incorporated into the main questionnaire which was distributed to 135 professionals in the industry with the aim of identifying the relative significance of factors influencing running costs of commercial buildings using RSI. Accordingly, subsequent sections present the results of the analysis carried out in detail.

4.4.1 Pilot study findings: Factors influencing running costs of buildings

As observed from the literature review, the factors influencing the operations costs of a building may vary from the influential factors of the maintenance costs. And also, there are several other factors which are contributing to both operations and maintenance costs. These factors seem to be dependent on the regional climatic conditions, locational characteristics, and economic factors which the particular building is located. Hence, a pilot study was conducted by approaching 06 subject experts (refer Table 3.2 for experts' profile) through known contacts, in order to refine the running costs factors to the local context while seeking for specific factors to the local context.

All the pilot study participants confirmed that the list of factors presented is the key factors contributing to the growing operation and maintenance costs of commercial buildings in Sri Lanka. However, referring to the operation costs factors, all experts highlighted few other sub-factors such as number of occupants, building services, size, height, and function under the main category of building characteristics. In addition, four (04) of the experts (E01, E02, E03, E05) elaborated, the poor quality of materials and components, unavailability of skilled and educated building operation staff, and inconsistency of failure reporting procedure, which belong to the main category of managerial factors not only influencing the maintenance costs but also the operation costs of a building, though the literature suggests that these factors are responsible for the maintenance costs. Further, the poor incorporation of building services, which is part of the design and construction defects was identified as another contributor to the operation costs of commercial buildings in Sri Lanka since it has a significant influence on utility cost of a building (E01, E02, E03). Moreover, all the experts were of the view that expectations of tenants tend to influence the operation costs of a building. For example, the comfort level can vary from person to person, thus the required level of air conditioning, ventilation and lighting, varying contribution to utility cost and consequently, the operation costs. According to experts, harsh climatic conditions influence the operation costs of a building, especially in high temperature and humid levels, and rainy seasons due to environmental changes. Finally, cultural practices have been identified by four (04) experts (E02, E04, E05, E06) as a variable influencing the operation costs due to the impact of personal behaviour and clothing etc.

However, none of the experts opined new sub-factors to the maintenance costs factors thus, confirmed the list of sub-factors which contribute the maintenance costs.

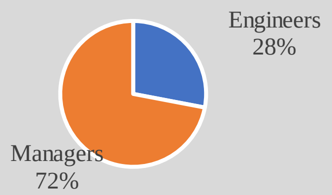
Therefore, the pilot study offered eight (08) major determinants of the running costs with the 24 and 46 sub-factors contributing to the operations costs and maintenance costs, respectively. The detailed analysis of the relative significance of these sub-factors to the total running costs is presented in the next section.

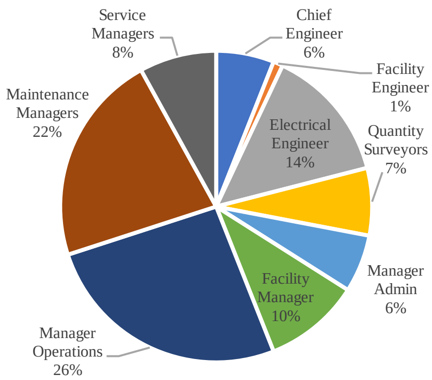
4.4.2 Profile of the survey respondents

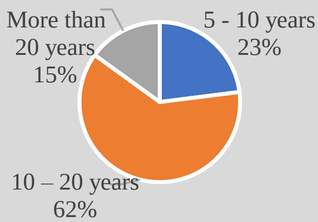
Followed by the pilot study, the main questionnaire, which consists of 48 sub-factors under the eight (08) major factors, was administered among 165 well-experienced representatives of the building operations and maintenance management within commercial buildings in Sri Lanka, who formed a fair sample of various professions and designations involved with building operations and maintenance. As shown in Table 4.1, out of the 142 responses received and 135 were found to be useful and valid for the analysis. The response rate was high (76%) probably due to the reason that most of the questionnaires were hand-delivered to the respondents with their consents obtained over the telephone and with formal appointments made. Further, all the respondents possess more than 5 years of experience in building operations and maintenance. The profile of survey respondents based on their profession, designation, and work experience is presented in Table 4.14.

Table 4. 14: The demographic profile of survey respondents

Criteria		**Respondents No.**	**%**	**Graphical Representation of Criteria**
Profession	Engineers	35	28	
	Managers	90	72	
Designation	Chief Engineer	08	06	
	Facility Engineer	01	01	
	Electrical Engineer	17	14	
	Quantity Surveyor	09	07	
	Manager Admin	08	06	
	Facility Manager	12	10	
	Manager Operation	32	26	
	Maintenance Manager	28	22	
	Service Manager	10	08	
Work experience	5≤ years≤10	29	23	
	10<years≤20	77	62	
	20<years	19	15	







As shown in Table 4.14, most of the respondents are managers (72%), while 28% of respondents are from the engineering discipline. In detail, managers include 26% of Manager Operations, 22% of Maintenance Managers, 10% of Facility Managers, 8% of Service Managers, and 6% of Admin Managers. Further, four types of designations including Electrical Engineers (14%), Quantity Surveyors (7%), Chief Engineers (6%), and Facility Engineers (1%) cover the engineering profession. In terms of work experience in the field of building operations and maintenance, majority of the respondents hold 10 to 20 years of experience, while 23% and 15% of respondents have less than 10 years and more than 20 years of work experience.

The ordinal data gathered from these respondents were then analysed using the weighted average mean and developed an RSI for factors influencing running costs of commercial buildings, is presented in the next section.

4.4.3 The relative significant index for factors influencing the running costs of commercial buildings

The respondents were asked to indicate the level of significance of each sub-factor to the running costs of commercial buildings in Sri Lanka, based on a five-point scale where, 1-Highly insignificant, 2-Insignificant, 3-Neither, 4-Significant and 5-Highly significant. However, some of the respondents do not respond to some of the factors as they do not have any idea over particular factors. The respondents' views were analysed using the RSI to rank the significance of these factor on the running costs of commercial buildings. Accordingly, the RSI formula was used to rank the factors based on the weighted mean of respondents' opinions. The results of the RSI for the factors influencing running costs of commercial buildings is presented in Table 4.15.

Table 4. 15: Relative significance index for factors influencing the running costs of commercial buildings

Main factor and Sub-factors	N (out of 135)	Mode	RSI	Rank
Environmental factors			**0.996**	
• Natural deterioration	135	5	1.000	1
• Harsh climatic conditions	135	5	0.992	2
Maintenance factors			**0.988**	
• Failure to identify the true cause of a defect	118	5	1.000	1
• Lack of preventive maintenance	113	5	1.000	1
• Faulty maintenance	123	5	0.984	2
• Poor workmanship	124	5	0.984	2
• Low concern for future maintenance	119	5	0.982	3
• Failure to execute maintenance at the right time	135	5	0.978	4

Managerial factors			**0.966**	
• Budget constraints	135	5	1.000	1
• Lack of building maintenance manuals standards	135	5	0.995	2
• Poor quality of spare parts and materials	135	5	0.989	3
• Unavailability of the required spare parts tools and materials	135	5	0.971	4
• Poor financial control when executing maintenance work	135	5	0.971	4
• Poor or lack of training	135	5	0.968	5
• Poor management by maintenance units	135	5	0.957	6
• Unqualified and unavailability of maintenance contractors	135	5	0.954	7
• Unavailability of skilled and educated labours	135	5	0.928	8
• Ineffective failure reporting procedure	120	5	0.925	9
Building characteristics			**0.952**	
• Building age	135	5	1.000	1
• Building services	135	5	1.000	1
• Occupancy	135	5	1.000	1
• Building size	135	5	0.973	2
• Building materials and components	135	5	0.957	3
• Function	135	5	0.942	4
• Building height	135	5	0.936	5
• Type of structure	135	5	0.915	6
• Location	135	5	0.842	7
• Finishes	110	1	0.453	8
Design and construction defects			**0.942**	
• Poor supervision	135	5	0.974	1
• Architectural design defects	135	5	0.971	2
• Poor quality control on-site	135	5	0.946	3
• Poor incorporation of building services	135	5	0.942	4
• Defective construction materials	135	5	0.930	5
• Poor structural design	135	5	0.918	6
• Lack of proper reinforcement	135	5	0.912	7
• Site defects	122	4	0.787	8
Social factors			**0.886**	
• Third-party vandalism			0.948	1
• Cultural practices			0.824	2

Tenant factors			**0.883**	
• Vandalism by tenants	135	5	1.000	1
• Misuse of property	135	5	1.000	1
• Expectation of Tenants	135	5	1.000	1
• Lack of understanding the importance of maintenance work	135	5	0.955	2
• Accessibility to the property	122	3	0.746	3
• Existence of buy policy	116	3	0.595	4
Political factors			**0.730**	
• Changes in operation and maintenance standards	135	5	0.963	1
• Health and safety regulations	135	5	0.944	2
• Price inflation	117	5	0.814	3
• Changes in taxes and utility tariffs	135	1	0.200	4

The running costs of offices based in Sri Lanka are basically influenced by environmental factors (0.996), and then by maintenance factors (0.988), managerial factors (0.966), building characteristics (0.952), building design and construction defects (0.942), social factors (0.886), tenant factors (0.883), and political factors/regulatory requirements (0.730), respectively.

Sub-factors with RSI of 1.000

According to the overall significance of sub-factors shown in Table 4.15, natural deterioration under the environmental factors; failure to identify the true cause of a defect, and lack of preventive maintenance as maintenance factors; insufficient fund under the managerial factors; vandalism by tenants, misuse of property, and expectation of tenants stated under the tenant factors; and building services, building age, and occupancy as building characteristics have resulted with maximum RSI (1.00) indicating that these factors are 100% contributing to the running costs of commercial buildings.

In more detail, deterioration of a building can occur either as natural deterioration or as forced deterioration. Natural deterioration defines as physical wear that occurs even though the building is used and maintained properly. It could occur due to various reasons basically, continuous usage of building and exposure to normal environmental. The speed or frequency of natural deterioration can be reduced only by way of enhancing the inherent reliability of building. If people attached to the building maintenance works failed to detect the true cause of the defect that could end up with unnecessary corrective actions, incurring unnecessary costs for maintenance, where the defect remains seeking for required maintenance. Further, not practising strategic maintenance methods such as preventive and predictive maintenance lead to excessive maintenance works and increased breakdown time and labour costs, which ultimately result in decreased productivity. As Sri Lanka is a country, which has a developing economy, the insufficient fund has become a key issue in many aspects. This has found most in other developing countries such as Nigeria, Kenya and Malaysia due to less attention and budget allocations for building maintenance work (Olayinka and Owolabi, 2015; Omari, 2015; Kerama, 2013). Three sub-factors out of six identified under the tenant factors have obtained RSI of 1.000 indicating that the demand made by tenants for a better lifestyle or a living environment is rapidly increasing. This phenomenon has led to the need for maintenance and a corresponding rise in operation and maintenance costs. Building services, which gives life to a building structure has an immense impact on building maintenance. For example, a building cannot be converted to a place where humans can be occupied, i.e. office, without building services such as plumbing, electricity, telecommunication, housekeeping, and security etc. Thus, the proper maintenance of these building services directly affects the performance of the building and smooth functioning of the building operations although it is a significant portion of the total building running costs. And also, it is apparent that any property deteriorates as it is aged and thus, required necessary maintenance to upgrade its quality in many aspects; for buildings, in performance, safety and market value. However, none of the design and construction defects, political factors or regulatory requirements, and social factors have resulted with relative important score equals to 1.000 thus, indicate these determinants have comparatively less influence upon the running costs of commercial buildings.

Sub-factors with RSI of 0.900s

The second most important sub-factor influencing the running costs is the lack of building maintenance manuals, standards, and specifications (0.995). Building maintenance manuals, standards and specifications are set of technical documents, which provides accurate information and guidance on techniques, methods, and equipment to be used during building maintenance works. Following these guidelines leads to correct maintenance at the right time, consequently, reduce the repetitive maintenance costs and performance failures. Harsh climatic conditions (0.992) is ranked as the third influential sub-factor accounting for running costs of commercial buildings. The poor quality of spare parts and materials (0.989) was ranked as the fourth, thus, supporting the findings of El-Haram and Horner (2002), and N. De Silva et al. (2012). It is absolute that the use of less quality spare parts occurs frequent replacements incurring additional costs on the same task. Although delay and failure in reporting problems (0.987) is not highlighted by previous investigations, respondents have identified this as the fifth sub-factor accounts for running costs of commercial buildings. If tenants/occupants are reporting experiencing issues at its early stage, most of the time it could be corrected through fewer costs and effort. Otherwise, it could be converted to a massive issue, where it is required to spend a reasonable amount of money.

Except aforementioned sub-factors ranked up to five, the respondents identified an extensive set of sub-factors influencing the running costs of commercial buildings. Few of them are poor workmanship (0.9840), faulty maintenance (0.9840), low concern to future maintenance (0.9824), failure to execute maintenance at the right time (0.981), poor supervision (0.974), architectural design defects (0.974), unavailability of the required spare parts, tools and materials (0.971), poor financial control when executing maintenance work (0.971), building size (0.971) and changes in legislation (0.971), respectively.

Sub-factors with RSI of 0.899 to 0.500

Except for finishes and changes in taxes and utility tariffs, all the other sub-factors (46) are resulted with an RSI of above 0.500, indicating that those factors are highly contributing to the running costs of commercial buildings.

Accordingly, the running costs of a commercial building based in a developing country and a tropical climate like Sri Lanka is influenced by 48 sub-factors under eight main factors, outlined as shown in Figure 4.2. In this figure, the factors have been clustered into three: (1) operations cost factors; (2) maintenance costs factors; (3) factors common to both operations and maintenance costs, of commercial buildings, based on the findings of both literature review and the pilot study conducted.

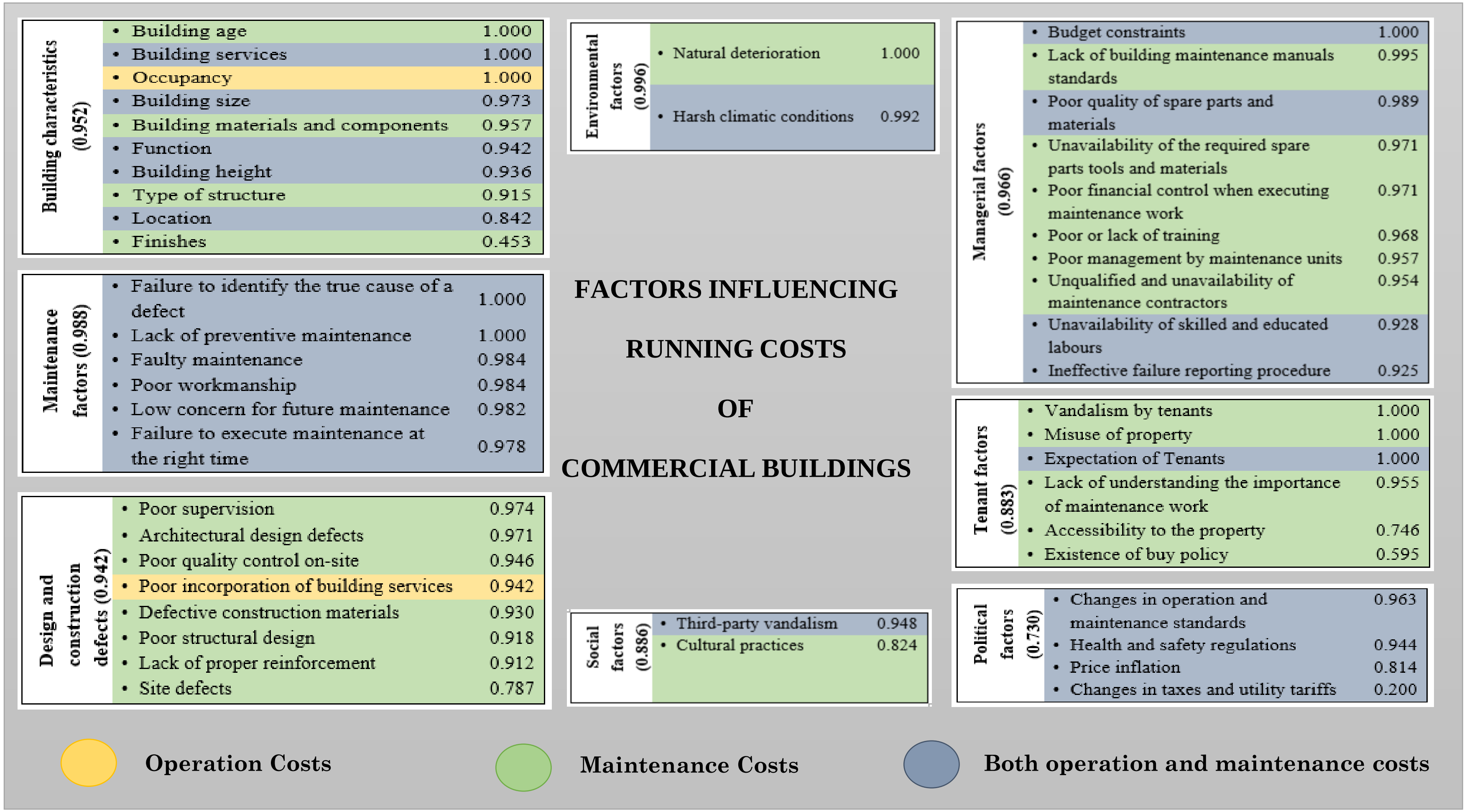


Figure 4. 2: Factors influencing running costs of commercial buildings

As per Figure 4.2, there are sub-factors which commonly influencing both operation and maintenance costs while there are specific factors affecting operation and maintenance costs. Accordingly, altogether 22 sub-factors which influence both operation and maintenance costs while the operation costs and maintenance costs are specifically influenced by 2 and 24 sub-factors, respectively.

4.5 Correlation analysis of building characteristics and the running costs of commercial buildings

The building characteristics were correlated with the running costs of commercial buildings to explore the relationship between running costs and building characteristics of commercial buildings with the target of accomplishing the third objective of the study. Accordingly, the data related to scale independent variables such as working days/week, working hours/day, operated years, GIFA, NFA, CA, building height, number of floors, window area, WFR, and occupancy were correlated using the Pearson correlation coefficient and other three nominal independent variables: building shape, type of structure, and grouping of buildings were correlated using the Spearman correlation coefficient. The results derived from the correlation analysis are presented in Table 4.16 together with correlation coefficient values and two-tailed significance values.

According to the correlation coefficients and the significance of correlations at 5% and 1% confidence levels, there exist nine (9) statistically significant and positive correlations including five (5) strong, and four (4) moderate correlations between building characteristics and running costs.

Table 4. 16: The correlation between building characteristics and running costs of commercial buildings

Building Characteristic		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
A. Working days/week	Pearson Correlation	1													
	Sig. (2-tailed)														
B. Working hours/day	Pearson Correlation	.659**	1												
	Sig. (2-tailed)	0.000													
C. Operated yrs.	Pearson Correlation	-0.182	0.134	1											
	Sig. (2-tailed)	0.227	0.376												
D. Gross Internal Floor Area (m^2)	Pearson Correlation	0.143	.463**	.407**	1										
	Sig. (2-tailed)	0.342	0.001	0.005											
E. Net Floor Area (m^2)	Pearson Correlation	0.143	.463**	.407**	1.000**	1									
	Sig. (2-tailed)	0.342	0.001	0.005	0.000										
F. Circulation Area (m^2)	Pearson Correlation	0.143	.463**	.407**	1.000**	1.000**	1								
	Sig. (2-tailed)	0.342	0.001	0.005	0.000	0.000									
G. Building height (m)	Pearson Correlation	0.109	.462**	.458**	.930**	.930**	.930**	1							
	Sig. (2-tailed)	0.472	0.001	0.001	0.000	0.000	0.000								
H. Number of floors	Pearson Correlation	0.111	.464**	.446**	.933**	.933**	.933**	.993**	1						
	Sig. (2-tailed)	0.465	0.001	0.002	0.000	0.000	0.000	0.000							
I. Window area (m^2)	Pearson Correlation	0.016	.307*	0.123	.478**	.478**	.478**	.493**	.500**	1					
	Sig. (2-tailed)	0.914	0.038	0.415	0.001	0.001	0.001	0.000	0.000						
J. Window-to-Floor-Ratio	Pearson Correlation	0.019	0.221	0.188	0.132	0.132	0.132	0.159	0.150	0.115	1				
	Sig. (2-tailed)	0.900	0.140	0.211	0.383	0.383	0.383	0.290	0.321	0.447					
K. Occupancy	Spearman Correlation	-0.038	0.257	.312*	.631**	.631**	.631**	.662**	.652**	.391**	0.249	1			
	Sig. (2-tailed)	0.800	0.085	0.035	0.000	0.000	0.000	0.000	0.000	0.007	0.095				
L. Shape	Pearson Correlation	-0.011	-0.103	-0.091	-0.133	-0.133	-0.133	-0.087	-0.102	0.004	0.049	-0.094	1		
	Sig. (2-tailed)	0.942	0.494	0.549	0.377	0.377	0.377	0.563	0.501	0.978	0.747	0.532			
M. Type of structure	Spearman Correlation	-0.045	0.203	0.207	0.073	0.073	0.073	0.095	0.102	-0.142	0.055	0.165	-0.142	1	
	Sig. (2-tailed)	0.767	0.177	0.167	0.629	0.629	0.629	0.531	0.501	0.347	0.716	0.274	0.347		
N. Grouping of buildings	Spearman Correlation	-0.186	-0.126	0.066	-0.208	-0.208	-0.208	-0.189	-0.165	-0.061	0.214	-.348*	-0.136	-0.222	1
	Sig. (2-tailed)	0.215	0.405	0.663	0.166	0.166	0.166	0.208	0.273	0.688	0.154	0.018	0.367	0.138	
Average running cost/ m^2	Pearson Correlation	0.082	.336*	.452**	.943**	.943**	.943**	.945**	.950**	.430**	0.085	.586**	-0.091	0.056	-0.165
	Sig. (2-tailed)	0.590	0.023	0.002	0.000	0.000	0.000	0.000	0.000	0.003	0.576	0.000	0.548	0.712	0.273

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Positive strong correlations

The correlation analysis indicates a strong and positive correlation between running costs and each of the building characteristics of the number of floors, building height, GIFA, NFA, and CA. The height of the building and number of floors having a strong positive correlation with the coefficients of 0.945** and 0.950**, respectively, indicate that increase of either building height and/or the number of floors may result in a significant increase of running costs of commercial buildings. Further, the number of floors is the most correlated building characteristic than the height, which is the second topmost. In a new light, it is obvious that building height and number of floors are interrelated building characteristics as the building height increases with the increase of the number of floors but vice-versa may not be the case always.

Similar to building height and number of floors, it is clear that GIFA, NFA, and CA are interconnected parameters as one GIFA equals the addition of NFA and CA. Accordingly, the third-highest correlation value with the running costs is derived for GIFA, NFA, and CA which is 0.943** with a two-tailed significance of 0.000 at the 0.01 confidence level. These results indicate that the running costs of commercial buildings are highly correlated with GIFA than NFA and CA. With these results, the running costs can be increased with an increase of GIFA and/or NFA, and/or CA of that building. Simply, it is concluded that the running costs of a commercial building is highly and positively influenced by its area.

However, it should be noted that there exist another set of correlations between these building characteristics itself, as evidenced from Table 4.16. For example, the building height is positively, strongly correlated with the number of floors (0.993**) and building area (0.930**) which refers to GIFA, NFA, and CA. Also, there is a positive, strong correlation of the number of floors with GIFA, NFA, and CA in correlation coefficients of (0.993**), (0.930**), (0.993**), respectively. Besides, a 100% positive correlation can be seen among building area measures such as GIFA, NFA, and CA. These intercorrelations may lead to a multicollinearity effect which needs to be carefully addressed in cost model development. Therefore, the effects of these intercorrelations were statistically checked and presented in section 4.6.

It is important to note that all these correlations and intercorrelations are of 0.000 two-tailed significance value which indicates that these relationships are of 100% significance. However, most of the experts in the field of statistical analysis are of the view that these three percentage digit significance statistics do not reflect the exact significance of correlation values; thus, cannot expect a 100% significance but approximately.

Followed by the correlation analysis, a detailed analysis was performed to see closer scrutiny of the relationship between strongly correlated building characteristics and running costs and the results are presented in Table 4.17.

Table 4. 17: A detailed scrutiny of highly correlated building characteristics

Building characteristic	**Classification**	**Mean running costs/GIFA (LKR/m^2)**
Building height	Low-rise (<35m)	190.53
	High-rise (35≤H<100m)	1,776.81
	Skyscraper (≥100m)	5,682.01
Number of floors	Low-rise (<12 floors)	2,073.24
	High-rise (12≤flr.<39 flr.)	6,405.79
	Skyscraper (≥40 floors)	6,405.79
GIFA	Less than 10,000	12,292.12
	10,000 to 40,000	3,094.64
	40,000 to 80,000	879.20
NFA	Less than 10,000	3,094.64
	10,000 to 30,000	7,791.64
	30,000 to 60,000	879.20
CA	Less than 5,000	3,133.37
	5,000 to 15,000	8,547.05
	15,000 to 30,000	879.20

As observed in Table 4.17, the highly correlated building characteristics were classified into several ranges to understand the behaviour of running costs with respect to changes in this building design variables. Accordingly, the mean running costs of a low-rise commercial building for a per GIFA (sq.m) is approximately 191 LKR, while it is nine (9) and 30 times greater in high-rise and skyscraper commercial buildings, respectively. A similar building classification can be done using the number of floors.

In this case, a commercial building with less than 12 floors accounts for a nearly 2073 LKR of running costs per unit area of GIFA and an increasing running costs of nearly three (3) and six (6) times of this can be observed in high rise and skyscraper buildings. Furthermore, the ratio among per GIFA running costs of a commercial building with less than 10,000 m^2: 10,000 to 40,000 m^2: 40,000 to 80,000 m^2 is 1:4:9, which indicates a rise in running costs with respect to increasing GIFA. A much similar ratio can be seen in both NFA and CA. It is similar for both NFA and CA which is 1:4:10 with different criteria as less than 10,000 m^2: 10,000 to 30,000 m^2: 30,000 to 60,000 m^2 and less than 5,000 m^2: 5,000 to 15,000 m^2: 15,000 to 30,000 m^2 for NIFA and CA, respectively. The detailed analysis clearly shows the behaviour of running costs among different ranges of each building characteristic while confirming the positive relationship of these building characteristics with running costs.

Positive moderate correlations

The correlation analysis further revealed three moderate and positive correlations between building characteristics and running costs of commercial buildings. Accordingly, the running costs shows the highest, moderate and positive correlation with the occupancy (0.586**) while operated years, window area, and working hours/day have correlation values of 0.452**, 0.430**, and 0.336*, respectively. These results indicate that any increase in the number of occupants, operated years, window area, and working hours/day may increase the running costs of commercial buildings. Further, the significance values resulted indicate that the associations of these variables with the running costs are statistically significant as these have p values lesser than 0.05.

Similar to the intercorrelations observed among highly correlated building characteristics, there are another set of correlations among above-discussed moderately correlated variables. For example, the occupancy is positively, moderately correlated with GIFA, NFA, and CA in a correlation value of 0.631**. The number of occupants located in a building has a direct relationship with its GIFA and NFA, as a standard area should allocate for each occupant in a building. The occupancy if further correlated positively, moderately with building height (0.662**) and the number of floors (0.652**). New occupants can accommodate inside a building with

the increase in building height due to the addition of new floors. This is reflected by the strong correlation between the building height and number of floors explained above. In addition, the occupancy is negatively correlated with the grouping of buildings
(-.348*) whereas it is positively correlated with the operated years. These statistical correlations are also hard to evident and justify in the practical context. Window area, one of the moderately correlated building variables with the running costs, shows two intercorrelations. Here, the window area is positively correlated with occupancy (0.391**) and working hours/day (0.307*). Even though it is hard to justify these relationships, it is believed that having more windows provides good ventilation for its occupants and as a result of that can accommodate many people.

The same detailed analysis was repeated for the moderately correlated building characteristics. The results are presented in Table 4.18.

Table 4. 18: A detailed scrutiny of moderately correlated building characteristics

Building characteristic	**Classification**	**Mean running costs/GIFA (LKR/m^2)**
Occupancy	≤1000	2,698.22
	1001 - 2000	4,271.51
	2001 - 3000	7,090.95
Operated years	First 10 years	2,686.85
	11 - 25 years	5,632.91
	26 - 50 years	6,306.67
Window area	Less than 10000	2,409.98
	10,000 to 50,000	4,633.56
	50,000 to 100,000	8,820.64
	Greater than 100,000	6,988.36
Working hours/day	Less than 8 hrs.	4,460.89
	8 hrs. (standard)	3,189.88
	More than 8 hrs.	3,963.64

Accordingly, the number of occupants (occupancy) is classified into three based on the minimum and the maximum number of occupants in the selected buildings. The running costs of a building with less than 1000 occupants is around 2,698.22 LKR, while it is two (2) and three (3) times higher in buildings with 1001 – 2000 and 2001 – 3000 occupants, respectively. Based on the number of years that a building is in its operations; it seems that first 10 years account for lesser running costs than next

15 and 25 years (26 – 50) in a ratio of 1.0:2.1:2.3. Next, the window area is classified into four ranges and the variations in running costs is as 1:2:4:3 for buildings with window area (m2) less than 10000: 10000 to 50000: 50000 to 100000: greater than 100000. Similar to most of the countries, the daily working hours in commercial buildings located in Sri Lanka can be mainly classified into three: less than eight hours; eight hours; more than eight hours. The detailed inspection shows that eight hours working day, which is the normal standard time, is the most optimum in terms of running costs (3,189.88 LKR), where it shows 40% and 24% increase in running costs for buildings working less than 8 hours and more than 8 hours, respectively.

Having established these correlations of building characteristics with running costs of commercial buildings and intercorrelations among building characteristics, the study further extends to develop the model for estimating running costs of a commercial building in Sri Lanka to accomplish the fourth objective set for the study.

4.6 An early-stage supportive model for the estimation of running costs in commercial buildings

This section presents the development of the multiple linear regression model for the prediction of running costs of commercial buildings. In developing the model, the following steps were followed as described in the research methodology.

Firstly, both dependent and independent variables should be the continuous form of data. In this study, the dependent variable, which is running costs/sq.m and independent variables including working days/week, working hours/day, functional years, GIFA, NFA, CA, building height, number of floors, window area, WFR, and number of occupants are scale data. In addition, three dummy variables namely, the building shape (1=Regular, 2=Irregular), the grouping of buildings (1=Detached, 2=Attached), and type of structure (1=Steel frame, 2=Concrete, 3=Pre-cast panels) were added to the analysis to represent the nominal data collected. Therefore, satisfied the first assumption.

Next, the relationship between the dependent variable and the independent variables as well as among the independent variables need to be linear. Accordingly, a scatterplot analysis was conducted between each independent variable and the dependent variable and the charts derived are presented in Figure 4.3.

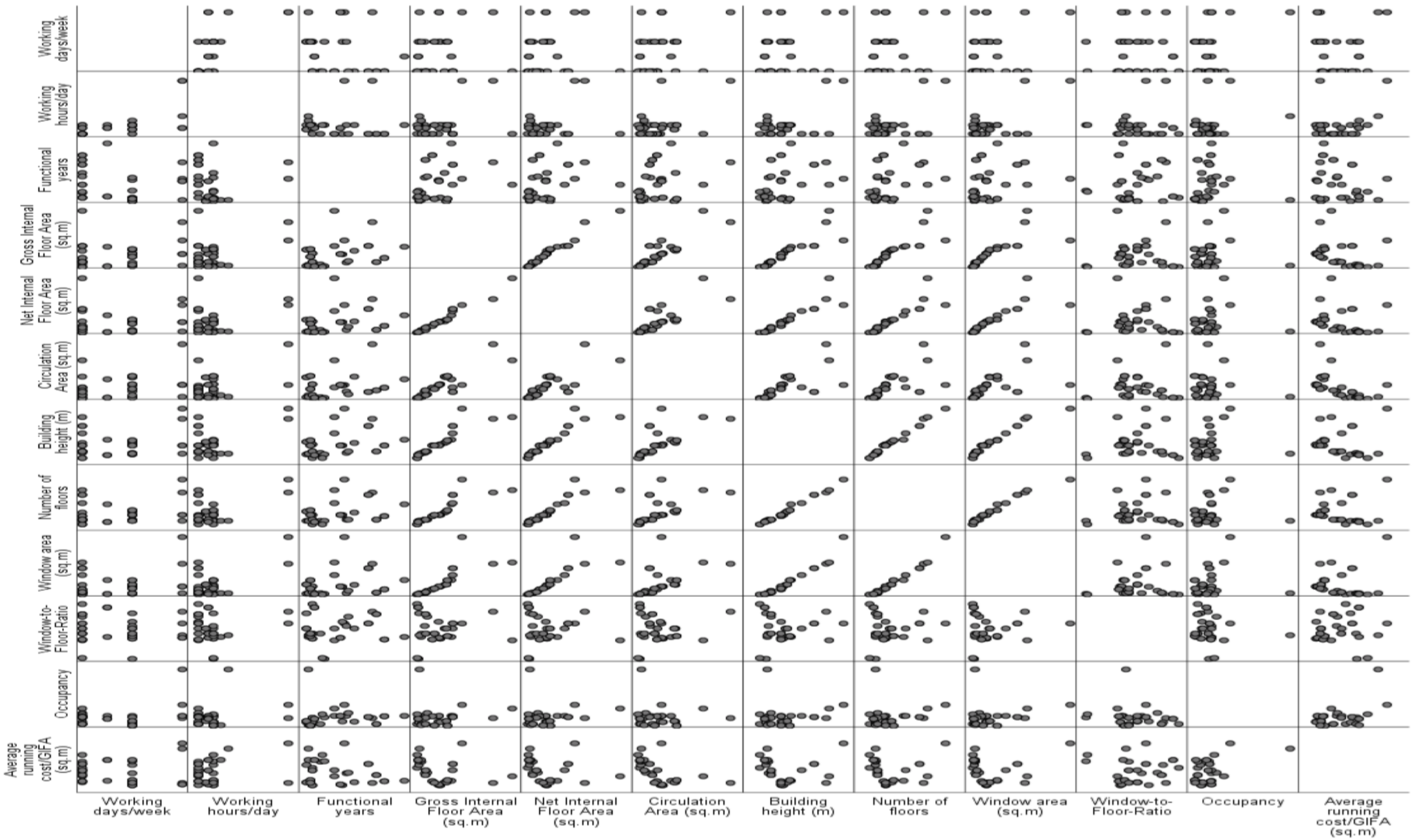


Figure 4. 3: Scatterplot matrix for the relationship between the dependent variable and the independent variables

As shown in the scatterplot matrix, five (5) out of 11 continuous independent variables represent strong linear relationships with the independent variable including GIFA, NFA, CA, building height, and the number of floors. Although other six (6) independent variables do not represent strong linear relationships with the dependent variable as the points are more scattered and it is observed that the points are trying to gather along the diagonal. Accordingly, it is concluded that all the independent variables have linear relationships with the dependent variable, thus satisfied the second assumption.

In third, the dependent variable should have the same variance for all the values of the independent variable (homoscedasticity) (Field, 2009). This can be checked via the scatterplot chart drawn between the regression ZRES and the regression standardised predicted (ZPRE) value shown in Figure 4.4.

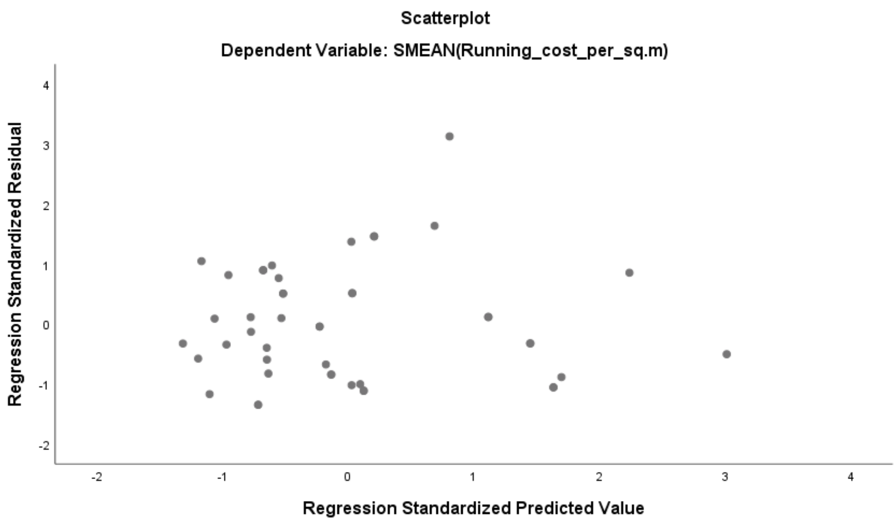


Figure 4. 4: The scatterplot chart between the regression ZRES and the regression standardized predicted value

If the points are uniformly spread over the chart area without taking any shape, it is said that there is situational homoscedasticity (Field, 2009), which needs to fulfil to carry out a regression analysis. According to Figure 4.4, regression data values between ZRES and ZPRE are uniformly distributed within the plot area thus, the dependent variable has the same variance for all the values of the independent variables.

Next, the Shapiro-Wilk normality test was conducted to explore the normal distribution of residual values. If the significance of the standardized residual (ZRESI) is greater than 0.05 it indicates that the ZRESI is normally distributed (Field, 2009).

Table 4. 19: Test of normality: Shapiro-Wilk (with 46 cases)

	Statistic	df	Significance
Standardized Residual	0.939	46	0.017

As observed in Table 4.19, the significance of ZRES is 0.017; this indicates that the data set includes an extreme value(s). The Extreme Values table (Table 4.20) plays from the analysis shows the highest and lowest extreme values.

Table 4. 20: Extreme values of standardized residuals

			Case Number	Value
Standardized Residual	Highest	1	6	3.12792
		2	8	1.63685
		3	13	1.46096
		4	41	1.46096
		5	10	1.37188
	Lowest	1	46	-1.34714
		2	23	-1.34714
		3	33	-1.16956
		4	39	-1.11263
		5	9	-1.11263

From all extreme values shown in Table 4.20, case number 6 results in a highly extreme value which is over 3. This can be visually represented by the Normal Q-Q plot of the standardized residual chart shown in Figure 4.5.

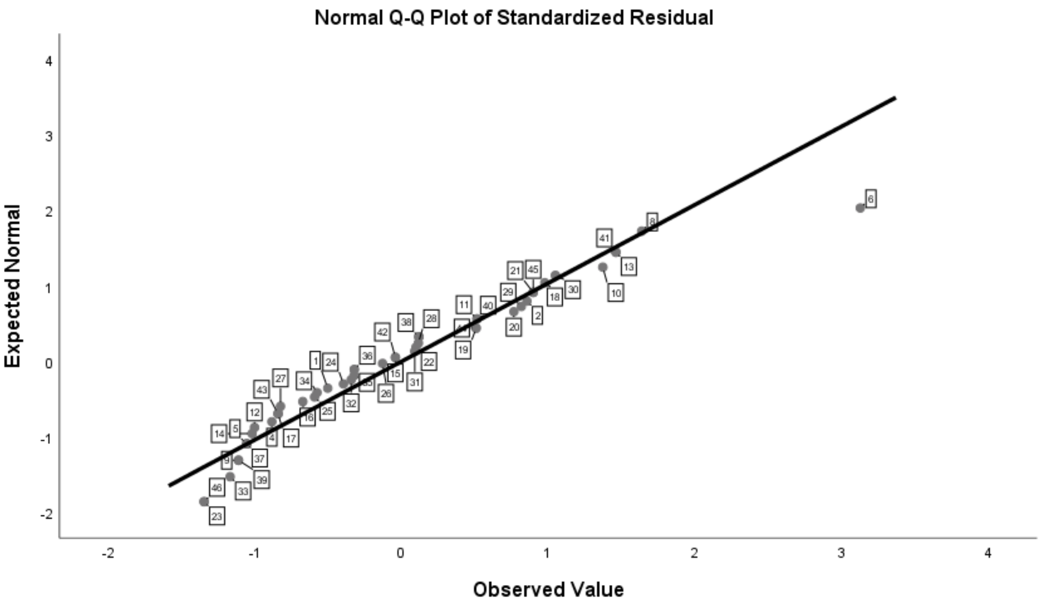


Figure 4. 5: Normal Q-Q plot of standardized residual (average annualized running costs/GIFA)

The graph shows the extreme value indicating the case number: six (6). Therefore, case number 6 was excluded from further analysis and now the data set was limited to 45 commercial building data. With this exclusion, the Shapiro-Wilk normality test was repeated with only 45 cases.

Table 4. 21: Test of normality: Shapiro-Wilk (with 45 cases)

	Statistic	df	Significance
Standardized Residual	0.955	45	0.078

As shown in Table 4.21, the significance of ZRESI is now greater than 0.05; it indicates that the ZRESI is normally distributed. This is further confirmed by the Normal Q-Q Plot of Standardized residual shown in Figure 4.6.

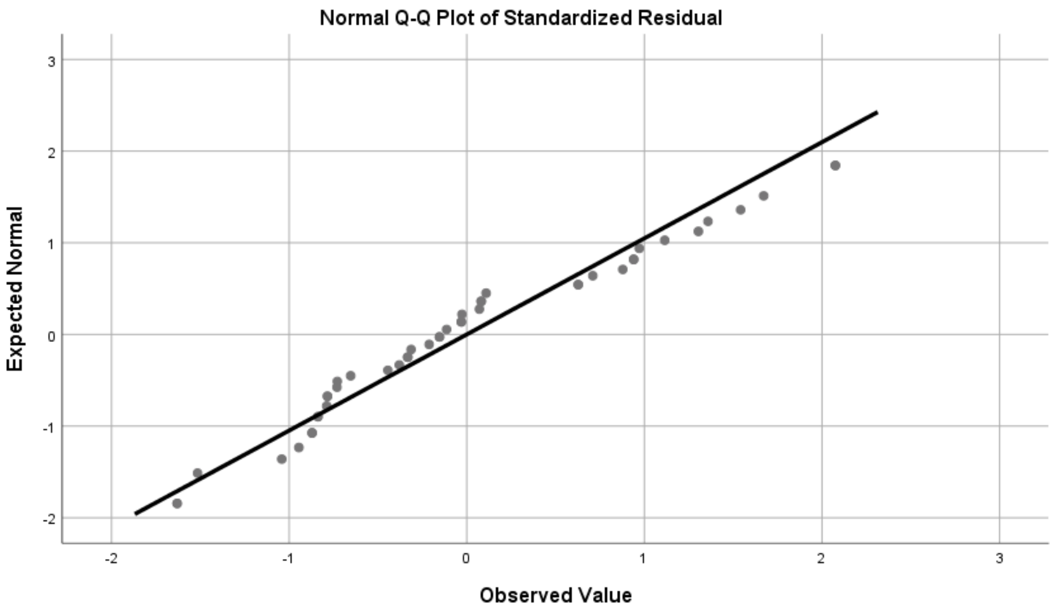


Figure 4. 6: Normal Q-Q plot of standardized residual (45 buildings only) (average annualized running costs/GIFA)

As observed above, in this instance, all values have been gathered between the standardized residual values of -2 to 2 which indicates nonexistence of extreme values. Accordingly, both statistics and plot charts conclude that the ZRESI for the study is normally distributed thus, satisfied the fourth assumption.

Moreover, the data series should free from significant outliers (Field, 2009). Although the scatterplot matrix shown in Figure 4.5 indicates several outliers the significance and impact of these outliers towards the regression analysis can be further revealed through case-wise diagnostics, which will be appeared with the results of the regression analysis. And the errors of the estimate should be independent (Field, 2009) also. That means, there is no relationship between the residual variable and the independent variables. This can be checked with the results of the Durbin-Watson statistic. Except above, the effect of multicollinearity should be checked before model the formula for the estimation (Field, 2009). These three assumptions were checked with the results of the analysis.

Accordingly, the data collected were analysed using the stepwise-forward multiple linear regression analysis to develop the model for estimation of running costs of commercial buildings. Stepwise regression allows building a model by successively adding or removing variables based solely on the t-statistics of their estimated coefficients while eliminating correlations between independent variables, which can reduce the model accuracy (Field, 2009). Accordingly, the regression analysis offered three models and Table 4.22 provides the summary of the models computed for estimating running costs of commercial buildings in tropics.

Table 4. 22: Model summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	0.954a	0.910	0.908	874.88645	
2	0.969b	0.939	0.936	727.56214	
3	0.978c	0.956	0.953	626.75186	2.114

a. Predictors: (Constant), NIFA

b. Predictors: (Constant), NIFA, Number of floors

c. Predictors: (Constant), NIFA, Number of floors, Working hours per day

d. Dependent Variable: Running costs/sq. m

The results of the hedonic multiple linear regression analysis do not contain a table called 'Case-wise Diagnostics', which indicate that there are extreme values in the data series. Therefore, it confirms that the data series subjected to the regression analysis is free from outliers. According to the Durbin-Watson statistic shown here: 2.114, the errors of all estimates are independent of the independent variables as the rule of thumb is that test statistic values in the range of 1.5 to 2.5 are relatively normal (Field, 2009). Values outside of this range could be cause for concern.

Subsequently, the best fit model is identified considering the highest adjusted R^2, as it is more accurate than R^2 and this ranges between 0 and -1. Of all three models, the third model yields the highest adjusted R^2, which is 0.953. Therefore, the third model was selected as the best model. Accordingly, the goodness of fit of the model is 95.3%, which implies that approximately 95% proportion of variance in the annual running costs/sq.m in commercial buildings is expressed by the independent variables entered to the model, namely, NIFA, number of floors, and working hours/day.

The next table is the Analysis of variance (ANOVA) table, which reports how well the regression equation fits the data (i.e. predicts the dependent variable) and is shown from Table 4.23.

Table 4. 23: ANOVA statistics

Model		Sum of Squares	df	Mean Square	F statistic	Significance
1	Regression	331741221.062	1	331741221.062	433.407	.000[b]
	Residual	32913331.142	43	765426.306		
	Total	364654552.204	44			
2	Regression	342421992.450	2	171210996.225	323.438	.000[c]
	Residual	22232559.754	42	529346.661		
	Total	364654552.204	44			
3	Regression	348549018.506	3	116183006.169	295.768	.000[d]
	Residual	16105533.698	41	392817.895		
	Total	364654552.204	44			

a. Dependent Variable: SMEAN(Running cost per sq.m)

b. Predictors: (Constant), SMEAN(NFA)

c. Predictors: (Constant), SMEAN(NFA), SMEAN(Number of floors)

d. Predictors: (Constant), SMEAN(NFA), SMEAN(Number of floors), SMEAN(Working hours per day)

This table indicates that the regression model predicts the dependent variable significantly well. Here, the significance value of the third model is 0.000 which is less than 0.05 and indicates that, overall, the regression model statistically significantly predicts the outcome variable (i.e., it is a good fit for the data).

Finally, the multicollinearity effect of the selected model was checked using the collinearity Statistics shown in Table 4.24.

Table 4. 24: Multicollinearity statistics for the best fit model

Model		**Unstandardized Coefficients**		**95.0% Confidence Interval for B**		**Collinearity Statistics**	
		B	**Standard error**	**Lower Bound**	**Upper Bound**	**Tolerance**	**VIF**
1	(Constant)	-271.651	242.490	-760.679	217.377		
	NFA	.189	.009	.170	.207	1.000	1.000
2	(Constant)	-119.292	204.489	-531.969	293.384		
	NFA	.100	.021	.057	.142	.127	7.895
	Number of floors	138.047	30.732	76.027	200.068	.127	7.895
3	(Constant)	446.901	227.120	-11.778	905.579		
	NFA	.106	.018	.069	.143	.126	7.951
	Number of floors	149.680	26.638	95.885	203.476	.125	7.993
	Working hours per day	-95.147	24.092	-143.801	-46.493	.775	1.291

a. Dependent Variable: Running cost/sq.m

Although there is no formal criterion for determining the bottom line of the tolerance value or VIF, a tolerance value of less than 0.1 or VIF greater than 10 generally indicates significant multicollinearity (Chatterjee and Hadi, 2012). With that point, the collinearity statistics for the third model in Table 4.24 show that the tolerances are greater than 0.1 and the VIFs are below than 10. This indicates the absence of multicollinearity in this model.

The multiple regression analysis provides the Collinearity Diagnostics to further confirm the multicollinearity effect, is presented in Table 4.25.

Table 4. 25: Collinearity diagnostics

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	SMEAN (NFA)	SMEAN (Number of floors)	SMEAN (Working hours per day)
1	1	1.843	1.000	.08	.08		
	2	.157	3.427	.92	.92		
2	1	2.752	1.000	.03	.00	.01	
	2	.228	3.475	.84	.02	.04	
	3	.021	11.547	.12	.98	.95	
3	1	3.618	1.000	.01	.00	.00	.01
	2	.263	3.710	.23	.02	.05	.09
	3	.098	6.064	.67	.01	.00	.90
	4	.021	13.246	.09	.97	.95	.00

a. Dependent Variable: SMEAN(Running cost per sq.m)

Here, the absence of eigenvalues closes to zero (0) is an indication for non-multicollinearity (International Business Machines Corporation [IBM], 2019).

Satisfying all the requirements to be full filled to carry out a multiple linear regression analysis, the annual ruining costs/ sq.m in commercial buildings in tropical climates could be expressed by:

$$\text{Annual Running Costs per GIFA } (\frac{\text{LKR}}{\text{sq}}.\text{m})$$
$$= 446.901 + 0.106(\text{ Net floor area})$$
$$+ 149.680 (\text{ Number of floors})$$
$$- 95.147(\text{Working hours per day})$$

Equation 4.1: Building characteristics-based running costs estimation model for commercial buildings

As per Equation 2, the NFA and number of floors are positively correlated while working hours/day is negatively correlated with running costs, as represented by positive and negative partial regression coefficients, respectively. However, this is justifiable for the working hours to be negatively correlated when all the predictor variables are considered together in a multiple regression due to the combine regression effects while the bivariate correlation analysis shows an independent positive relationship between working hours/day and running costs.

With the use of this developed model, one can estimate or benchmark the running costs of a commercial property at its early design stages using only three basic design variables namely, NFA, number of floors and working hours per day. As this model provides an estimate of up to a 95% proportion of variance in annualised running costs per sq. m. of a commercial building, one can argue that how this model provides an accurate final figure for the expected costs to be estimated. Indeed, this provides a benchmark for costs to be incurred during the operational phase of a commercial building, therefore, one can observe an increase or decrease in the running costs of a commercial building with respect to varying NFA, the number of floors, and working hours/day as these are modelled with the running costs. Consequently, the use of this model at early design stages of commercial building construction will reduce the excessive costs to be incurred during the operational phase of the commercial buildings due to its improper design features.

4.6.1 Validation of the developed cost model

The model developed is tested and validated with a new set of seven commercial buildings in Sri Lanka. A summary profile of the buildings selected for the model validation is presented in Table 4.26.

Table 4. 26: Profile of the buildings selected for model validation

Function	Shape	Working hours/day	NFA	No. of floors	Running costs/GIFA (LKR/m^2)
A. Office	Regular	24	76026	43	12292.12
B. Office	Regular	9	41000	22	7337.59
C. Bank	Regular	6	35567	32	7972.90
D. Bank	Regular	6	41000	30	8277.07
E. Retail	Irregular	9	15063	9	2639.38
F. Retail	Irregular	7	22000	9	3404.67
G. Office	Irregular	24	45477	34	7972.90

The results of the model validation are shown in Table 4.27.

Table 4. 27: Validation of the developed running costs model

Building	Actual running cost	Predicted running cost	Prediction error	
			No.	Per cent (%)
A. Office	7972.90	8435.88	-462.98	-5.8%
B. Office	8277.07	8712.42	-435.35	-5.3%
C. Bank	12292.12	12658.37	-366.25	-3.0%
D. Bank	3404.67	3459.99	-55.32	-1.6%
E. Retail	7972.90	8073.06	-100.15	-1.3%
F. Retail	7337.59	7229.54	108.05	1.5%
G. Office	2639.38	2534.40	104.98	4.0%
			Mean value of accuracy	-1.6%
			Standard deviation of accuracy	3.0%

The actual value shown in the table refers to the actual average running cost per sq. m collected from a new sample of seven commercial buildings. The predicted values were taken from substituting model variables with actual building characteristics data. For example, the running costs of building A = $446.901 + 0.106(76026) + 149.680(43) - 95.147(24)$ = 8435.88 LKR.

The validation of the model is established based on the difference between actual cost and predicted cost, which is the prediction error. The closer the value of accuracy between actual and the predicted running costs is to zero, the more accurate is the model. The results demonstrate that the predicted running cost values are in -5.8% to 4.0% from the actual running costs of commercial buildings in Sri Lanka. In the developed model, the mean value of accuracy is -1.6%, while the standard deviation of model accuracy is 3.0%.

However, one could argue for a difference in the running costs in different types of commercial buildings due to their business nature. Even though there are differences in business nature, there are no observed differences in terms of building characteristics. This has been confirmed by the normality test conducted for each building characteristic as there is no observed abnormalities.

4.7 Running cost indices for commercial building stock in Sri Lanka

Next step of the analysis is to construct cost indices for running costs of commercial buildings in Sri Lanka. The same data set of running costs and building characteristics considered for the model development was used for the construction of index values. Three data sets covering (1) all commercial buildings (this includes 45 commercial buildings considered for the model development); (2) office buildings; (3) banks with quarterly running costs for three consecutive years: 2014; 2015, 2016 were prepared. However, the running costs indices for other types of buildings, namely institutions, retails, and multi-purpose buildings were not constructed due to inadequate samples.

Following the data preparation, the indices were constructed using the hedonic price imputation approach. Initially, the natural logarithm values for the dependent variable (i.e. annualised running cost/sq.m) and 11 continuous independent variables (i.e. working days/week, working hours/day, age, GIFA, NFA, CA, height, number of floors, window area, WFR, occupancy) were imputed. Then, three dummy variables were introduced for the three nominal independent variables namely the building shape, type of structure, and grouping of buildings. Accordingly, the hedonic index model for the running costs imputation of commercial buildings is presented as:

Ruining costs/ GIFA (LKR/sq.m) = Constant + working days/week + working hours/day + Functional years + GIFA + NFA + CA + building height + number of floors + window area + WFR + occupancy + building shape + type of structure + grouping of buildings + Q1_2014 + Q2_2014 + Q3_2014 + Q4_2014 + Q1_2015 + Q2_2015 + Q3_2015 + Q4_2015 + Q1_2016 + Q2_2016 + Q3_2016 + Q4_2016

An abstract of this model can be presented as:

Ruining costs/ GIFA (LKR/sq.m) = Constant + Building characteristics + Q1_X + Q2_X + Q3_X + Q4_X + …………+ Q1_n

Subsequently, a multiple linear regression analysis was run for each category of data set (i.e. all buildings, offices, banks) with the use of these imputed logarithms. The hedonic regression analysis provides correlation coefficient values for all independent variables. However, the Pearson correlations resulted for time variables (i.e. Q1_2014, Q2_2014, Q3_2014, Q4_2014, Q1_2015, Q2_2015, Q3_2015, Q4_2015, Q1_2016, Q2_2016, Q3_2017, Q4_2018) were only required for the hedonic index construction. Finally, an index value for each of these coefficient values was constructed imputing the 'e raised' (EXP) value to the power of a given coefficient value.

Following the aforementioned procedure: the hedonic price imputation approach, running cost indices for office buildings, banks and all buildings were imputed, and the resulted indices are presented in Table 4.28.

Table 4. 28: Quarterly running costs indices for different types of commercial buildings and all commercial buildings in Sri Lanka

							Base = Year 2014 (First quarter)
Year	**Quarter**	**Coefficients (r)**			**Index**		
		Office buildings	**Banks**	**All commercial buildings**	**Office buildings**	**Banks**	**All commercial buildings**
2014	First quarter	0.000	0.000	0.000	1.000	1.000	1.000
	Second quarter	-0.022	-0.018	-0.017	0.978	0.982	0.983
	Third quarter	-0.016	-0.013	-0.011	0.984	0.987	0.989
	Fourth quarter	-0.009	-0.008	-0.006	0.991	0.992	0.994
2015	First quarter	0.002	0.002	0.002	1.002	1.002	1.002
	Second quarter	-0.006	-0.004	-0.005	0.994	0.996	0.995
	Third quarter	-0.003	-0.002	-0.002	0.997	0.998	0.998
	Fourth quarter	0.008	0.006	0.007	1.008	1.006	1.007
2016	First quarter	0.014	0.012	0.010	1.014	1.012	1.010
	Second quarter	0.010	0.009	0.007	1.011	1.009	1.007
	Third quarter	0.013	0.011	0.009	1.013	1.011	1.009
	Fourth quarter	0.015	0.012	0.011	1.015	1.012	1.011

As observed in Table 4.28, index values for offices, banks, and all commercial (this includes all commercial building population in Sri Lanka) buildings shows a slight change over the years. The fluctuation of the annualised running cost of office buildings, banks and all commercial buildings over the past recent years is further described below.

In office buildings, overall, it seems a slight increase in annualised running cost as depicted in Figure 4.7.

Figure 4. 7: The trend of running costs of office buildings

As observed in Figure 4.7, the running cost of office buildings resulting in an increasing trend and a noticeable increase in running cost can be seen during the first quarter of each year and a slight reduction can be seen in the second quarter of each year. It is further observed that the highest running cost has resulted in the fourth quarter of 2016: indicates that the running cost of office buildings can be increased further in future.

Figure 4.8 depicts how the running cost of banks have been changed over the years in Sri Lanka.

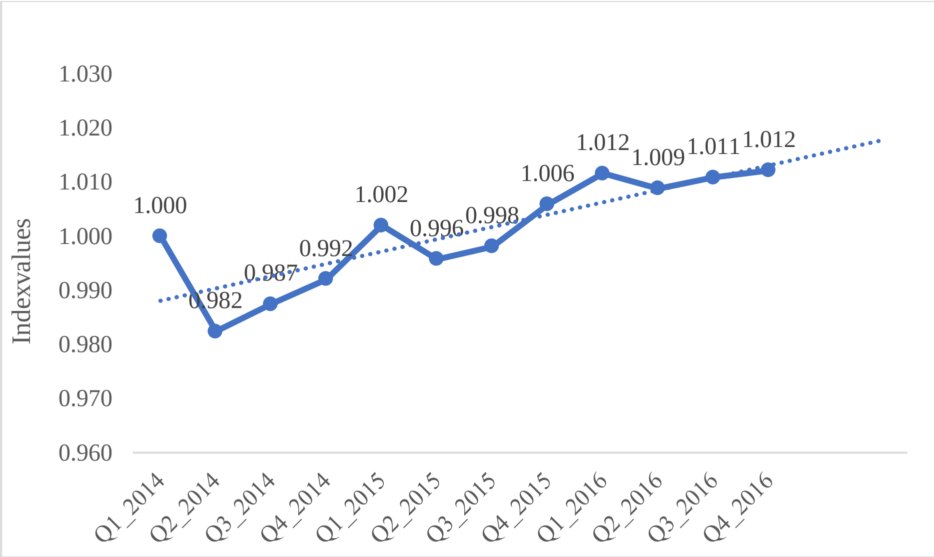


Figure 4. 8: The trend of running costs of banks

Similar to the office buildings, the running cost of banks over the years has shown an increasing trend. Further, a high running cost can be seen in the first quarter of each year and a comparatively reduced running cost can be seen in the second quarter of each year. In banks, the highest and similar index has resulted in both the first and last quarter of 2016.

Finally, the graphical representation of the constructed index for running cost of all commercial buildings is presented in Figure 4.9.

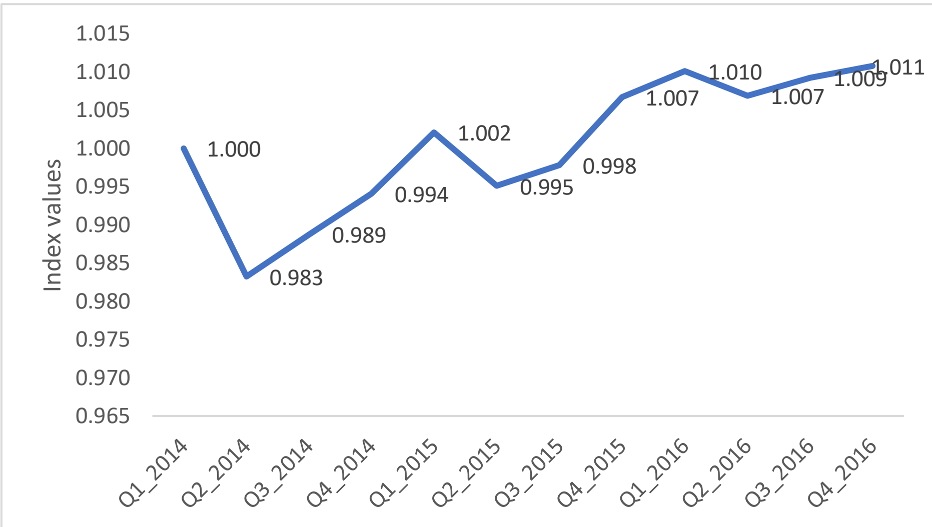


Figure 4. 9: The trend of running costs of all commercial buildings

According to Figure 4.9, the running cost of the commercial building stock in Sri Lanka has resulted in an increasing trend over the last recent years and this has been further confirmed by the indices constructed for running cost of offices and banks in Sri Lanka. Similar to aforementioned indices, commercial buildings, as a whole, resulting in an increased running cost during the first quarter of each year whereas the running cost of commercial buildings has been reduced during the second quarter of each year.

Though the running cost of commercial buildings noticed an increasing trend, the slope of the graph indicates that the running cost of commercial buildings is increasing but the per cent change over the quarters is decreasing. The linear forecast trendlines further illustrates that the running costs of commercial buildings in Sri Lanka can be continuously increased in future. On average, it is nearly 0.06% (the sum of all fluctuations in percent is divided by the number of quarters) increment per each quarter for offices and banks while 0.04% for all commercial buildings in Sri Lanka. Further, the running cost trend of offices and banks are much similar to the trend of all commercial buildings, thus, a similar fluctuation of running costs of commercial buildings over four quarters of an operational year can be seen. This may basically be due to decay in building systems over time; consequently, this increases the maintenance cost of a building and due to inflation.

Accordingly, one can use the model developed to estimate the running costs of a commercial building at its early design stages with the use of only three building variables which are known at early design stages and then can forecast the trend of running costs using the percentage differences of index values over years provided in the developed running costs indices.

4.8 Summary

This chapter presents the outcomes derived through different data analyses conducted to accomplish the research objectives formed for this study. The chapter was mainly divided into six key sections to present six key findings of the data analysis. Initially performed Pareto analysis reveals four (4) running costs elements namely, utilities, services, administrative costs, and services which are responsible for 80% of the total running costs of a commercial building. The study further identified 48 sub-factors influencing the running cost. Of which, 22 sub-factors are influencing both operation and maintenance costs while the operation costs and maintenance costs are specifically influenced by 24 and 46 sub-factors, respectively. The RSI developed for running costs factors revealed that the running costs of a commercial building in Sri Lanka is influenced by environmental factors, maintenance factors, managerial factors, building characteristics, building design and construction defects, social factors, tenant factors, and political factors/regulatory requirements, respectively. According to the correlation analysis performed, the number of floors, building height, GIFA, NFA, and CA are strongly, positively correlated with running costs, while the regression analysis indicates that the annual ruining costs per GIFA (LKR/m2) in a commercial building could be expressed using three (3) building characteristics: (1) NFA; (2) number of floors, (3) working hours per day. The validation exercise performed demonstrates that the mean prediction accuracy of the model developed is -1.6%. Finally, the running costs indices constructed show slightly increasing trends in running costs of offices, banks, and all buildings over the years. These findings are collated and discussed in light of the relevant literature towards deriving the conclusions and contributions of the study.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

This chapter collates the research findings in terms of significant running costs elements, factors influencing running costs, the impact of building characteristics on running costs, running costs modelling, and running costs indices, and synthesises with reference to relevant literature. The outcome of the synthesis is presented in five main sections.

5.2 Significant running costs elements of commercial buildings

As per the findings, the commercial buildings in Sri Lanka complies with the BS-ISO 15686-5 (2008) to a greater extend. While the standard comprises of 64 cost elements, in the Sri Lankan context, the costs data is maintained for 60 elements. The cost elements such as porterage, built-in-fittings, emergency lighting, and grounds maintenance are not maintained in most of the commercial buildings as these are not considered as significant cost items and, in some cases, these were merged with some other cost elements, thus not reported as separate cost elements. Further, an item like heating is not available in Sri Lanka due to the tropical climatic condition which demands less usage of space heating. Out of the 60 elements, the Pareto analysis confirmed that the utility costs (39%), services costs (19%), admin costs (14%), and cleaning costs (8%) are the key constituents which contribute to 80% of total running costs of commercial buildings in Sri Lanka. This complies with BOMA (2016) where utilities, admin works, and cleaning contribute to 80% of running costs of commercial buildings in the USA. However, the percentages of each elemental running costs on the total running costs have considerable changes in these two contexts. The current study found that the utility costs of commercial buildings in Sri Lanka is 9% higher than the USA whereas the cleaning costs is 8% lesser. The rise in utility costs may be due to the frequent and abundant use of air conditioners in Sri Lanka as the country normally experiencing high temperature and humidity levels throughout the years. However, the allocation of the cost for the administrative works is more similar in both countries and only has a 2% difference.

These significant cost contributions provide a useful piece of cost information to building investors/owners, constructors and facilities management while informing them to pay their due consideration to these key cost elements especially during design and construction phases than an in-use phase, in order to build and maintain cost-effective facilities. Having identified the significant running costs elements, the study further expanded to investigate the factors contributing to these significant running costs so as to provide a clear understanding on optimising the running costs during the design and construction stages of a building.

5.3 Factors influencing running costs of commercial buildings in tropical, developing countries

While the literature highlights 46 factors influencing the running costs of buildings under the eight major factors of environment, maintenance, managerial, building characteristics, building design and construction defects, social, tenant, and political /regulatory requirements, the current study confirms that there are two other factors such as occupancy level and poor incorporation of building services also contribute to the running costs of commercial buildings. The current study, therefore, provides a list of 48 factors under the similar major factors mentioned above. In addition, the study further revealed that factors such as building services, building size, building height, the function of the building, poor quality of materials and components, unavailability of skilled and educated building operation staff, the inconsistency of failure reporting procedure, the expectation of tenants, harsh climatic conditions, and cultural practices, found form the literature, are not only contributing to maintenance costs but operation costs also.

Even though there is enough literature focused on running costs influencing factors, this study revealed factors which are specifically contributing to the operation costs, maintenance costs, and also factors contributing to both operation and maintenance costs. Accordingly, the study found 24 and 46 sub-factors determining the operation costs and maintenance costs, respectively. Within these, there are 22 factors which influence both the operation and maintenance costs (i.e. running costs) of a commercial building. In another point, this is one of the first studies to present a broad classification of factors influencing the running costs of buildings, commercial buildings particularly. Unlike previous studies (El-Haram and Horner, 2002; Ali, 2009; Kerama, 2013; Omari, 2015) which clustered these factors into four/five major categories, this study classified these into eight major categories.

Despite many studies focused on identifying the factors influencing the running costs of buildings, a study dedicated to investigating the significance of these salient factors upon the running costs of commercial buildings, particularly in tropical, developing countries has not been evidenced. Hence, the current study ranked 48 factors influencing the running costs of commercial buildings in Sri Lanka, based on their relative significance to running costs. Similar to the Ferami et al. (2014) study, which states the building age, size, vandalism by users as the top three factors that influencing the running costs of tertiary educational institutions in Nigeria, this study concludes the same factors with an RSI value of 1.000. In addition, in line with Talib et al. (2014), the current study confirmed that the impact of a lack of preventive maintenance and budget constraints are at high influence for building maintenance costs. However, it is still hard to build a discussion on the ranking of these factors as this is one of the first studies to rank the factors influencing running costs of commercial buildings.

The RSI developed for factors influencing the running costs of commercial buildings prioritises the key factors to be considered when operating a building as these are highly influencing its running costs. Consequently, these key factors identified implied that these are the key contributors to four significant running costs components: utilities, services, admin works, and cleaning, which accounts for 80% of the running costs of a commercial building. Therefore, one can pay attention to control these key factors and thereby optimise the running costs. Some of these key factors including natural deterioration, failure to identify the true cause of a defect, lack of preventive maintenance, insufficient fund, vandalism by tenants, misuse of property, and expectation of tenants can be monitored and controlled during the in-use phase while building characteristics such as building age, the number of occupants, building size and height are to be decided at the early design stages of building construction.

In a new expression, of these eight categories of main running costs factors, the environmental factors, tenant factors, social and political factors are out of the control of those who are designing, constructing, and operating & maintaining a building. Also, the maintenance factors, managerial factors, building design and construction defects are hard to quantify, consequently unable to assess the impact of these on running costs. Nonetheless. The building characteristics identified are mostly in quantitative nature and well known at the early design stages of building construction. Thus, this is the only category which needs to control during the building design and construction phases in order to optimise the costs to be incurred during the in-use phase of a facility. Therefore, the current study further contributes to identifying the impact of these building characteristics on running costs.

5.4 The impact of building characteristics on running costs of commercial buildings

Investigating the relationship between building characteristics and running costs of commercial buildings is the third objective set for this study. Previous studies have examined the principal design variables which influence construction costs of buildings but limited studies investigating the impact on running costs of a building. Unlike previous studies such as Ashworth (2004), Ayyad (2011), Catalina et al. (2011), Krem (2012), Smith & Jaggar (2007), and Yang et al. (2015), this study investigated not only the behaviour of running costs with respect to 14 key building characteristics but the statistical significance of the nexus between running costs and building characteristics and among these building characteristics. Table 4.42 presents a comparison of literature findings and the current study findings on the effects of design variables on running costs of buildings.

Table 5. 1: The impact of design variables on running costs of buildings

Design variable	Literature findings	Current study findings
Number of floors	Heating costs are likely to fall as the number of stories increases (Catalina et al., 2011)	Total running costs are likely to increase significantly with the increase of floors 97.5% of the proportion of the variance of running costs can be explained by the number of floors
Building shape	Shape of a building has an important effect on its running costs (Krem2012)	Building shape and running costs are less correlated with each other and it can determine only 30.2% of the proportion of the variance of running cots
window area / WWR	Costs of energy increase with the increase of WWR (Catalina et al., 2011; Yang et al., 2015)	Running costs is likely to increase as the window area increases while the changes in window area can explain a 65.6% proportion in the variance of running costs
WFR	Costs of energy decreases with the increase of WFR (Ayyad, 2011) Rooms with reduced perimeter/floor area ratio result in a subsequent reduction in maintenance and heating costs, but these saving may offset the increased lighting costs (Catalina et al., 2011)	Running costs increases with the increase of WFR but has a very low correlation between them WFR can explain 29.2% of the proportion in the variance in running costs
Grouping of buildings	Grouping of buildings can have a significant influence on total costs (Ferry & Brandon, 1991) Grouping of buildings produces lower costs in using and maintaining buildings (Ashworth, 2004) Grouping of buildings reduces service costs (Smith & Jaggar, 2007)	Grouping of buildings correlates with running costs but less significant But the grouping of building can express 40.6% of the proportion of the variance in running costs

As summarised in Table 5.1, though the previous studies have focused on design variables that affect the running costs, their main concern was into the energy consumption of buildings. However, in line with Catalina et al. (2011) and Yang et al. (2015), both the energy cost and running costs increase with the increase of the window area. It is further confirmed that the same building characteristic may have different relationships with running costs and energy costs. For example, contrary to Catalina et al. (2011), heating costs are likely to fall as the number of stories increases, while the vice versa is true as per the current findings. This could be due to the effect of other elemental costs of the running costs. A similar situation can be observed from

WFR where energy cost decreases with the increase of WFR (Ayyad, 2011) while running costs increases with the increase of WFR.

While the literature does not support a statistical proof of the significance of building characteristics upon the running costs, the current study provides an in-depth quantification of the impact of each building characteristics on the running costs. The study found nine significant correlations with running costs. Of which, five-building characteristics: GIFA, NFA, building height, number of floors, and CA, which can determine over 97% of the variance of proportion in running costs whereas the level of occupancy, number of years in operation, window area, and working hours/day can determine nearly 77%, 67%, 66%, and 58.%, respectively.

The correlations between building characteristics and running costs together with significant running cost elements identified provide indications on what building design variables significantly influence the running costs elements which constitute 80% of the running costs of a commercial building.

5.5 An early-stage supportive model for the estimation of running costs in commercial buildings

The main focus of this study was to develop a cost model for the prediction of running costs of commercial buildings and thereby provides an indication of influencing building design variables on running costs of buildings. Unlike previous models such as Al-Hajj and Horner (1998) and Kirkham et al. (1999), the currently developed model has considered an extensive number of building characteristics (14). The developed model has considered building attributes such as building life span, occupancy, and level of building operations, and location of case buildings, which were ignored in previous studies, although these have frequently cited as building characteristics which have a greater impact on building running costs.

The bivariate correlation analysis has indicated that building characteristics such as the number of floors, building height, GIFA, NFA, CA, occupancy, operated years, window area, working hours/day are significantly correlated with the running costs. However, the regression model has used only NFA, the number of floors, and working hours/day to predict the running costs. On one hand, this is due to the existence of multicollinearity effects between some of the predictor variables and on the other hand, some of the predictor variables have been excluded from the model due to their extent of correlation and prediction ability. This is supported by Chatterjee and Hadi (2012) who emphasised that a linear combination of a few independent variables that strongly correlate with the dependent than a linear combination of an extensive number of independent variables that correlate moderately and less with the dependent.

Further, Falk and Miller (1992) stressed the point that in multiple linear regression, it is possible to appear highly intercorrelated predictors in a model but has the potential to overestimate the dependent. However, the authors further stated that the presence of a less correlated predictor could counteract the effect of overestimation of the dependent. Accordingly, in the developed model, the prediction of annualised running costs of a commercial building is represented by the above three-building characteristics. This model offered a higher level, 95% of prediction ability than the models developed by Al-Hajj and Horner (1998) and Kirkham et al. (1999).

Subsequently, evaluating the reliability of the developed cost model for estimating running costs of commercial buildings is the final objective set for the study. Unlike previous studies which attempted to develop cost indices but no indication on model validation, this study validated the prediction accuracy of the developed cost model via a test sample of seven commercial buildings. The model validation demonstrates that the current model has the model accuracy of -1.6%. Unlike previously developed models, which the applicability limit to the later stages of building's life cycle, the model developed can be used to forecast the running costs at its early design stages, as it is based on building characteristics that are well-known at the early design stages of a building's construction.

This running costs estimation model developed, which is applicable in the early design stage of a construction project, together with the significant running costs elements identified provides cost implications during the in-use stage of a building, which is extremely useful for building design team to build a cost-efficient facility. With the use of the model developed, one can estimate the total running costs per GIFA (sq.m) and then can estimate the percentage contribution of running costs for each elemental running cost.

5.6 Running cost indices for commercial building stock in Sri Lanka

The final objective set for the study is to construct running costs indices for commercial buildings particularly in Sri Lanka as the literature in section 2.8 evidenced the absence of regional-based running costs indices and emphasis on importance of constructing running costs indices. Further, it is a known fact that most of the facilities management professionals employed in Sri Lanka are using the BCIS (2008) classification of LCC for collecting running costs data and Building Running Costs Online as an expenditure tool; even though it is not acceptable for a country like Sri Lanka due to context differences such as economic (i.e. the UK is a developed country whereas Sri Lanka is still developing and low-income country), climate and seasonal changes (i.e. the UK has seasonal changes throughout the year which highly impacts on building operation costs whereas Sri Lanka is a country with a tropical climate), social and cultural (i.e. differences in user behaviour patterns).

The developed hedonic indices for running costs revealed that there is an increasing trend of running costs in both offices and banks throughout the study period. Further, the running costs of offices, banks, and all commercial buildings were in continuous increasing trend which ranges between 0.978-1.015, 0.982-1.012, and 0.983-1.011, respectively. The information provided by indices can be of more useful to commercial developers to capture the price movement of the operational costs of commercial buildings, which the existing models and indices fail to measure. Further, the running costs indices are important since many investors, and the government also, in some way are tied to the commercial building market. Whilst all existing running cost indices are based in developed countries, the constructed indices can be generalised to nations, which are developing alike Sri Lanka. With the use of developed model along with indices, both construction industry professionals and investors can make informed decisions on implications of running costs in commercial properties at its early design stages, eliminating excessive costs to be incurred during the operational phase of buildings. And the finding of the study may also have policy implications for building cost management and resource allocation at the national level.

5.7 Summary

This chapter has presented a synthesis of the research findings which involved the collated outputs of three approaches: a pilot study, questionnaire survey, and documentary review. While the current study contributes to the theory by identifying significant running costs components, key factors influencing running costs, statistical relationships between 14 key building characteristics and running costs, and developing a three-building characteristic based, simplified running costs estimation model, the study further provides a running costs index to the industry practice in order to facilitate early-stage running costs estimation. The collective analysis would help practitioners in terms of understanding the factors influencing running costs, designing commercial buildings with optimised running costs, running costs estimation during early design stages of construction, running costs prediction during the in-use phase of a commercial facility.

CHAPTER SIX

6.0 CONCLUSIONS

6.1 Introduction

Having discussed the findings and outcomes of the study in Chapter four, an attempt is made in this chapter to draw conclusions based on those findings. The conclusions drawn based on the findings and a statement of the potential contribution of the research to the theory and practice of LCC studies are presented. They are followed by the limitations of the research and prospects for further research.

6.2 Conclusions of the study

The first objective of the study was to analyse the running costs of commercial buildings and thereby to explore significant cost components which constitute the running costs of commercial buildings in Sri Lanka. A Pareto analysis performed on the running costs data collected from 46 commercial buildings including office, bank, institution, retail, and multi-purpose facilities confirmed that four out of 13 cost elements, only 30% of the cost elements contribute to 80% of the running costs. The key constituents include utility with the contribution of approximately 39% to the running costs of a commercial building. Next, the costs incurred for the administrative work, maintenance of building services, and cleaning are significantly influencing the running costs with the contribution of approximately 19%, 14%, and 8%, respectively. Accordingly, the building owners and practitioners in the construction and facilities management industries can pay careful attention to these four (4) cost elements and thereby control 80% of running costs of a commercial building.

Having identified the key running costs elements of a commercial building, the current study further expanded to identify the factors influencing the running costs. Therefore, the second objective of this study was to investigate the factors influencing the running costs of commercial buildings in Sri Lanka. The O&M costs of commercial buildings are influenced by eight (08) categories of factors namely, building characteristics, maintenance, managerial, design and construction defects, tenant, environmental, political, and social. The expert survey carried out in the current study extended the 46 sub-factors revealed through literature to 48 sub-factors concluding that occupancy and poor incorporation of building services also influence the running costs of commercial buildings in Sri Lanka. The study further revealed, operation costs of a building is influenced by 24 sub-factors, whereas the maintenance cost is affected by an extensive set of sub-factors, which is 46. As per the RSI analysis performed, environmental factors, collectively, is the top determinant influencing both operation and maintenance costs of commercial buildings with an RSI of 0.996. Further, the study concludes that building age, occupancy, building services, natural deterioration, failure to identify the true cause of a defect, lack of preventive maintenance, budget constraints, poor supervision during construction are the foremost factors influencing the running costs. The impact of most of the sub-factors identified, except very few namely building function, age, and location, can be controlled up to a greater extent. Thus, early consideration of these factors during the building design and construction will result in a reduction of unnecessary costs to be incurred during the operational phase of a building. Further, there are statistically significant inter-correlations between most of the sub-factors. Thus, the reduction or elimination of bad impacts of one particular determinant can lead to control of the severe influence of the correlated variable on building operation or maintenance cost.

Among these, building characteristics are quantifiable and mostly available in the early design stage of a construction project and therefore, these can control to optimise the in-use phase costs. Therefore, the third objective of the study was to investigate the nexus between building characteristics and running costs. The correlation analysis performed confirmed that five (05) out of 14 building characteristics: number of floors (0.950), building height (0.945), GIFA (0.943), NFA (0.943), and CA (0.943) have statistically significant positive correlations with running costs of commercial buildings. This indicates that an increase in these variables will lead to an increase in running costs of commercial buildings. Similarly, the running costs of a commercial building are highly and positively influenced by its area: GIFA, NFA and CA. The analysis further revealed that occupancy (0.586**), number of years in operation (0.452**), window area (0.430**), and working hours/day (0.336*) are having moderate and positive correlations with the running costs of commercial buildings. Accordingly, the increase in age of a commercial building by one year may increase its running costs. Similarly, a 1% increase in the window area and a one-hour increase in working hours per day will result in increased running costs. Early consideration of significant building characteristics at buildings' lifecycle particularly, which resulted in significant correlation values, would enable reduction of unnecessary costs to be incurred during the operational phase of a building.

While detecting the significant correlations of building characteristics with running costs, the fourth objective was to develop a regression model, that is based on building characteristics, to estimate the running costs of commercial buildings. The main purpose of developing this model is to support in estimation of running costs of commercial buildings at its early design stage. Accordingly, the current study confirmed that approximately 95% proportion of variance in the annual running costs/sq. m of a commercial building in Sri Lanka could be expressed by three independent variables entered into the model: NFA, number of floors, and working hours/day. Finally, the validation exercise performed demonstrates that the current model has the accuracy of -1.6%. As this model provides an estimate of up to a 95% proportion of variance in annualised running costs per sq. m. of a commercial building, one can argue that how this model provides an accurate final figure for the expected costs to be estimated. Indeed, this provides a benchmark for costs to be incurred during the operational phase of a commercial building, therefore, one can observe an increase or decrease in the running costs of a commercial building with respect to varying NFA, the number of floors, and working hours/day as these are modelled with the running costs. Consequently, the use of this model at early design stages of commercial building construction will reduce the excessive costs to be incurred during the operational phase of the commercial buildings due to its improper design features.

The final objective formed for this study was to construct a cost index to forecast the trend in running cost variation of commercial buildings in Sri Lanka. Accordingly, the study provides quarterly running costs indices for commercial buildings for three recent years, 2014 to 2016. The offices, banks, and all commercial buildings in all quarters in 2014 are similar indicating that there is no change in the trend of running costs among offices, banks, and commercial buildings as a whole in 2014. Further, there are slight increases in running costs of offices and banks over time and conversely, a significant decrease in all commercial buildings. Moreover, it is observed that running costs in the first and fourth quarters are slightly high in every year in all categories. Running costs indices are important since many investors, and also the government, in some way are tied to the commercial building market. The developed running costs indices can be seen as an important tool for the construction and facilities management professionals, as it has the potential to collaborate with the organization of the architectural, engineering and construction industry, assisting in market transparency, marking of running costs, and the reduction of information asymmetry.

The estimated running costs using the proposed running costs model along with the elemental breakdown of running costs would enable designers/investors to decide and optimise the elemental running cost and thereby total running costs. The influential factors identified should receive careful attention not only in the construction phase but during the in-use phase also. Special consideration should be given in designing a building as building characteristics are significantly correlated with the running costs. While the current study findings have implications for design and construction phases of a commercial building, the running costs index constructed can help building owners and practitioners to predict the running costs by observing its trend over years.

The model and indices developed along with other significant research findings such as significant running costs elements and running costs determinants may applicable to the commercial property population in Sri Lanka and would have potentialities in applying to regions with similar economic (e.g. inflation rates), climatic (e.g. tropical warm climate with less/no seasonal changes) and social characteristics like Sri Lanka.

6.3 Recommendations of the study

While providing useful research findings to the AECO industry to promote early-stage running costs estimation in order to design and construct sustainable buildings as well as to run commercial buildings while maintaining optimum running costs, the study provides following recommendations to building owners, designers and constructors, and facilities managers. These are,

- Careful attention should be given to four key running cost constituents such as utilities, admin costs, building services, and cleaning
- The significant running costs influencing factors including building age, occupancy, building services, natural deterioration, failure to identify the true cause of a defect, lack of preventive maintenance, budget constraints, and poor supervision during construction should receive proper attention throughout the life cycle of a commercial facility
- Especially, the factors contributing to key elemental running costs should be properly managed
- The running costs model developed is recommended to apply during all phases of a construction project including the early design stage to estimate the running costs of a commercial building
- The index constructed can be used to observe the trends of running costs and thereby predict the running costs of commercial buildings in Sri Lanka over the years

6.4 Contribution of the research to theory and practice

This study contributes to the existing body of knowledge by introducing a more simplified but reliable and practically applicable cost model for running costs estimation together with running costs indices of commercial buildings, particularly offices, banks, retails and institutional buildings based in Sri Lanka. The contribution to the knowledge of the present study is stated in this section under two categories: the theory and the practice.

6.4.1 Contribution to the theory

Construction and facilities management industry professionals, usually from developing countries, are criticised for their inability to apply LCC during the RIBA stages (i.e. particularly in the stages of strategic definition, preparation and brief, concept design, developed design, technical design, and in-use) of a building construction project. The most highlighted reason for this criticism is the lack of reliable historical cost data related to building operation and maintenance. This is basically due to the absence of a context-specific template for running costs data collection.

In this circumstance, this study provides a much refined and context-specific template for running cost data collection and a simplified and much accurate cost model to estimate the running costs of commercial buildings. The study further establishes a context-specific knowledge on how the elemental running costs is contributing to the total running costs of a typical commercial building. Moreover, the relative significance index for factors influencing the running costs of commercial buildings in a tropical climate like Sri Lanka provides a prioritisation for running costs determinants. Thus, it is a unique contribution to the theory. Although the academic research in LCC and cost modelling is from far earlier, cost modelling for running costs of buildings has been simply ignored despite its significant contribution to the LCC structure of a building project. This research thus contributes to a less explored area of research by analysing and modelling running costs of buildings. In addition, this study is also among the first to use hedonic price imputation approach in constructing index values for running costs of buildings. The outcome of this research will help to bridges one of the critical gaps in LCC research by contributing, in the form of research findings and methodological point of view. Also, this study will serve as a base for future studies in facilities management cost of buildings.

6.4.2 Contribution to practice

This study addresses the LCC related issues that lead to discouraging construction and industry-related professionals including facilities managers in estimating running costs of buildings. The significant elemental running costs items identified provides important indications on running costs that facilities management professionals should pay more attention.

Despite the significant contribution of running costs to the LCC structure, often running costs is given less focus in investment decision-making and investors tend to mostly rely on initial cost alone. This is basically due to the absence of a reliable tool to estimate the running costs at the early stages of a building construction project. Early-stage supportive running costs estimation model introduced by the study would enable construction professionals to benchmark the running costs and thereby optimise the building design. Generally, the clients are curious to know their likely financial commitments and costs implications as the phases evolve at the design and construction phases. The model developed is equally applicable during the concept design, developed design, technical design, and in-use stages of a building construction project as the building characteristics, the predictor variables for the model, are well known at these stages.

The running costs index constructed in this study filled an important gap in particularly in construction and facilities management, and therefore a significant contribution to the practice. Use of operation and maintenance costs indices produced by the BCIS, UK to make design and cost decisions in building constructions based in developing nations and tropical climates may lead to many ineffective decisions. The developed regional-specific running costs indices will be beneficial for industry practitioners in measuring relative changes in running costs in commercial buildings over a period of time. These findings would enable an investor to optimise the running costs by controlling the impact of physical characteristics of commercial buildings, and consequently, this controls the total LCC. The proposed indices will further benefit governments, policymakers and academics for building cost management and resource allocation at the national level.

6.5 Limitations of the study

It was targeted a sufficient sample of respondents to scale the impact level of factors influencing the running costs of commercial buildings to ensure the validity and rigour of the study and all possible running cost and building characteristics data were collected by referring to relevant documents. However, the cost of carbon emissions was not considered for the model and index formation due to non-availability. Further, though the model developed is only based on the building characteristics, the running costs model developed implies approximately 95% proportion of variance in the annual running costs/sq. m in commercial buildings with a mean value of accuracy is -1.6%. This is basically due to the absence of a reliable method to quantify the impact of identified qualitative determinants of running costs. Nonetheless, the model is validated to overcome this limitation.

Although the literature findings show that barriers in application of LCC are mostly in common in developing countries, including some of the serious gaps and barriers identified in the Sri Lankan construction and facilities management industry, the findings can only be generalised to tropical climates and developing economies. This is basically due to the varying running costs rates across regions. However, the use of hedonic approaches aids to solve this problem to some extent where the research outcomes can be applied to regions which have similar economic (e.g. inflation rates), climatic (e.g. tropical and warm) and social characteristics to Sri Lanka, which the study is contextualised.

6.6 Further research recommended

Given the above constraints and limitations of the current study, the following is recommended for further study.

The current study has developed running costs indices for commercial buildings. However, it is important to present the running costs trends in other sectors such as residential and industrial. Thus, it is recommended the future study to develop indices to other sectors of the construction industry.

A shortcoming of this study is that the running costs index introduced by the study has not been tested for applicability and practical implications as it is beyond the scope of this research study. Thus, it is recommended that the cost index be applied in context to test its validity in practice. It is further recommended to construct elemental running costs indices, especially for key constituents of the running costs.

Very importantly, adopting building information modelling (BIM) greatly enhances the modelling and predictability of building performance and costs. Hence, incorporating LCC into the existing BIM framework is essential in order to push its utilisation within the AECO industry. Although the concept of BIM as a 3D model is well known in developed countries, for example in the UK, USA and Australia, the Corporative Research Centre for Construction Innovative (CRC, 2009) found that there is a low uptake due to the lack of understanding of LCC analysis thus, become a major consideration if modelling is to assist decision-making successfully. Life cycle economics, therefore, have yet to be fully integrated into BIM applications, and this remains an essential part of the roadmap towards the future development of BIM.

REFERENCES

Al-Hajj, A., & Horner, M. (1998). Modelling the running costs of buildings. *Construction Management and Economics*, 16(4), 459-470. doi: 10.1080/014461998372231

Ali, A. S., & Kamaruzzaman, S. N. (2010). Cost performance for building construction projects in Klang Valley. *Journal of Building Performance*, 1(1).

Ali, A., Kamaruzzaman, S., Sulaiman, R., & Cheong Peng, Y. (2010). Factors affecting housing maintenance cost in Malaysia. *Journal of Facilities Management, 8*(4), 285-298. doi: 10.1108/14725961011078990

Ali, A. S. (2009). Cost decision making in building maintenance practice in Malaysia. Journal of Facilities Management, 7(4), 298-306. doi: 10.1108/14725960910990044

Al-Juwairah, Y. A. (1997). *Factors affecting construction costs in Saudi Arabia*. (Doctoral dissertation, King Fahd University of Petroleum and Minerals). Retrieved from https://eprints.kfupm.edu.sa/id/eprint/10044/1/10044.pdf

Al-Khatam, J. A. (2003). Buildings Maintenance Cost. Master of Engineering Report (CEM-600). *Construction Engineering and Management*, KFUPM, Dhahran, Saudi Arabia.

Altunisik, R., Coskun, R., Bayraktaroglu, S., & Yildirim, E. (2004). *Research methods in social sciences*. Sakarya: Sakarya Bookstore.

Anghelache, C., Marinescu, R. T., Gheorghe, M., Bichir, V., & Nan, S. (2011). The Laspeyres and Paasche Indices Used in Economic and Financial Analysis. In *Proceedings of the International Symposium, Economic-Financial Crisis and the Emergency of the Reform*, Artifex University of Bucharest.

Ashworth, A. (1996). Estimating the Life Expectancy of Building Components in Life Cycle Costing Calculations. *Structural Survey*, 14(2), 4-8.

Ashworth, A. (2004). *Cost studies of buildings* (ed.). Essex: Pearson Education Limited.

Ashworth. (1994) *Cost Studies of Buildings*. London: Longman.

Ayyad, T. M. (2011). The impact of building orientation, opening to wall ratio, aspect ratio and envelope materials on buildings energy consumption in the tropics. (Doctoral dissertation, The British University in Dubai (BUiD)). Retrieved from https://bspace.buid.ac.ae/bitstream/1234/132/1/90055.pdf

Barrett, P., & Baldry, D. (2009). *Facilities management: Towards best practice*. John Wiley & Sons.

Bartlett, J. E., Kotrlik, J. W. K. J. W., & Higgins, C. C. H. C. C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, 19(1), 43.

Bhattacherjee, A. (2012). Social science research: Principles, methods, and practices.

Bishesh, B., & Banga. B. (2016). Special economic zones in India as a regional development stimulator. *Imperial Journal of Interdisciplinary Research (IJIR)*, 2(6), 1318-1322.

Bors, D. (2018). Data analysis for the social sciences: Integrating theory and practice. Sage.

Boussabaine, A. & Kirkham, R. (2005). *Whole Life-cycle Costing: Risk and Risk Responses*. Oxford, UK: Blackwell Publishing.

Bromilow, F. J. & Pawsey, M. R. (1987). Life cycle cost of university buildings. *Construction Management and Economics*, 5(4), S3-S22.

BSI. (2013). BS 8544:2013 Guide for life cycle costing of maintenance during the in-use phases of buildings. London, United Kingdom: BSI.

BS-ISO. (2008). BS EN 15868-5:2008 Building and constructed asset – Service life planning; Part 5 – Life cycle costing. London; United Kingdom: BSI.

BOMA. (2016), 2016 Office Experience Exchange Report. BOMA: Washington.

Caplehorn, P. (2012). *Whole life costing: a new approach*. Routledge.

Catalina, T., Virgone, J., & Iordache, V. (2011, November). Study on the impact of the building form on the energy consumption. In *Proceedings of building simulation*, (pp. 1726-1729).

Leeuwen G. V. (February 1995). A Hedonic Approach to Output Indices for Construction. Voorburg: CBSN.

Chatterjee, S., & Hadi, A. S. (2012). *Regression analysis by example* (5th ed.). Retrieved from http://pdf.th7.cn/down/files/1508/Regression%20Analysis%20by%20Example,%205th%20Edition.pdf.

Che-Ghani, N. Z., Myeda, N. E., & Ali, A. S. (2016). Operations and maintenance cost for stratified buildings: A critical review. In *MATEC Web of Conferences* (Vol. 66, pp. 00041). EDP Sciences.

Chiurugwi, T., Udeaja, C., & Hogg, K. (2010). Exploration of Drivers and Barriers to Life Cycle Costing (LCC) in Construction Projects: Professional Quantity Surveying Assessment. In *Proceedings of the International Conference on Computing in Civil and Building Engineering*, University of Nottingham, UK.

Churcher, D. (2008). A BSRIA Guide: Whole-Life Cycle Costing Analysis (BSRIA B6 5/2008). Berkshire, United Kingdom: BSRIA.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.). London: Routledge Falmer.

Cole, R. J., & Sterner, E. (2000). Reconciling Theory and Practice of Life- Cycle Costing. *Building Research and Information*, 28(5/6), 358-375.

Collis, J., & Hussey, R. (2003). *Business Research*. Pal grave Macmillan: Basingstoke.

Craft, R. C., & Leake, C. (2002). The Pareto principle in organizational decision making. *Management Decision*.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches. Retrieved from https://www.google.lk/url.

Dainty, A. (2007, July). A review and critique of construction management research methods. In *Proceedings of Construction Management and Economics 25th Anniversary Conference, University of Reading*, (pp. 1533-1543).

Datta, P. P., & Roy, R. (2010). Cost modelling techniques for availability type service support contracts: a literature review and empirical study. *CIRP Journal of Manufacturing Science and Technology*, 3(2), 142-157.

De Silva, N., Ranasinghe, M., & De Silva, C. (2012). Risk factors affecting building maintenance under tropical conditions. *Journal of Financial Management of Property and Construction*, 17(3), 235-252. doi: 10.1108/13664381211274353

Dhillon, B. S. (2009). *Life cycle costing for engineers*. Crc Press.

Dragos, D., & Neamtu, B. (2013). Sustainable Public Procurement: LCC in the New EU Directive Proposal. *European Procurement & Public Private Partnership*, 8(1), 1930.

Durairaj, S. K., Ong, S. K., Nee, A. Y., & Tan, R. B. (2002). Evaluation of life cycle cost analysis methodologies. *Corporate Environmental Strategy*, 9(1), 30-39.

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2002). *Management research: An introduction* (2nd ed.). Retrieved from https://books.google.lk/books?id=EczlVa2192gC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

El-Haram, M., & Horner, M. (2002). Factors affecting housing maintenance cost. *Journal of Quality in Maintenance Engineering*, *8*(2), 115-123. doi: 10.1108/13552510210430008

El-Haram, M. A., Marenjak, S., & Horner, M. W. (2002). Development of a Generic Framework for Collecting Whole Life Cost Data for the Building Industry. *Journal of Quality in Maintenance Engineering*, 8(2), 144-151.

Eurostat (2013), *Handbook on Residential Property Prices Indices (RPPIs)*, Publications Office of the European Union: Luxembourg.

Falk, R. F., & Miller, N. B. (1992). *A primer for soft modeling*. University of Akron Press.

Faremi, O., Adenuga, O., Dada, M., & John, B. (2014). Factors Affecting Maintenance Cost of Institutional Buildings. In Proce*edings of the 9th Unilag Annual Research Conference and Fair*, University of Lagos, Nigeria.

Fernandez, G. (2010). *Statistical data mining using SAS applications*. CRC press.

Ferry, D. J., & Brandon, P. S. (1991). *Cost Planning of Buildings* (6th ed.), Chapters 14–19.

Field, A. (2009). *Discovering statistics using SPSS:(and sex and drugs and rock'n'roll).* Sage.

Flanagan, R., & Jewel, C. (2005). *Whole life appraisal for construction*. Oxford: Blackwell Science.

Geekiyanage, D., Ramachandra, T., & Rotimi, J. O. (2017). A Morphology-based Model for Forecasting Cooling Energy Demand of Condominium Buildings in Sri Lanka. In *Proceedings of the 33rd annual conference of Association of Researchers in Construction Management* (Vol. 289, p. 289).

Gianola, D., de los Campos, G., González-Recio, O., Long, N., Okut, H., Rosa, G. J. M., ... & Wu, X. L. (2010, August). Statistical learning methods for genome-based analysis of quantitative traits. In *Proceedings of the 9th World Congress on Genetics Applied to Livestock Production* (Vol. 14, pp. 1-6).

Glucha, P. & Baumann, H. (2004). The life cycle costing (LCC) approach: a conceptual discussion of its usefulness for environmental decision-making. *Building and Environment*, 39, 571-580.

Göb, R., McCollin, C., & Ramalhoto, M. F. (2007). Ordinal methodology in the analysis of Likert scales. *Quality & Quantity*, 41(5), 601-626.

Goh, B. H., & Sun, Y. (2016). The development of life-cycle costing for buildings. *Building Research & Information*, 44(3), 319-333.

Goh, B. (2016). Designing a whole-life building cost index in Singapore. *Built Environment Project and Asset Management*, 6(2), 159-173. doi: 10.1108/bepam-09-2014-0045

Green, A., & Benge, D. P. (2014). *NRM 3: Order of Cost Estimating and Cost Planning for Building Maintenance Works*. UK: Royal Institution of Chartered Surveyors (RICS).

Green, M. (2009). Issues paper: Digital modelling & the built environment. *Built Environ*. Digital Modelling Working Group Discussion paper Nov, Dept of Innovation, Industry, Science & Research, Australian Gov.

Günaydın, H. M., & Doğan, S. Z. (2004). A neural network approach for early cost estimation of structural systems of buildings. *International Journal of Project Management*, 22(7), 595-602.

Higham, A., Fortune, C., & James, H. (2015). Life cycle costing: evaluating its use in UK practice. *Structural Survey*, 33(1), 73-87. doi: 10.1108/ss-06-2014-0026

Hourigan, N. (2012). *Improving the service provision of life cycle costing in Ireland's PQS offices.* (MSc. Advanced Construction Cost Management, DIT, Dublin).

Huang, X. X., Newnes, L. B., & Parry, G. C. (2012). The adaptation of product cost estimation techniques to estimate the cost of service. *International Journal of Computer Integrated Manufacturing*, 25(4-5), 417-431.

Hughes, W., Ancell, D., Gruneberg, S., & Hirst, L. (2004), Exposing the myth of the 1:5:200 ratio relating initial cost, maintenance and staffing costs of office buildings, in Khosrowshahi, F. (Ed.), In *Proceedings of the 20th Annual ARCOM Conference,* UK.

Hunter K., Hari S., & Kelly J. (2005). A whole life costing input tool for surveyors in UK local government. *Structural Survey*, 23(5), 346-358(13).

Ibrahim, A.D. (2007), "Effect of changes in layout shape on unit construction cost of residential buildings", Samaru Journal of Information Studies, Vol. 7 No. 1, pp. 24-31.

ISO, B. (2017). 15686-5: 2017. Buildings and constructed assets. Service life planning. *Life-cycle costing*. BSI, 17.

Ive, G. (2006). Re-examining the costs and value ratios of owning and occupying buildings. *Building research & information*, 34(3), 230-245.

Jakobsen, J. C., Wetterslev, J., Winkel, P., Lange, T., & Gluud, C. (2014). Thresholds for statistical and clinical significance in systematic reviews with meta-analytic methods. *BMC medical research methodology*, 14(1), 120.

Johnson, J. W. (2001). Determining the relative importance of predictors in multiple regression: Practical applications of relative weights. *Child Development*, 59, 969-992.

Kantardzic, M. (2011). Data mining: concepts, models, methods, and algorithms. John Wiley & Sons.

Kehily, D. (2010), *Guide to Life Cycle Costing, Society of Chartered Surveyors*, Ireland, Dublin, available at: http://www.scsi.ie (accessed 6 August 2016).

Kelly, J., & Hunter, K. (2009). *Life cycle costing sustainable design*. Coventry; United Kingdom: RICS.

Kerama, N.S. (2013). *Factors affecting housing maintenance management cost in Kakamega municipality, Kenya*. (Thesis (PgDip), The University of Nairobi, Nairobi). Retrieved from shorturl.at/ktCFQ

Kirkham, R. (2014). Ferry and brandon's cost planning of buildings. John Wiley & Sons.

Kirkham, R. J. (2005). Re-engineering the Whole Life Cycle Costing Process. *Construction Management and Economics*, 23(1), 9-14.

Kirkham, R. J. (2012). *Ferry and Brandon's Cost Planning of Buildings* (8th ed.). Oxford: United Kingdom: Blackwell Publishing.

Kirkham, R. J., Boussabaine, A. H., & Awwad, B. H. (2002). Probability distributions of facilities management costs for whole life cycle costing in acute care NHS hospital buildings. *Construction Management & Economics*, 20(3), 251-261.

Kirkham, R. J., Boussabaine, A. H., Grew, R. G., & Sinclair, S. P. (1999). Forecasting the running costs of sport and leisure centres. In *Proceedings of the Eighth International Conference on Durability of Building Materials and Components*, 8 dbmc (pp. 1728-1738).

Korpi, E., & Ala-Risku, T. (2008). Life cycle costing: a review of published case studies. *Managerial Auditing Journal*, 23(3), 240-261. doi: 10.1108/02686900810857703

Krem, M. (2012). *Effect of building morphology on energy and structural performance of high-rise office buildings*. (University of Massachusetts, Amherst). Retrieved from https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1582&context=open_access_dissertations

Krstić, H., & Marenjak, S. (2017). Maintenance and operation costs model for university buildings. *Technical Gazette*, 24(1), 193-200.

Kulatunga, K. J., Amaratunga, D., & Haigh, R. (2007). Researching construction client and innovation: methodological perspective.

Kumar, R. (2011). *Research methodology: A step-by-step guide for beginners*. Retrieved from http://www.sociology.kpi.ua/wpcontent/uploads/2014/06/Ranjit_Kumar-Research_Methodology_A_Step-byStep_G.pdf.

Lai, J., & Yik, F. (2008). Benchmarking operation and maintenance costs of luxury hotels. *Journal of Facilities Management*, 6(4), 279-289. doi: 10.1108/14725960810908145

Langdon, D. (2007). *Life Cycle Costing (LCC) as a contribution to sustainable construction: a common methodology*. Literature Review, Davis Langdon Management Consulting.

Liu, H., Gopalkrishnan, V., Quynh, K. T. N., & Ng, W. K. (2009). Regression models for estimating product life cycle cost. *Journal of Intelligent Manufacturing*, 20(4), 401-408.

Maguire, D. J., Smith, R., & Kouyoumjian, V. (2008). The business benefits of GIS: an ROI approach. ESRI, Inc.

Mahmoud, T. (1994). *Assessment of the problems facing the maintenance industry in Saudi Arabia.* (Doctoral dissertation, King Fahd University of Petroleum and Minerals). Retrieved from http://eprints.kfupm.edu.sa/10131/1/10131.pdf

Manion, L., & Morrison, K. (2000). *Research methods in education*. Routledge.

Marcus, A. H., & Elias, R. W. (1998). Some useful statistical methods for model validation. *Environmental Health Perspectives*, 106(suppl 6), 1541-1550.

Marenjak, S., El-Haram, M. A., & Horner, M. R. (2003, September). A generic approach to minimize whole life costs in the building industry. In *Proceedings of 19th Annual ARCOM Conference.*

Matel, E., Vahdatikhaki, F., Hosseinyalamdary, S., Evers, T., & Voordijk, H. (2019). An artificial neural network approach for cost estimation of engineering services. *International Journal of Construction Management*, 1-14.

Meikle, J. (2001). A review of recent trends in house construction and land prices in Great Britain. *Construction Management & Economics*, 19(3), 259-265.

Meng, X., & Harshaw, F. (2013, 2-4 September). The Application of Whole Life Costing in PFI/PPP Projects. *In Proceedings of the 29th Annual ARCOM Conference*, Reading, UK.

Munn, P., & Drever, E. (1990). Using Questionnaires in Small-Scale Research. *A Teachers' Guide*. Scottish Council for Research in Education, 15 St. John Street, Edinburgh, EH8 8JR, Scotland, United Kingdom.

Mwitondi, K. S. (2012). Statistical data mining using SAS applications.

Narayan, V. (2003), Effective Maintenance Management: Risk and Reliability Strategies for Optimizing Performance, *Industrial Press*, New York, NY.

New York City Rent Guidelines Board. (2017). *2017 Price Index of Operating Costs.* New York.

Niazi, A., Dai, J. S., Balabani, S., & Seneviratne, L. (2006). Product cost estimation: Technique classification and methodology review.

Oduyemi, O., Okoroh, M., & Dean, A. (2014). Barriers to Life Cycle Costing Usage. In *Proceedings of the 30th Annual ARCOM Conference*, Portsmouth, UK.

Office of Government Commerce (OGC). (2003). *Achieving Excellence Guide 7: Whole-life Costing.* Retrieved from http://www.ogc.gov.uk/SDToolkit/reference/ogc_library/achievingexcellence/ae7.pdf

Office of Government Commerce (OGC). (2007). Whole-life costing and cost management - Achieving Excellence in Construction Procurement Guide. London, United Kingdom: OGC.

Ofori, I., Duodu, P., & Bonney, S. (2015). Establishing factors influencing building maintenance practices: Ghanaian perspective. J*ournal of Economics and Sustainable Development*, 6(24), 184-193.

Olayinka, A., & Owolabi, O. (2015). Evaluation of the factors affecting housing maintenance and its probable solutions. *International Journal of Latest Research in Engineering and Technology*, *1*(4), 59-64.

Olubodun, F., Kandwa, J., Oladapo, A., & Thompson, J. (2010). An Appraisal of the Level of Application of Life Cycle Costing within the Construction Industry in the UK. *Structural Survey*, 28(4), 254-265.

Omari, D. O. (2015). *An Investigation into factors affecting the maintenance cost of commercial buildings in Nairobi, Kenya.* (Unpublished Dissertation, Department of Real Estate and Construction Management, School of the Built Environment).

Opoku, A. (2013). The Application of Whole Life Costing in the UK Construction Industry: Benefits and Barriers. *International Journal of Architecture, Engineering and Construction*, 2(1), 35-42.

Perera, B. A. K. S., Chethana, I. M., Illankoon, S., & Perera, W. A. N. (2016). Determinants of operational and maintenance costs of condominiums. *Built-Environment Sri Lanka*, 12(1).

Perera, O., Morton, B., & Perfrement, T. (2009). Life cycle costing in sustainable public procurement: A question of value. *International Institute for Sustainable Development: A white paper from IISD*.

Pessenlehner, W., & Mahdavi, A. (2003). Building morphology, transparence, and energy performance. In *Proceedings of the Eighth International IBPSA Conference*, (pp. 1025-1030).

Philip, C. H., & Chow, W. K. (2001). Energy use in commercial buildings in Hong Kong. *Applied Energy*, 69(4), 243-255.

Raheja, D. G. (1991). *Assurance Technologies*. NY: McGraw-Hill, Inc.

Ramachandra, T. (2013). *Exploring feasible solutions to payment problems in the construction industry in New Zealand*. (Doctoral dissertation, AUT University). Retrieved from http://hdl.handle.net/10292/5554

RIBA. (2012). *RIBA plan of work 2013*. RIBA: London.

RICS (2014). New Rules of Measurement: NRM 3: Order of cost estimating and cost planning for building maintenance works, ISBN 978 1 78321 024 4. RICS: UK.

RICS. (2012). New Rules of Measurement-NRM 2: Detailed Measurement for Building Works.

Robinson, H., Symonds, B., Gilbertson, B., & Ilozor, B. (Eds.). (2015). *Design Economics for the Built Environment: Impact of Sustainability on Project Evaluation*. John Wiley & Sons.

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of political economy*, 82(1), 34-55.

Ross, T. J. (2004). *Fuzzy logic with engineering applications* (2). New York: Wiley.

SAE, J. (1993). 1100 Motor Vehicle Dimensions Society of Automotive Engineers Inc. Warren Dale, Jun.

Saghatforoush, E., Trigunarsyah, B., & Too, E. G. (2012). Assessment of operability and maintainability success factors in provision of extended constructability principles.

Saunders, M., Lewis, P., & Thornhill, A. (2009). Understanding research philosophies and approaches. *Research methods for business students*, 4(106-135).

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students* (7th ed.). Harlow, England: Pearson Education.

Schaude, J. (2011). *Life Cycle Cost Calculation Models for Buildings*. Retrieved from http://www.inpro-project.eu/media/lcc_juttaschade.pdf

Seeley, I. H. (1996). *Building Economics* (4 ed.). New York: Palgrave McMillan.

Smith, J., Jaggar, D., Love, P. E. D., & Olatunji, O. A. (2007). *Building Cost Planning for the Design Team* (ed.).

Somerville, C. T. (1999). Residential construction costs and the supply of new housing: endogeneity and bias in construction cost indexes. *The Journal of Real Estate Finance and Economics*, 18(1), 43-62.

Sri Lanka Sustainable Energy Authority. (2014). Annual Report. SLSEA: Colombo.

Sterner, E. (2000). Life-cycle costing and its use in the Swedish building sector. *Building Research & Information*, 28(5-6), 387-393.

Taherdoost, H. (2016). Sampling methods in research methodology; how to choose a sampling technique for research. H*ow to Choose a Sampling Technique for Research* (April 10, 2016).

Taherdoost, H. (2017). Determining sample size; how to calculate survey sample size. *International Journal of Economics and Management Systems*, 2, 236-239.

Talib, R., Ahmad, A. G., Zakaria, N., & Sulieman, M. Z. (2014). Assessment of factors affecting building maintenance and defects of public buildings in Penang, Malaysia. *Architecture Research*, 4(2), 48-53.

Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social & behavioral research* (6th ed.). Thousand Oaks, CA: SAGE Publications.

Ungar, B. L. (2003). *Factors Affecting the Construction and Operating Costs of Federal Buildings*. Washington DC, USA: General Services Administration.

Van Teijlingen, E. R., & Hundley, V. (2001). *The importance of pilot studies*.

Wang, N., Wei, K., & Sun, H. (2014). Whole life project management approach to sustainability. *Journal of Management in Engineering*, 30(2), 246-255.

Waziri, B. S. (2016). Design and construction defects influencing residential building maintenance in Nigeria. *Jordan Journal of Civil Engineering*, 10(3).

Weddikkara, C. (2001). Towards sustainable development - an overview. Financial Times

Weerasinghe, A., Ramachandra, T., & Rotimi, J. O. (2016). A Simplified model for predicting running cost of office buildings in Sri Lanka. In *Proceedings of the 32nd Annual ARCOM Conference.*

Williams, C. (2007). Research Methods. *Journal of Business & Economics Research*, 5(3), 65-72.

Winch, G., & Courtney, R. (2001). Re-engineering. Manoliadis et al., sustainable construction and drivers of change in Greece: A Delphi study. *Construction Management and Economics*, 24(1), 113-120.

Wong, I. L., Perera, S., & Eames, P. (2010). Goal Directed Life Cycle Costing as a Method to Evaluate the Economic Feasibility of Office Buildings with Conventional and TIFacades. *Construction Management and Economics*, 28(7), 715-735.

Yang, Q., Liu, M., Shu, C., Mmereki, D., Uzzal Hossain, M., & Zhan, X. (2015). Impact Analysis of Window-Wall Ratio on Heating and Cooling Energy Consumption of Residential Buildings in Hot Summer and Cold Winter Zone in China. *Journal of Engineering*, 2015, 1-17. doi: 10.1155/2015/538254

Yıldırım, A., & Simsek, H. (2006). *Qualitative research methods in social studies*. Ankara: Seckin Publications.

Yin, R. K. (2003). *Case study research: Design and methods* (2nd ed.). London, England: Sage Publication.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage Publications.

Yu, M. K., & Ive, G. (2008). The compilation methods of building price indices in Britain: a critical review. *Construction Management and Economics*, 26(7), 693-705.

Zhiliang, M., Zhenhua, W., Wu, S., & Zhe, L. (2011). Application and extension of the IFC standard in construction cost estimating for tendering in China. *Automation in Construction*, 20(2), 196-204.

BIBLIOGRAPHY

Ashworth, A., Hogg, K., & Higgs, C. (2013). W*illis's Practice and Procedure of the Quantity Surveyor* (13th ed.). West Sussex, United Kingdom: John Wiley & Sons.

Aye, L., Bamford, N., Charters, B., & Robinson, J. (2000). Environmentally Sustainable Development; a Life Cycle Costing Approach for a Commercial Office Building in Melbourne, Australia. *Construction Management and Economics*, 18(8), 927-934.

Bouachera, T., Kishk, M., & Power, L. (2007). Towards a Generic Framework for Whole Life Costing in the Oil Industry. In *Proceedings of the 23rd Annual ARCOM Conference,* Belfast, UK.

Clift, M. (2003). *Life Cycle Costing in the Construction Sector*. UNEP Industry and Environment, April-September 37-41.

Clift, M., & Bourke, K. (1999). *Study on whole life costing*. London; United Kingdom: BRE Press.

Ferry, D. J. O., & Flanegan, R. (1991). *Life Cycle Costing – A Radical Approach*. CIRIA Report 122: London.

Flanagan, R., Norman, G., Meadows, J. and Robinson, G. (1989). *Life Cycle Costing: Theory and Practice.* Oxford: BSP Professional Books.

Fu, C., Kaya, S., Kagioglou, M., & Aouad, G. (2007). The development of an IFC-based lifecycle costing prototype tool for building construction maintenance. *Construction Innovation,* 7(1), 85-99.

Kirk, S. J., & Dell'Isola, A. J. (1995). *Life Cycle Costing for Design Professionals*. New York: McGrew-Hill.

Kirkham, R., Alisa, M., Pimenta de Silva, A., Grindley, T., & Brondsted, J. (2004). EUROLIFEFORM: An integrated probabilistic whole life cycle cost and performance model for building and civil infrastructure. *In Proceedings of the construction and building research conference of the Royal Institution of Chartered Surveyors*, London, UK.

Kishk, M., Al-Hajj, A., Pollock, R., Aouad, G., Bakis, N., & Sun, M. (2003). *Whole Life Costing in Construction: A state of the art review.* Coventry; London: RICS.

Pelzeter, A. (2007). Building Optimisation with Life Cycle Costing - The Influence of Calculation Methods. Journal of Facilities Management, 5(2), 115-128.

APPENDICES

Questionnaire Survey - A model for forecasting the running costs of commercial buildings in Sri Lanka

Dear Sir/ Madam,

I am a postgraduate student of the University of Moratuwa and for my degree of Master of Philosophy I investigate “A model for forecasting the running costs of commercial buildings in Sri Lanka”. As you are a professional who engages in the construction industry including facilities management, you were identified as a potential respondent for this questionnaire survey.

Given the dramatically increased running costs of commercial buildings, there is a critical need to develop models and tools to promote early-stage running costs estimation. This research, therefore, aims to develop an early-stage supportive running costs estimation model along with a running costs index for commercial buildings in Sri Lanka. This survey investigates factors influencing the running costs of commercial buildings, with special emphasis on their level of impact on running costs, and intends to develop a building characteristics-based model for running costs estimation. The outcome of this survey would be used for my thesis and any possible conference and journal publications.

This questionnaire consists of two sections: general information and, factors influencing running costs.

Your participation in this survey is highly appreciated and your privacy and confidentiality will be strictly maintained.

Should you need any further information or clarification, please feel free to contact the researcher or the supervisor via the contact details given below. A summary of this thesis will be made available to you upon your request.

Thank you.

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General Information

1. 1. Please indicate your profession

Check all that apply.

- [ ] Engineering
- [ ] Management

2. 2. Please state your designation

____

3. 3. Please state the number of years you have been working in the architectural, engineering, construction and operations (AECO) industry

____

Factors Influencing The Running Costs of Buildings

Following is a list of factors influencing the running costs of buildings identified from a comprehensive review of the literature. Please rank the level of influence of each factor presented on the running costs of commercial buildings in the local context based on your experience in the field of building construction, operation and maintenance.

The Likert scale defined for the impact levels is:
1 - Insignificant, 2 - Little significant, 3 - Moderately significant, 4 - Very significant, 5 - Extremely significant.

4. Building Characteristics

Check all that apply.

	1	2	3	4	5
Building age	☐	☐	☐	☐	☐
Building services	☐	☐	☐	☐	☐
Building size	☐	☐	☐	☐	☐
Building materials and components	☐	☐	☐	☐	☐
Function	☐	☐	☐	☐	☐
Building height	☐	☐	☐	☐	☐
Type of structure	☐	☐	☐	☐	☐
Occupancy	☐	☐	☐	☐	☐
Location	☐	☐	☐	☐	☐
Finishes	☐	☐	☐	☐	☐

5. Maintenance Factors

Check all that apply.

	1	2	3	4	5
Failure to identify the true cause of defect					
Faulty maintenance					
Failure to execute maintenance at the right time					
Lack of preventive maintenance					
Poor workmanship					
Low concern to future maintenance					

6. Managerial Factors

Check all that apply.

	1	2	3	4	5
Budget constraints	☐	☐	☐	☐	☐
Lack of building maintenance manuals standards	☐	☐	☐	☐	☐
Poor quality of spare parts and materials	☐	☐	☐	☐	☐
Unavailability of the required spare parts tools and materials	☐	☐	☐	☐	☐
Poor financial control when executing maintenance work	☐	☐	☐	☐	☐
Poor or lack of training	☐	☐	☐	☐	☐
Poor management by maintenance units	☐	☐	☐	☐	☐
Unqualified and unavailability of maintenance contractors	☐	☐	☐	☐	☐
Unavailability of skilled and educated labours	☐	☐	☐	☐	☐
Failure reporting	☐	☐	☐	☐	☐

7. Design and Construction Defects

Check all that apply.

	1	2	3	4	5
Poor supervision	☐	☐	☐	☐	☐
Architectural design defects	☐	☐	☐	☐	☐
Poor quality control on site	☐	☐	☐	☐	☐
Defective construction materials	☐	☐	☐	☐	☐
Poor structural design	☐	☐	☐	☐	☐
Lack of proper reinforcement	☐	☐	☐	☐	☐
Site defects	☐	☐	☐	☐	☐
Poor incorporation of building services	☐	☐	☐	☐	☐

8. Environmental Factors

Check all that apply.

	1	2	3	4	5
Natural deterioration	☐	☐	☐	☐	☐
Harsh climatic conditions	☐	☐	☐	☐	☐

9. Tenant Factors

Check all that apply.

	1	2	3	4	5
Vandalism by tenants	☐	☐	☐	☐	☐
Expectation of Tenants	☐	☐	☐	☐	☐
Lack of understanding the importance of maintenance work	☐	☐	☐	☐	☐
Existence of buy policy	☐	☐	☐	☐	☐
Accessibility to the property	☐	☐	☐	☐	☐
Misuse of property	☐	☐	☐	☐	☐

10. Social Factors

Check all that apply.

	1	2	3	4	5
Third party vandalism	☐	☐	☐	☐	☐
Cultural practices	☐	☐	☐	☐	☐

11. Political/Regulatory Factors

Check all that apply.

	1	2	3	4	5
Changes in taxes and utility tariffs	☐	☐	☐	☐	☐
Changes in Operation and maintenance standards	☐	☐	☐	☐	☐
Health and safety regulations	☐	☐	☐	☐	☐
Price inflation	☐	☐	☐	☐	☐

12. Please state any other factors influencing the running costs of commercial buildings in Sri Lanka if available

____

____

____

____

____

Questionnaire Survey - A model for forecasting the running costs of commercial buildings in Sri Lanka

Dear Sir/ Madam,

I am a postgraduate student of the University of Moratuwa and for my degree of Master of Philosophy I investigate "A model for forecasting the running costs of commercial buildings in Sri Lanka". As you are a professional who engages in the construction industry including facilities management, you were identified as a potential respondent for this questionnaire survey.

Given the dramatically increased running costs of commercial buildings, there is a critical need to develop models and tools to promote early-stage running costs estimation. This research, therefore, aims to develop an early-stage supportive running costs estimation model along with a running costs index for commercial buildings in Sri Lanka. This survey investigates factors influencing the running costs of commercial buildings, with special emphasis on their level of impact on running costs, and intends to develop a building characteristics-based model for running costs estimation. The outcome of this survey would be used for my thesis and any possible conference and journal publications.

This questionnaire consists of two sections: general information and, factors influencing running costs.

Your participation in this survey is highly appreciated and your privacy and confidentiality will be strictly maintained.

Should you need any further information or clarification, please feel free to contact the researcher or the supervisor via the contact details given below. A summary of this thesis will be made available to you upon your request.

Thank you.

Researcher:
H.G.M. Devindi (178015E)
Email: d.geekiyanage22@gmail.com, 178015e@uom.lk
Mobile: +94 (77) 6161579

Supervisor:
Ch.QS.Dr. Thanuja Ramachandra
E-mail: thanuja03@hotmail.com, thanujar@uom.lk

General Information

1. Please indicate your profession

- [ ] Engineering
- [x] Management

2. Please state your designation

Facilities Manager

3. Please state the number of years you have been working in the architectural, engineering, construction and operations (AECO) industry

5 yrs

Factors Influencing The Running Costs of Buildings

Following is a list of factors influencing the running costs of buildings identified from a comprehensive review of the literature. Please rank the level of influence of each factor presented on the running costs of commercial buildings in the local context based on your experience in the field of building construction, operation and maintenance.

The Likert scale defined for the impact levels is:
1 - Insignificant, 2 - Little significant, 3 - Moderately significant, 4 - Very significant, 5 - Extremely significant.

Building Characteristics

	1	2	3	4	5
Building age	☐	☐	☐	☐	☑
Building services	☐	☐	☐	☐	☑
Building size	☐	☐	☐	☐	☑
Building materials and components	☐	☐	☐	☐	☑
Function	☐	☐	☐	☐	☑
Building height	☐	☐	☐	☐	☑
Type of structure	☐	☐	☐	☑	☐
Occupancy	☐	☐	☐	☐	☑
Location	☐	☐	☐	☑	☐
Finishes	☐	☑	☐	☐	☐

Maintenance Factors

	1	2	3	4	5
Failure to identify the true cause of defect	☐	☐	☐	☐	☑
Faulty maintenance	☐	☐	☐	☐	☑
Failure to execute maintenance at the right time	☐	☐	☐	☐	☑
Lack of preventive maintenance	☐	☐	☐	☑	☐
Poor workmanship	☐	☐	☐	☐	☑
Low concern to future maintenance	☐	☐	☐	☑	☐

Managerial Factors

	1	2	3	4	5
Budget constraints	☐	☐	☐	☐	☑
Lack of building maintenance manuals standards	☐	☐	☐	☐	☑
Poor quality of spare parts and materials	☐	☐	☐	☐	☑
Unavailability of the required spare parts tools and materials	☐	☐	☐	☐	☑
Poor financial control when executing maintenance work	☐	☐	☐	☐	☑
Poor or lack of training	☐	☐	☐	☐	☑
Poor management by maintenance units	☐	☐	☐	☐	☑
Unqualified and unavailability of maintenance contractors	☐	☐	☐	☐	☑
Unavailability of skilled and educated labours	☐	☐	☐	☑	☐

	1	2	3	4	5
Failure reporting				✓	

Design and Construction Defects

	1	2	3	4	5
Poor supervision					✓
Architectural design defects					✓
Poor quality control on site					✓
Defective construction materials				✓	
Poor structural design				✓	
Lack of proper reinforcement				✓	
Site defects			✓		
Poor incorporation of building services					✓

Environmental Factors

	1	2	3	4	5
Natural deterioration	☐	☐	☐	☐	☑
Harsh climatic conditions	☐	☐	☐	☐	☑

Tenant Factors

	1	2	3	4	5
Vandalism by tenants	☐	☐	☐	☐	☑
Expectation of Tenants	☐	☐	☐	☐	☑
Lack of understanding the importance of maintenance work	☐	☐	☐	☑	☐
Existence of buy policy	☐	☑	☐	☐	☐
Accessibility to the property	☐	☐	☑	☐	☐
Misuse of property	☐	☐	☐	☐	☑

Social Factors

	1	2	3	4	5
Third party vandalism	☐	☐	☐	☐	☑
Cultural practices	☐	☐	☐	☑	☐

Political/Regulatory Factors

	1	2	3	4	5
Changes in taxes and utility tariffs	☑	☐	☐	☐	☐
Changes in Operation and maintenance standards	☐	☐	☐	☐	☑
Health and safety regulations	☐	☐	☐	☑	☐
Price inflation	☐	☐	☑	☐	☐

Please state any other factors influencing the running costs of commercial buildings in Sri Lanka if available

Building characteristics data collection template

Property name:		**No.**	
Address:			
Contact person:			
Documents referred:			

Building characteristic	
1. Working days/week	
2. Working hours/day	
3. Operated years	
4. Occupancy	
5. Number of floors	
6. Building height	sq.ft/sq.m
7. Gross internal floor area (GIFA)	sq.ft/sq.m
8. Net floor area (NFA)	sq.ft/sq.m
9. Circulation area (CA)	sq.ft/sq.m
10. Window area	sq.ft/sq.m
11. Wall-to-floor ratio (WFR)	
12. Building shape	Regular / Irregular
13. Grouping of buildings	Yes / No
14. Type of structure	

Details on any refurbishments or renovation projects carried out in last three years and any changes caused to above building characteristics

Running cost data collection template

Property name:	
Address:	
Contact person:	
Documents referred:	

No.	

Running cost element	**Year:**												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total annual elemental cost (LKR)**
Operations costs													
1. Insurance													
2. Utilities													
2.1. Gas													
2.2. Electricity													
2.3. Fuel oil													
2.4. Water rates													
2.5. Effluent and drainage charges													
3. Administrative costs													
3.1. Services attendants													
3.2. Laundry													
3.3. Porterage													
3.4. Security													
3.5. Waste disposal													
3.6. Property management													
4. Taxes													
Maintenance costs													
1. Decoration													
1.1. External Decoration													
1.2. Internal Decorations													
2. Fabric													
2.1. External walls													
2.1.1. Walls													
2.1.2. Windows													
2.1.3. Doors													
2.1.4. Glazing													
2.2. Roof structures													
2.2.1. Covering flat													
2.2.2. Covering pitched													
2.2.3. Gutters and rain water pipes													
2.3. Other structural items													
2.3.1. Floors, staircases and steps													
2.3.2. Internal walls and partitions													
2.3.3. Internal glazing and windows													
2.3.4. Internal doors													
3. Fitting and fixtures													
3.1. Vandalism													
3.2. Built-in furniture													
3.3. Signs													
3.4. Ironmongery													
3.5. Key issues													
4. Internal finishes													
4.1. Wall finishes													
4.2. Floor finishes													
4.3. Ceilings													
5. Services													
5.1. Plumbing and internal drainage													
5.1.1. Cold water services													
5.1.2. Sanitary fittings													
5.2. Heating and ventilation													
5.2.1. Air conditioning and ventilation													
5.3. Lift and escalator													
5.4. Fire detection and protection system													
5.5. Electric power and lighting													
5.5.1. Lighting conductors													
5.5.2. High voltage generation, transmission and distribution													
5.5.3. Power													
5.5.4. Lightning													
5.5.5. Lamp replacement													
5.6. Other M&E services													
5.6.1. Refrigeration equipment													
5.6.2. Security camera													
5.6.3. Fire alarms													
5.6.4. Loose appliances													
5.6.5. Built-in-fittings													
5.6.6. Emergency lighting													
5.7. Telecommunication and data													
6. Cleaning													
6.1. Windows													
6.2. Internal/ External surfaces													
7. External works													
7.1. Repairs and decoration													
7.1.1. Pest control services													
7.1.2. Drains													
7.1.3. Roads pavement													
7.2. Landscaping													
7.3. Grounds maintenance													
8. Maintenance management													
9. Repairs and replacement of minor components/ small areas													
Total monthly running costs (LKR)													

APPENDIX 05: SPSS output for correlation and regression analyses

```
DESCRIPTIVES VARIABLES=Running_cost_per_sq.m_1 Working_days_per_week_1
Working_hours_per_day_1
    Age_1 GIFA_1 NFA_1 CA_1 Height_1 Floors_1 Window_area_1 WFR_1
Occupancy_1 Shape_1
    Type_of_structure_1 AttachedORDetached_1
  /SAVE
  /STATISTICS=MEAN STDDEV VARIANCE RANGE MIN MAX SEMEAN KURTOSIS SKEWNESS.
```

Descriptives

Notes

Output Created		08-MAY-2020 21:04:38
Comments		
Input	Data	C:\Users\dgeek\OneDrive - University of Salford\MPHIL 2020\ARCOM\ mphil MAY07.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	46
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Running_cost_per_sq.m_1 Working_days_per_week_1 Working_hours_per_day_1 Age_1 GIFA_1 NFA_1 CA_1 Height_1 Floors_1 Window_area_1 WFR_1 Occupancy_1 Shape_1 Type_of_structure_1 AttachedORDetached_1 /SAVE /STATISTICS=MEAN STDDEV VARIANCE RANGE MIN MAX SEMEAN KURTOSIS SKEWNESS.
Resources	Processor Time	00:00:00.05
	Elapsed Time	00:00:00.23
Variables Created or Modified	ZRunning_cost_per_sq.m_1	Zscore: SMEAN(Running_cost_per_sq.m)
	ZWorking_days_per_week_1	Zscore: SMEAN(Working_days_per_week)

	ZWorking_hours_per_day_1	Zscore: SMEAN(Working_hours_per_day)
	ZAge_1	Zscore: SMEAN(Age)
	ZGIFA_1	Zscore: SMEAN(GIFA)
	ZNFA_1	Zscore: SMEAN(NFA)
	ZCA_1	Zscore: SMEAN(CA)
	ZHeight_1	Zscore: SMEAN(Height)
	ZFloors_1	Zscore: SMEAN(Floors)
	ZWindow_area_1	Zscore: SMEAN(Window_area)
	ZWFR_1	Zscore: SMEAN(WFR)
	ZOccupancy_1	Zscore: SMEAN(Occupancy)
	ZShape_1	Zscore: SMEAN(Shape)
	ZType_of_structure_1	Zscore: SMEAN(Type_of_structure)
	ZAttachedORDetached_1	Zscore: SMEAN(AttachedORDetached)

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean
	Statistic	Statistic	Statistic	Statistic	Statistic
SMEAN(Running_cost_per_sq.m)	46	12184.76	107.36	12292.12	4084.9217
SMEAN(Working_days_per_week)	46	2.00	5.00	7.00	5.7391
SMEAN(Working_hours_per_day)	46	18.00	6.00	24.00	9.0217
SMEAN(Age)	46	49.0	1.0	50.0	14.152
SMEAN(GIFA)	46	108052.03	8485.97	116538.00	34837.1424
SMEAN(NFA)	46	70490.00	5536.00	76026.00	22726.7383
SMEAN(CA)	46	37562.03	2949.97	40512.00	12110.4046
SMEAN(Height)	46	465.90	31.48	497.38	162.4137
SMEAN(Floors)	46	40.0	3.0	43.0	13.630
SMEAN(Window_area)	46	210807.70	1144.60	211952.30	25624.5711
SMEAN(WFR)	46	.65	.03	.68	.3608
SMEAN(Occupancy)	46	7590.0	210.0	7800.0	1638.226
SMEAN(Shape)	46	1.0	1.0	2.0	1.609
SMEAN(Type_of_structure)	46	2.0	1.0	3.0	1.826
SMEAN(AttachedORDetached)	46	1.0	1.0	2.0	1.761
Valid N (listwise)	46				

```
CORRELATIONS
  /VARIABLES=Running_cost_per_sq.m_1 Working_days_per_week_1
Working_hours_per_day_1 Age_1 GIFA_1
    NFA_1 CA_1 Height_1 Floors_1 Window_area_1 WFR_1 Occupancy_1 Shape_1
Type_of_structure_1
    AttachedORDetached_1
  /PRINT=TWOTAIL NOSIG
  /STATISTICS DESCRIPTIVES XPROD
  /MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		08-MAY-2020 21:05:09
Comments		
Input	Data	C:\Users\dgeek\OneDrive - University of Salford\MPHIL 2020\ARCOM\Trail mphil MAY07.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	46
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=Running_cost_per_sq.m_1 Working_days_per_week_1 Working_hours_per_day_1 Age_1 GIFA_1 NFA_1 CA_1 Height_1 Floors_1 Window_area_1 WFR_1 Occupancy_1 Shape_1 Type_of_structure_1 AttachedORDetached_1 /PRINT=TWOTAIL NOSIG /STATISTICS DESCRIPTIVES XPROD /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.03

Descriptive Statistics

	Mean	Std. Deviation	N
SMEAN(Running_cost_per_sq.m)	4084.9217	2927.33946	46
SMEAN(Working_days_per_week)	5.7391	.79400	46
SMEAN(Working_hours_per_day)	9.0217	4.40575	46
SMEAN(Age)	14.152	13.0383	46
SMEAN(GIFA)	34837.1424	22130.45868	46
SMEAN(NFA)	22726.7383	14437.26776	46
SMEAN(CA)	12110.4046	7693.19149	46
SMEAN(Height)	162.4137	121.75866	46
SMEAN(Floors)	13.630	10.0163	46
SMEAN(Window_area)	25624.5711	37051.87453	46
SMEAN(WFR)	.3608	.15640	46
SMEAN(Occupancy)	1638.226	1546.3732	46
SMEAN(Shape)	1.609	.4934	46
SMEAN(Type_of_structure)	1.826	.6767	46
SMEAN(AttachedORDetached)	1.761	.4313	46

Correlations

		SMEAN(Running_cost_per_sq.m)	SMEAN(Working_days_per_week)	SMEAN(Working_hours_per_day)	SMEAN(Age)	SMEAN(GIFA)	SMEAN(NFA)	SMEAN(CA)	SMEAN(Height)	SMEAN(Floors)	SMEAN(Window_area)	SMEAN(WFR)	SMEAN(Occupancy)	SMEAN(Shape)	SMEAN(Type_of_structure)	SMEAN(AttachedORDetached)
SMEAN(Running_cost_per_sq.m)	Pearson Correlation	1	.082	.336*	.452**	.943**	.943**	.943**	.945**	.950**	.430**	.085	.586**	-.091	.056	-.165
	Sig. (2-tailed)		.590	.023	.002	.000	.000	.000	.000	.000	.003	.576	.000	.548	.712	.273
	Sum of Squares and Cross-products	385619232.923	8537.666	194899.673	776121.568	2748140703.736	1792807083.996	955333697.909	15150676.843	1253007.790	2097703732.159	1743.393	119432580.500	-5912.249	4992.484	-9375.041

	Covariance	8569316.287	189.726	4331.104	17247.146	61069793.416	39840157.422	21229637.731	336681.708	27844.618	46615638.492	38.742	2654057.344	-131.383	110.944	-208.334
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Working_days_per_week)	Pearson Correlation	.082	1	.659**	-.182	.143	.143	.143	.109	.111	.016	.019	-.038	-.011	-.045	-.186
	Sig. (2-tailed)	.590		.000	.227	.342	.342	.342	.472	.465	.914	.900	.800	.942	.767	.215
	Sum of Squares and Cross-products	8537.666	28.370	103.761	-84.674	113221.294	73862.299	39359.020	472.504	39.565	21557.583	.107	-2123.054	-.196	-1.087	-2.870
	Covariance	189.726	.630	2.306	-1.882	2516.029	1641.384	874.645	10.500	.879	479.057	.002	-47.179	-.004	-.024	-.064
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Working_hours_per_day)	Pearson Correlation	.336*	.659**	1	.134	.463**	.463**	.463**	.462**	.464**	.307*	.221	.257	-.103	.203	-.126
	Sig. (2-tailed)	.023	.000		.376	.001	.001	.001	.001	.001	.038	.140	.085	.494	.177	.405
	Sum of Squares and Cross-products	194899.673	103.761	873.478	345.348	2030900.933	1324900.772	706000.150	11145.801	921.370	2255390.659	6.854	78651.974	-10.109	27.174	-10.761
	Covariance	4331.104	2.306	19.411	7.674	45131.132	29442.239	15688.892	247.684	20.475	50119.792	.152	1747.822	-.225	.604	-.239
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Age)	Pearson Correlation	.452**	-.182	.134	1	.407**	.407**	.407**	.458**	.446**	.123	.188	.312*	-.091	.207	.066
	Sig. (2-tailed)	.002	.227	.376		.005	.005	.005	.001	.002	.415	.211	.035	.549	.167	.663

	Sum of Squares and Cross-products	776121.568	-84.674	345.348	7649.935	5284838.703	3447675.522	1837164.268	32746.654	2618.587	2674553.522	17.236	282961.184	-26.261	82.217	16.674
	Covariance	17247.146	-1.882	7.674	169.999	117440.860	76615.012	40825.873	727.703	58.191	59434.523	.383	6288.026	-.584	1.827	.371
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(GIFA)	Pearson Correlation	.943**	.143	.463**	.407**	1	1.000**	1.000**	.930**	.933**	.478**	.132	.631**	-.133	.073	-.208
	Sig. (2-tailed)	.000	.342	.001	.005		.000	.000	.000	.000	.001	.383	.000	.377	.629	.166
	Sum of Squares and Cross-products	2748140703.736	113221.294	2030900.933	5284838.703	22039074061.050	14377651092.880	7661423537.240	112726222.230	9309507.741	17631350577.441	20504.269	972395377.880	-65540.927	49317.789	-89253.504
	Covariance	61069793.416	2516.029	45131.132	117440.860	489757201.357	319503357.620	170253856.383	2505027.161	206877.950	391807790.610	455.650	21608786.175	-1456.465	1095.951	-1983.411
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(NFA)	Pearson Correlation	.943**	.143	.463**	.407**	1.000**	1	1.000**	.930**	.933**	.478**	.132	.631**	-.133	.073	-.208
	Sig. (2-tailed)	.000	.342	.001	.005	.000		.000	.000	.000	.001	.383	.000	.377	.629	.166
	Sum of Squares and Cross-products	1792807083.996	73862.299	1324900.772	3447675.522	14377651092.880	9379561517.692	4998089946.433	73539309.675	6073252.140	11502179994.584	13376.392	634362464.318	-42756.991	32173.476	-58226.389
	Covariance	39840157.422	1641.384	29442.239	76615.012	319503357.620	208434700.393	111068665.476	1634206.882	134961.159	255603999.880	297.253	14096943.652	-950.155	714.966	-1293.920
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46

SMEAN(CA)	Pearson Correlation	.943**	.143	.463**	.407**	1.000**	1.000**	1	.930**	.933**	.478**	.132	.631**	-.133	.073	-.208
	Sig. (2-tailed)	.000	.342	.001	.005	.000	.000		.000	.000	.001	.383	.000	.377	.629	.166
	Sum of Squares and Cross-products	955333697.909	39359.020	706000.150	1837164.268	7661423537.240	4998089946.433	2663333788.633	39186914.488	3236255.768	6129170785.916	7127.877	338032899.078	-22783.928	17144.297	-31027.110
	Covariance	21229637.731	874.645	15688.892	40825.873	170253856.383	111068665.476	59185195.303	870820.322	71916.795	136203795.243	158.397	7511842.202	-506.310	380.984	-689.491
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Height)	Pearson Correlation	.945**	.109	.462**	.458**	.930**	.930**	.930**	1	.993**	.493**	.159	.662**	-.087	.095	-.189
	Sig. (2-tailed)	.000	.472	.001	.001	.000	.000	.000		.000	.000	.290	.000	.563	.531	.208
	Sum of Squares and Cross-products	15150676.843	472.504	11145.801	32746.654	112726222.230	73539309.675	39186914.488	667132.739	54471.603	100146473.436	136.558	5605025.157	-236.353	351.590	-447.349
	Covariance	336681.708	10.500	247.684	727.703	2505027.161	1634206.882	870820.322	14825.172	1210.480	2225477.187	3.035	124556.115	-5.252	7.813	-9.941
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Floors)	Pearson Correlation	.950**	.111	.464**	.446**	.933**	.933**	.933**	.993**	1	.500**	.150	.652**	-.102	.102	-.165
	Sig. (2-tailed)	.000	.465	.001	.002	.000	.000	.000	.000		.000	.321	.000	.501	.501	.273
	Sum of Squares and Cross-products	1253007.790	39.565	921.370	2618.587	9309507.741	6073252.140	3236255.768	54471.603	4514.717	8347122.898	10.558	454235.877	-22.652	31.043	-32.065

	Covariance	27844.618	.879	20.475	58.191	206877.950	134961.159	71916.795	1210.480	100.327	185491.620	.235	10094.131	-.503	.690	-.713
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Window_area)	Pearson Correlation	.430**	.016	.307*	.123	.478**	.478**	.478**	.493**	.500**	1	.115	.391**	.004	-.142	-.061
	Sig. (2-tailed)	.003	.914	.038	.415	.001	.001	.001	.000	.000		.447	.007	.978	.347	.688
	Sum of Squares and Cross-products	2097703732.159	21557.583	2255390.659	2674553.522	17631350577.441	11502179994.584	6129170785.916	100146473.436	8347122.898	61777863269.707	29938.832	1007524944.675	3505.510	-160120.321	-43686.388
	Covariance	46615638.492	479.057	50119.792	59434.523	391807790.610	255603999.880	136203795.243	2225477.187	185491.620	1372841405.993	665.307	22389443.215	77.900	-3558.229	-970.809
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(WFR)	Pearson Correlation	.085	.019	.221	.188	.132	.132	.132	.159	.150	.115	1	.249	.049	.055	.214
	Sig. (2-tailed)	.576	.900	.140	.211	.383	.383	.383	.290	.321	.447		.095	.747	.716	.154
	Sum of Squares and Cross-products	1743.393	.107	6.854	17.236	20504.269	13376.392	7127.877	136.558	10.558	29938.832	1.101	2713.077	.170	.262	.648
	Covariance	38.742	.002	.152	.383	455.650	297.253	158.397	3.035	.235	665.307	.024	60.291	.004	.006	.014
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Occupancy)	Pearson Correlation	.586**	-.038	.257	.312*	.631**	.631**	.631**	.662**	.652**	.391**	.249	1	-.094	.165	-.348*
	Sig. (2-tailed)	.000	.800	.085	.035	.000	.000	.000	.000	.000	.007	.095		.532	.274	.018

	Sum of Squares and Cross-products	119432580.500	-2123.054	78651.974	282961.184	972395377.880	634362464.318	338032899.078	5605025.157	454235.877	1007524944.675	2713.077	107607159.375	-3242.397	7754.509	-10443.213
	Covariance	2654057.344	-47.179	1747.822	6288.026	21608786.175	14096943.652	7511842.202	124556.115	10094.131	22389443.215	60.291	2391270.208	-72.053	172.322	-232.071
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Shape)	Pearson Correlation	-.091	-.011	-.103	-.091	-.133	-.133	-.133	-.087	-.102	.004	.049	-.094	1	-.142	-.136
	Sig. (2-tailed)	.548	.942	.494	.549	.377	.377	.377	.563	.501	.978	.747	.532		.347	.367
	Sum of Squares and Cross-products	-5912.249	-.196	-10.109	-26.261	-65540.927	-42756.991	-22783.928	-236.353	-22.652	3505.510	.170	-3242.397	10.957	-2.130	-1.304
	Covariance	-131.383	-.004	-.225	-.584	-1456.465	-950.155	-506.310	-5.252	-.503	77.900	.004	-72.053	.243	-.047	-.029
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SMEAN(Type_of_structure)	Pearson Correlation	.056	-.045	.203	.207	.073	.073	.073	.095	.102	-.142	.055	.165	-.142	1	-.222
	Sig. (2-tailed)	.712	.767	.177	.167	.629	.629	.629	.531	.501	.347	.716	.274	.347		.138
	Sum of Squares and Cross-products	4992.484	-1.087	27.174	82.217	49317.789	32173.476	17144.297	351.590	31.043	-160120.321	.262	7754.509	-2.130	20.609	-2.913
	Covariance	110.944	-.024	.604	1.827	1095.951	714.966	380.984	7.813	.690	-3558.229	.006	172.322	-.047	.458	-.065
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46

SMEAN(AttachedORDetached)	Pearson Correlation	-.165	-.186	-.126	.066	-.208	-.208	-.208	-.189	-.165	-.061	.214	-.348*	-.136	-.222	1
	Sig. (2-tailed)	.273	.215	.405	.663	.166	.166	.166	.208	.273	.688	.154	.018	.367	.138	
	Sum of Squares and Cross-products	-9375.041	-2.870	-10.761	16.674	-89253.504	-58226.389	-31027.110	-447.349	-32.065	-43686.388	.648	-10443.213	-1.304	-2.913	8.370
	Covariance	-208.334	-.064	-.239	.371	-1983.411	-1293.920	-689.491	-9.941	-.713	-970.809	.014	-232.071	-.029	-.065	.186
	N	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

```
OUTPUT MODIFY
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  /SELECT TABLES
  /IF COMMANDS=[LAST] SUBTYPES="Correlations"
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REGRESSION
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  /MISSING MEANSUBSTITUTION
  /STATISTICS COEFF OUTS CI(95) BCOV R ANOVA COLLIN TOL CHANGE ZPP
  /CRITERIA=PIN(.05) POUT(.10) CIN(95)
  /NOORIGIN
  /DEPENDENT Running_cost_per_sq.m_1
  /METHOD=STEPWISE Working_days_per_week_1 Working_hours_per_day_1 Age_1
GIFA_1 NFA_1 CA_1 Height_1
    Floors_1 Window_area_1 WFR_1 Occupancy_1 Shape_1 Type_of_structure_1
AttachedORDetached_1
  /PARTIALPLOT ALL
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS DURBIN HISTOGRAM(ZRESID) NORMPROB(ZRESID)
  /CASEWISE PLOT(ZRESID) OUTLIERS(3)
  /SAVE PRED ZPRED ADJPRED SEPRED MAHAL COOK LEVER MCIN RESID ZRESID SRESID
SDRESID.
```

Graph

```
[DataSet2] C:\Users\dgeek\OneDrive - University of Salford\MPHIL
2020\ARCOM\Trail mphil MAY07.sav
```


```
DATASET ACTIVATE DataSet2.
EXAMINE VARIABLES=ZRE_1
  /PLOT BOXPLOT STEMLEAF HISTOGRAM NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES EXTREME
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

Explore - trail 1 data set (46 buildings)

Notes

Output Created		08-MAY-2020 21:58:09
Comments		
Input	Data	C:\Users\dgeek\OneDrive - University of Salford\MPHIL 2020\ARCOM\Trail mphil MAY07.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>

	Split File	<none>
	N of Rows in Working Data File	46
Missing Value Handling	Definition of Missing	User-defined missing values for dependent variables are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any dependent variable or factor used.
Syntax		EXAMINE VARIABLES=ZRE_1 /PLOT BOXPLOT STEMLEAF HISTOGRAM NPPLOT /COMPARE GROUPS /STATISTICS DESCRIPTIVES EXTREME /CINTERVAL 95 /MISSING LISTWISE /NOTOTAL.
Resources	Processor Time	00:00:00.50
	Elapsed Time	00:00:00.50

```
[DataSet2] C:\Users\dgeek\OneDrive - University of Salford\MPHIL
2020\ARCOM\Trail mphil MAY07.sav
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Standardized Residual	46	100.0%	0	0.0%	46	100.0%

Descriptives

			Statistic	Std. Error
Standardized Residual	Mean		.0000000	.14244246
	95% Confidence Interval for Mean	Lower Bound	-.2868938	
		Upper Bound	.2868938	
	5% Trimmed Mean		-.0521238	
	Median		-.0862305	
	Variance		.933	
	Std. Deviation		.96609178	
	Minimum		-1.34714	
	Maximum		3.12792	
	Range		4.47506	
	Interquartile Range		1.62055	
	Skewness		.833	.350

	Kurtosis	.851	.688

Extreme Values

			Case Number	Value
Standardized Residual	Highest	1	6	3.12792
		2	8	1.63685
		3	13	1.46096
		4	41	1.46096
		5	10	1.37188
	Lowest	1	46	-1.34714
		2	23	-1.34714
		3	33	-1.16956
		4	39	-1.11263
		5	9	-1.11263

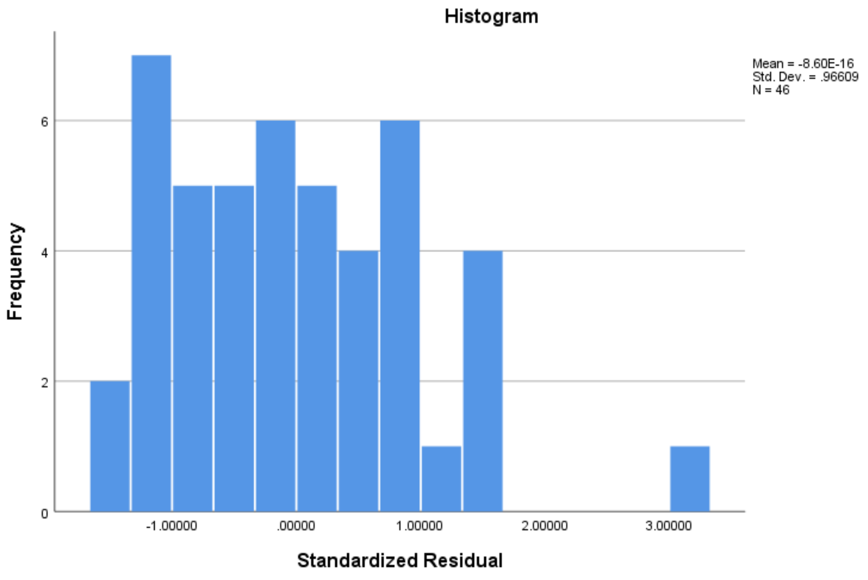
Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual	.109	46	.200*	.939	46	.017

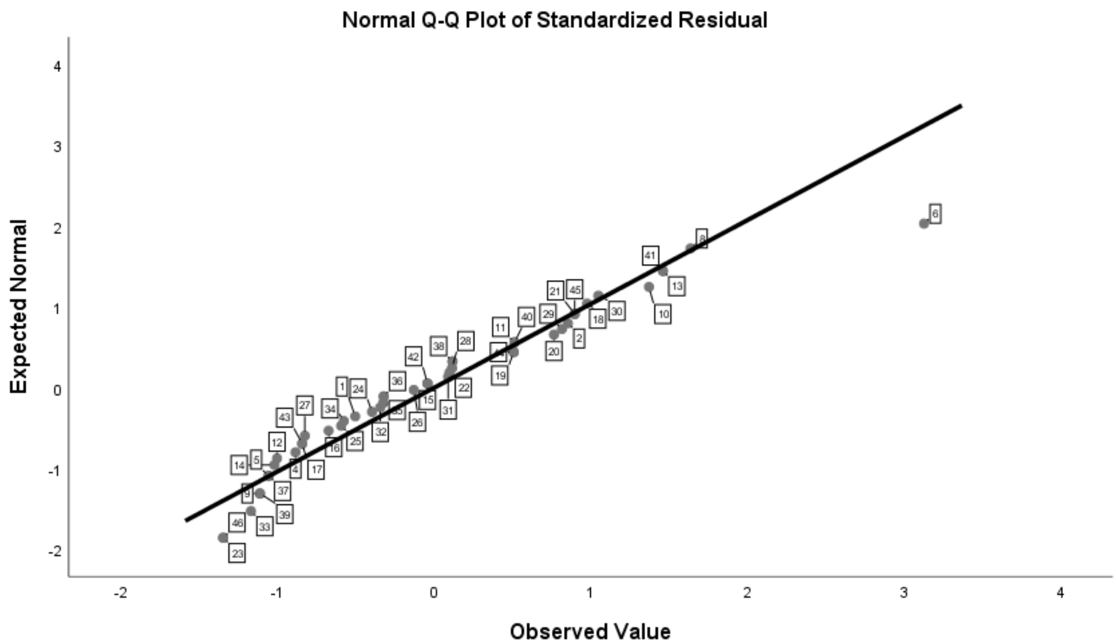
*. This is a lower bound of the true significance.

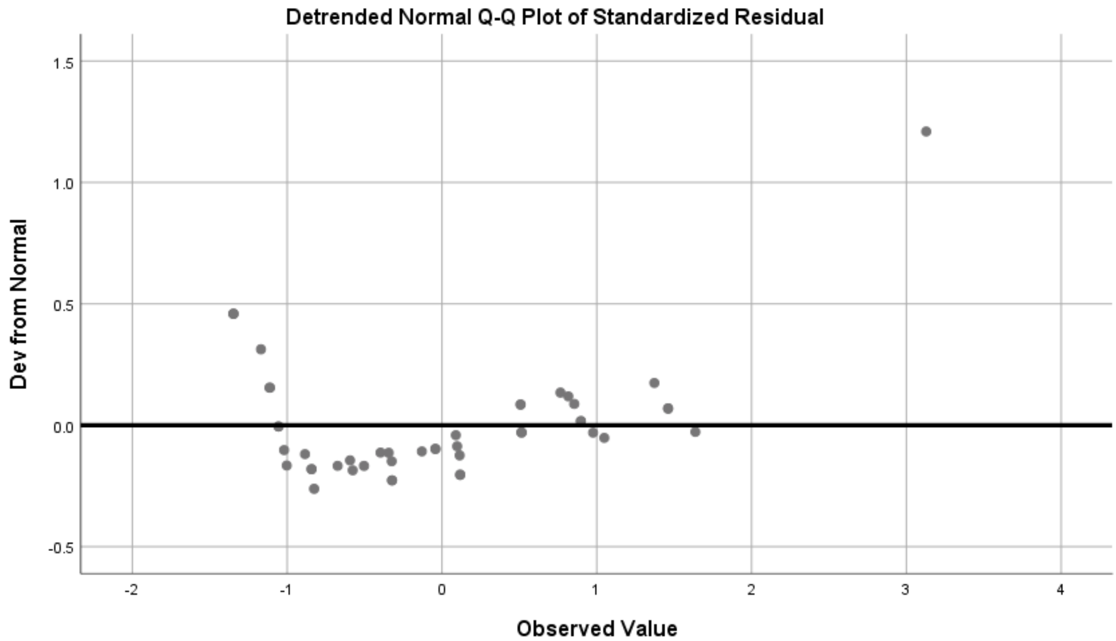
a. Lilliefors Significance Correction

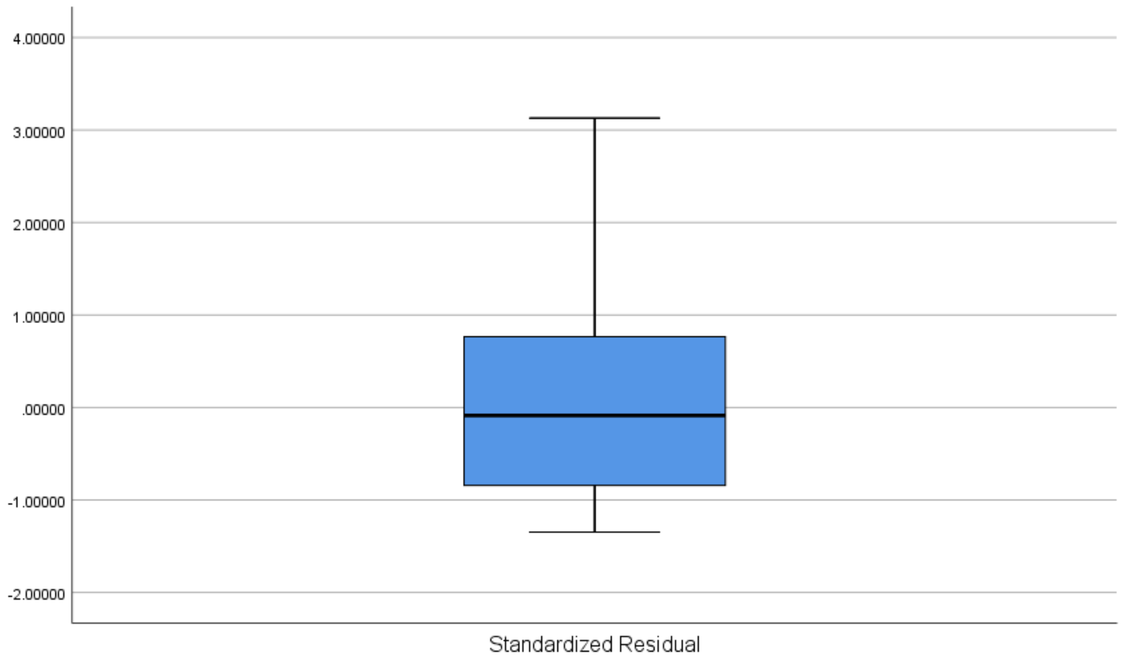
Standardized Residual



```
Standardized Residual Stem-and-Leaf Plot

 Frequency    Stem &  Leaf

     9.00       -1 .  000011133
     8.00       -0 .  55568888
     8.00       -0 .  00133333
     5.00        0 .  00111
    10.00        0 .  5555788889
     4.00        1 .  0344
     1.00        1 .  6
      .00        2 .
      .00        2 .
     1.00        3 .  1

 Stem width:   1.00000
 Each leaf:        1 case(s)
```








```
DATASET ACTIVATE DataSet1.
DATASET ACTIVATE DataSet1.

SAVE OUTFILE='C:\Users\dgeek\OneDrive - University of Salford\MPHIL
2020\ARCOM\Trail mphil 2.sav'
  /COMPRESSED.
```

```
EXAMINE VARIABLES=ZRE_1
  /PLOT BOXPLOT STEMLEAF HISTOGRAM NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES EXTREME
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

Explore - excluded case 6 (only 45 cases)

Notes

Output Created		09-MAY-2020 00:09:41
Comments		
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	N of Rows in Working Data File	45
Missing Value Handling	Definition of Missing	User-defined missing values for dependent variables are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any dependent variable or factor used.
Syntax		EXAMINE VARIABLES=ZRE_1 /PLOT BOXPLOT STEMLEAF HISTOGRAM NPPLOT /COMPARE GROUPS /STATISTICS DESCRIPTIVES EXTREME /CINTERVAL 95 /MISSING LISTWISE /NOTOTAL.
Resources	Processor Time	00:00:00.55
	Elapsed Time	00:00:03.51

```
[DataSet1] C:\Users\dgeek\OneDrive - University of Salford\MPHIL
2020\ARCOM\Trail mphil 2.sav
```

Descriptives

			Statistic	Std. Error
Standardized Residual	Mean		.0000000	.14213381
	95% Confidence Interval for Mean	Lower Bound	-.2864519	
		Upper Bound	.2864519	
	5% Trimmed Mean		-.0229174	
	Median		-.1539723	
	Variance		.909	
	Std. Deviation		.95346259	
	Minimum		-1.63058	
	Maximum		2.07521	
	Range		3.70579	
	Interquartile Range		1.57833	
	Skewness		.467	.354
	Kurtosis		-.458	.695

Extreme Values

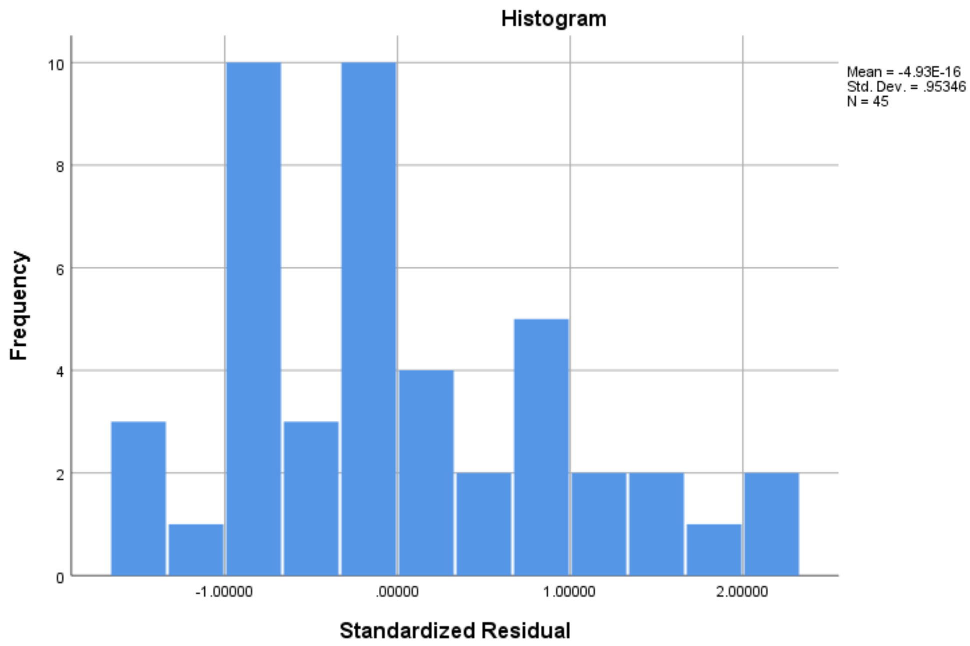
			Case Number	Value
Standardized Residual	Highest	1	12	2.07521
		2	40	2.07521
		3	7	1.67144
		4	9	1.54173
		5	28	1.35820
	Lowest	1	45	-1.63058
		2	22	-1.63058
		3	11	-1.51593
		4	32	-1.04169
		5	13	-.94524

Tests of Normality

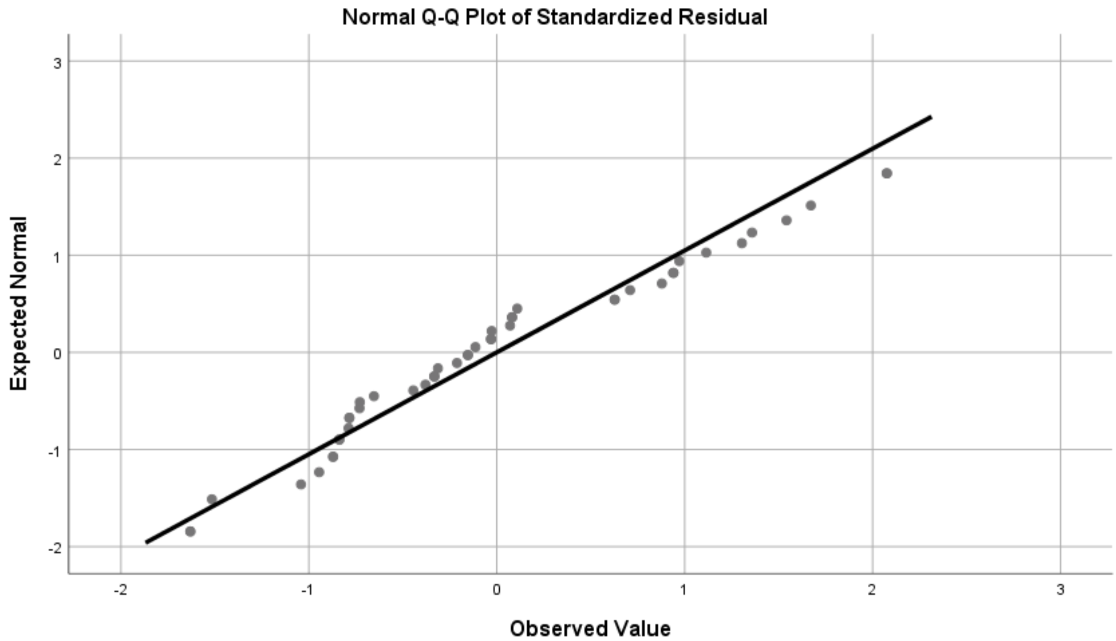
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual	.143	45	.021	.955	45	.078

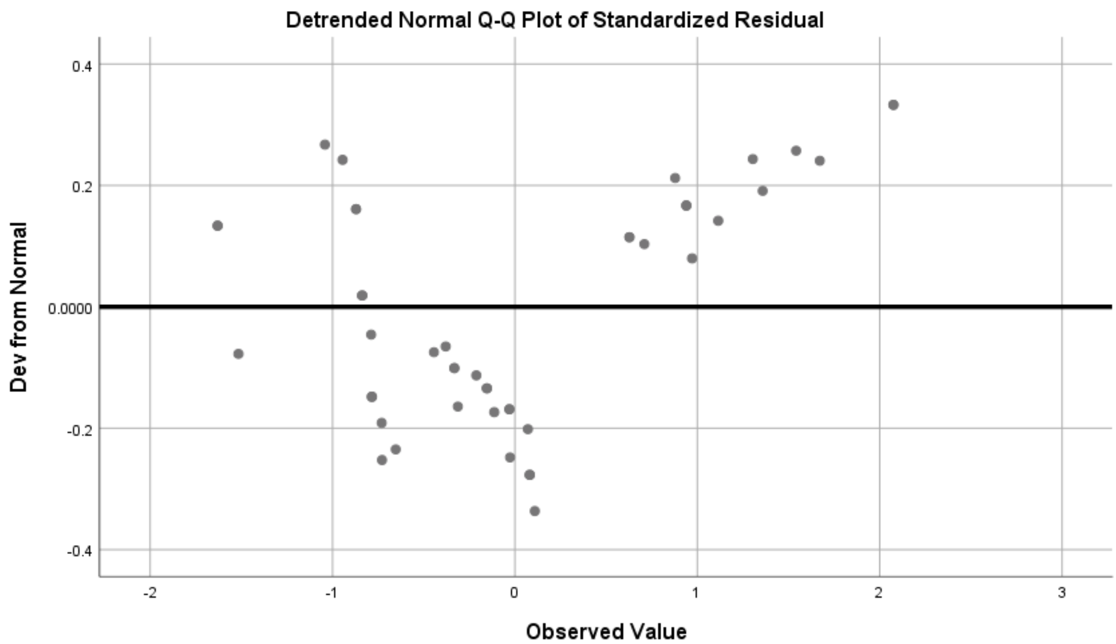
a. Lilliefors Significance Correction

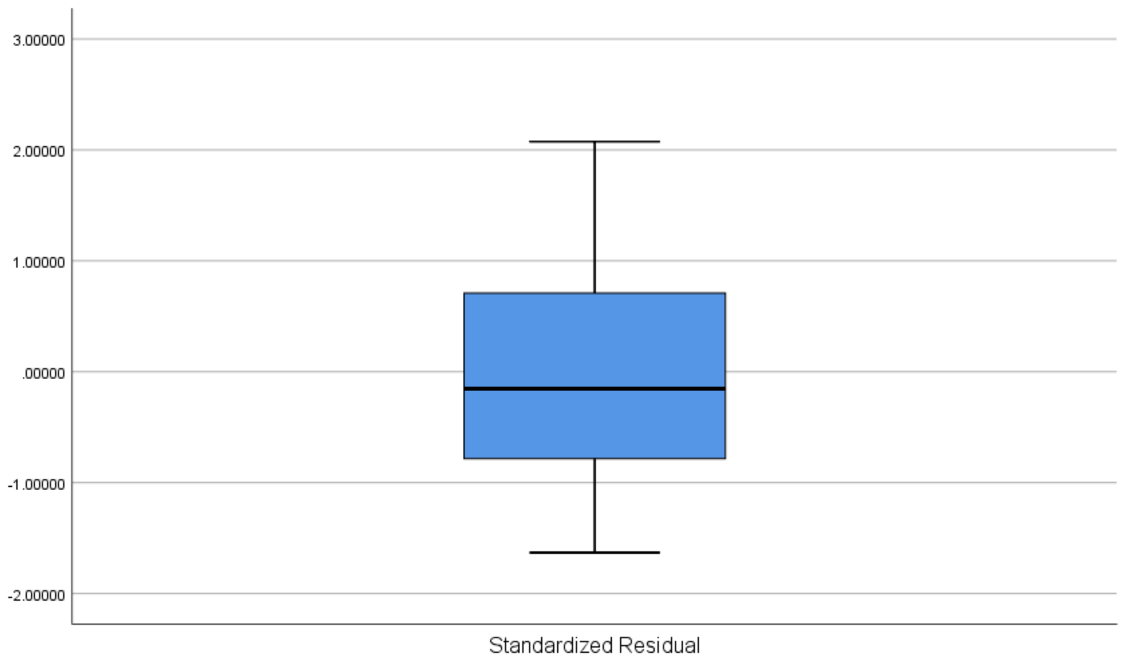
Standardized Residual




```
Standardized Residual Stem-and-Leaf Plot

 Frequency    Stem &  Leaf

     3.00       -1 .  566
     1.00       -1 .  0
    11.00       -0 .  67777788889
    12.00       -0 .  000111233334
     4.00        0 .  0001
     7.00        0 .  6678999
     3.00        1 .  133
     2.00        1 .  56
     2.00        2 .  00

 Stem width:   1.00000
 Each leaf:        1 case(s)
```


Normal Q-Q Plot of Standardized Residual
Expected Normal
Observed Value
3
2
1
0
-1
-2
-2
-1
0
1
2
3


Detrended Normal Q-Q Plot of Standardized Residual
Dev from Normal
Observed Value
0.4
0.2
0.0000
-0.2
-0.4
-2
-1
0
1
2
3




```
REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /MISSING MEANSUBSTITUTION
  /STATISTICS COEFF OUTS CI(95) BCOV R ANOVA COLLIN TOL CHANGE ZPP
  /CRITERIA=PIN(.05) POUT(.10) CIN(95)
  /NOORIGIN
  /DEPENDENT Running_cost_per_sq.m_1
  /METHOD=STEPWISE Working_days_per_week_1 Working_hours_per_day_1 Age_1
GIFA_1 NFA_1 CA_1 Height_1
    Floors_1 Window_area_1 WFR_1 Occupancy_1 Shape_1 Type_of_structure_1
AttachedORDetached_1
  /PARTIALPLOT ALL
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS DURBIN HISTOGRAM(ZRESID) NORMPROB(ZRESID)
  /CASEWISE PLOT(ZRESID) OUTLIERS(3)
  /SAVE PRED ZPRED ADJPRED SEPRED MAHAL COOK LEVER MCIN RESID ZRESID SRESID
SDRESID.
```

Regression - Significant variables only (final model)

Notes

Output Created		09-MAY-2020 00:39:51
Comments		
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	45
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	For each variable used, missing values are replaced with the variable mean.
Syntax		REGRESSION /DESCRIPTIVES MEAN STDDEV CORR SIG N /MISSING MEANSUBSTITUTION /STATISTICS COEFF OUTS CI(95) BCOV R ANOVA COLLIN TOL CHANGE ZPP /CRITERIA=PIN(.05) POUT(.10) CIN(95) /NOORIGIN /DEPENDENT Running_cost_per_sq.m_1 /METHOD=STEPWISE Working_hours_per_day_1 Age_1 NFA_1 Height_1 Floors_1 Window_area_1 Occupancy_1 /PARTIALPLOT ALL /SCATTERPLOT=(*ZRESID ,*ZPRED) /RESIDUALS DURBIN HISTOGRAM(ZRESID) NORMPROB(ZRESID) /CASEWISE PLOT(ZRESID) OUTLIERS(3) /SAVE PRED ZPRED ADJPRED SEPRED MAHAL COOK LEVER MCIN RESID ZRESID SRESID SDRESID.
Resources	Processor Time	00:00:00.67
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	Memory Required	10720 bytes
	Additional Memory Required for Residual Plots	2440 bytes
Variables	PRE_4	Unstandardized Predicted Value

Created or Modified	RES_4	Unstandardized Residual
	ADJ_4	Adjusted Predicted Value
	ZPR_4	Standardized Predicted Value
	ZRE_4	Standardized Residual
	SRE_4	Studentized Residual
	SDR_4	Studentized Deleted Residual
	SEP_4	Standard Error of Predicted Value
	MAH_4	Mahalanobis Distance
	COO_4	Cook's Distance
	LEV_4	Centered Leverage Value
	LMCI_4	95% Mean Confidence Interval Lower Bound for Running_cost_per_sq.m_1
	UMCI_4	95% Mean Confidence Interval Upper Bound for Running_cost_per_sq.m_1

Descriptive Statistics

	Mean	Std. Deviation	N
SMEAN(Running_cost_per_sq.m)	3984.2844	2878.81980	45
SMEAN(Working_hours_per_day)	9.0222	4.45553	45
SMEAN(Age)	13.356	12.0003	45
SMEAN(NFA)	22563.3158	14557.31480	45
SMEAN(Height)	159.8420	121.86454	45
SMEAN(Floors)	13.422	10.0283	45
SMEAN(Window_area)	25451.0993	37451.65729	45
SMEAN(Occupancy)	1632.409	1563.3379	45

Correlations

		SMEAN(Running_cost_per_sq.m)	SMEAN(Working_hours_per_day)	SMEAN(Age)	SMEAN(NFA)
Pearson Correlation	SMEAN(Running_cost_per_sq.m)	1.000	.346	.401	.954
	SMEAN(Working_hours_per_day)	.346	1.000	.147	.464
	SMEAN(Age)	.401	.147	1.000	.413
	SMEAN(NFA)	.954	.464	.413	1.000
	SMEAN(Height)	.947	.467	.443	.931
	SMEAN(Floors)	.952	.469	.430	.935
	SMEAN(Window_area)	.435	.307	.121	.477

	SMEAN(Occupancy)	.597	.257	.331	.632
Sig. (1-tailed)	SMEAN(Running_cost_per_sq.m)	.	.010	.003	.000
	SMEAN(Working_hours_per_day)	.010	.	.167	.001
	SMEAN(Age)	.003	.167	.	.002
	SMEAN(NFA)	.000	.001	.002	.
	SMEAN(Height)	.000	.001	.001	.000
	SMEAN(Floors)	.000	.001	.002	.000
	SMEAN(Window_area)	.001	.020	.215	.000
	SMEAN(Occupancy)	.000	.044	.013	.000
N	SMEAN(Running_cost_per_sq.m)	45	45	45	45
	SMEAN(Working_hours_per_day)	45	45	45	45
	SMEAN(Age)	45	45	45	45
	SMEAN(NFA)	45	45	45	45
	SMEAN(Height)	45	45	45	45
	SMEAN(Floors)	45	45	45	45
	SMEAN(Window_area)	45	45	45	45
	SMEAN(Occupancy)	45	45	45	45

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	SMEAN(NFA)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	SMEAN(Floors)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	SMEAN(Working_hours_per_day)	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: SMEAN(Running_cost_per_sq.m)

Model Summary[d]

					Change Statistics		
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1
1	.954[a]	.910	.908	874.88645	.910	433.407	1
2	.969[b]	.939	.936	727.56214	.029	20.177	1
3	.978[c]	.956	.953	626.75186	.017	15.598	1

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	331741221.062	1	331741221.062	433.407	.000[b]
	Residual	32913331.142	43	765426.306		
	Total	364654552.204	44			
2	Regression	342421992.450	2	171210996.225	323.438	.000[c]
	Residual	22232559.754	42	529346.661		
	Total	364654552.204	44			
3	Regression	348549018.506	3	116183006.169	295.768	.000[d]
	Residual	16105533.698	41	392817.895		
	Total	364654552.204	44			

a. Dependent Variable: SMEAN(Running_cost_per_sq.m)

b. Predictors: (Constant), SMEAN(NFA)

c. Predictors: (Constant), SMEAN(NFA), SMEAN(Floors)

d. Predictors: (Constant), SMEAN(NFA), SMEAN(Floors), SMEAN(Working_hours_per_day)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-271.651	242.490		-1.120	.269
	SMEAN(NFA)	.189	.009	.954	20.818	.000
2	(Constant)	-119.292	204.489		-.583	.563
	SMEAN(NFA)	.100	.021	.504	4.712	.000
	SMEAN(Floors)	138.047	30.732	.481	4.492	.000
3	(Constant)	446.901	227.120		1.968	.056
	SMEAN(NFA)	.106	.018	.535	5.780	.000
	SMEAN(Floors)	149.680	26.638	.521	5.619	.000
	SMEAN(Working_hours_per_day)	-95.147	24.092	-.147	-3.949	.000

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	SMEAN(Working_hours_per_day)	-.124[b]	-2.547	.015	-.366	.784
	SMEAN(Age)	.008[b]	.167	.868	.026	.829
	SMEAN(Height)	.441[b]	4.117	.000	.536	.133
	SMEAN(Floors)	.481[b]	4.492	.000	.570	.127
	SMEAN(Window_area)	-.026[b]	-.503	.618	-.077	.772
	SMEAN(Occupancy)	-.009[b]	-.149	.882	-.023	.601
2	SMEAN(Working_hours_per_day)	-.147[c]	-3.949	.000	-.525	.775
	SMEAN(Age)	-.017[c]	-.397	.694	-.062	.814
	SMEAN(Height)	-.002[c]	-.006	.995	-.001	.015
	SMEAN(Window_area)	-.062[c]	-1.437	.158	-.219	.749
	SMEAN(Occupancy)	-.064[c]	-1.279	.208	-.196	.568
3	SMEAN(Age)	-.027[d]	-.745	.460	-.117	.810
	SMEAN(Height)	.005[d]	.019	.985	.003	.015
	SMEAN(Window_area)	-.049[d]	-1.297	.202	-.201	.742
	SMEAN(Occupancy)	-.079[d]	-1.857	.071	-.282	.564

Coefficient Correlations[a]

Model			SMEAN(NFA)	SMEAN(Floors)	SMEAN(Working_hours_per_day)
1	Correlations	SMEAN(NFA)	1.000		
	Covariances	SMEAN(NFA)	8.209E-5		
2	Correlations	SMEAN(NFA)	1.000	-.935	
		SMEAN(Floors)	-.935	1.000	
	Covariances	SMEAN(NFA)	.000	-.608	
		SMEAN(Floors)	-.608	944.481	
3	Correlations	SMEAN(NFA)	1.000	-.916	-.083
		SMEAN(Floors)	-.916	1.000	-.111
		SMEAN(Working_hours_per_day)	-.083	-.111	1.000
	Covariances	SMEAN(NFA)	.000	-.447	-.037
		SMEAN(Floors)	-.447	709.557	-70.962
		SMEAN(Working_hours_per_day)	-.037	-70.962	580.408

a. Dependent Variable: SMEAN(Running_cost_per_sq.m)

Collinearity Diagnostics[a]

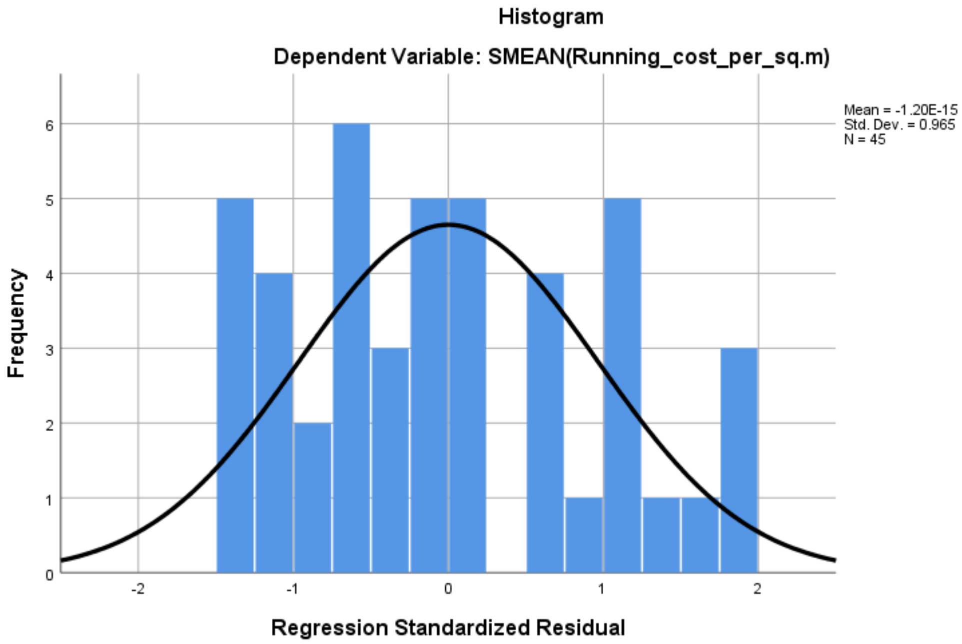
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	SMEAN(NFA)	SMEAN(Floors)
1	1	1.843	1.000	.08	.08	
	2	.157	3.427	.92	.92	
2	1	2.752	1.000	.03	.00	.01
	2	.228	3.475	.84	.02	.04
	3	.021	11.547	.12	.98	.95
3	1	3.618	1.000	.01	.00	.00
	2	.263	3.710	.23	.02	.05
	3	.098	6.064	.67	.01	.00
	4	.021	13.246	.09	.97	.95

Residuals Statistics[a]

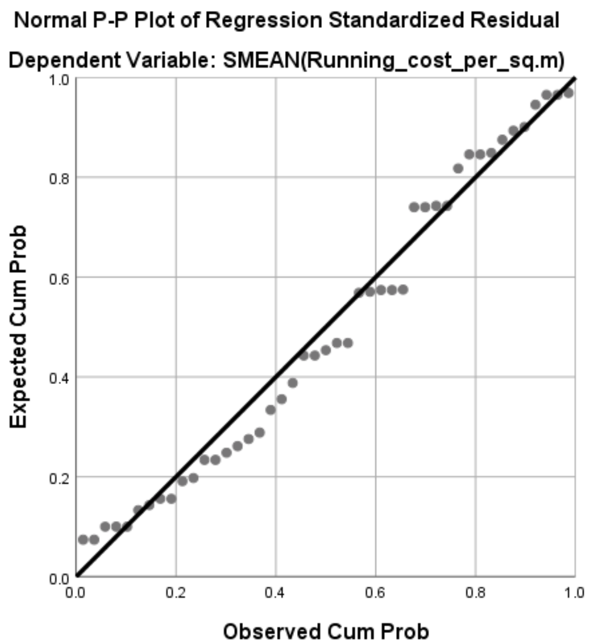
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	339.7817	12641.7627	3984.2844	2814.52813	45
Std. Predicted Value	-1.295	3.076	.000	1.000	45
Standard Error of Predicted Value	101.667	427.146	170.409	77.534	45
Adjusted Predicted Value	364.4169	12945.0156	3997.4468	2842.56923	45
Residual	-907.06012	1168.15833	.00000	605.00815	45
Std. Residual	-1.447	1.864	.000	.965	45
Stud. Residual	-1.480	1.957	-.009	1.003	45
Deleted Residual	-949.04041	1287.66980	-13.16234	655.71430	45
Stud. Deleted Residual	-1.503	2.030	-.005	1.016	45
Mahal. Distance	.180	19.459	2.933	4.213	45
Cook's Distance	.000	.126	.022	.031	45
Centered Leverage Value	.004	.442	.067	.096	45

a. Dependent Variable: SMEAN(Running_cost_per_sq.m)

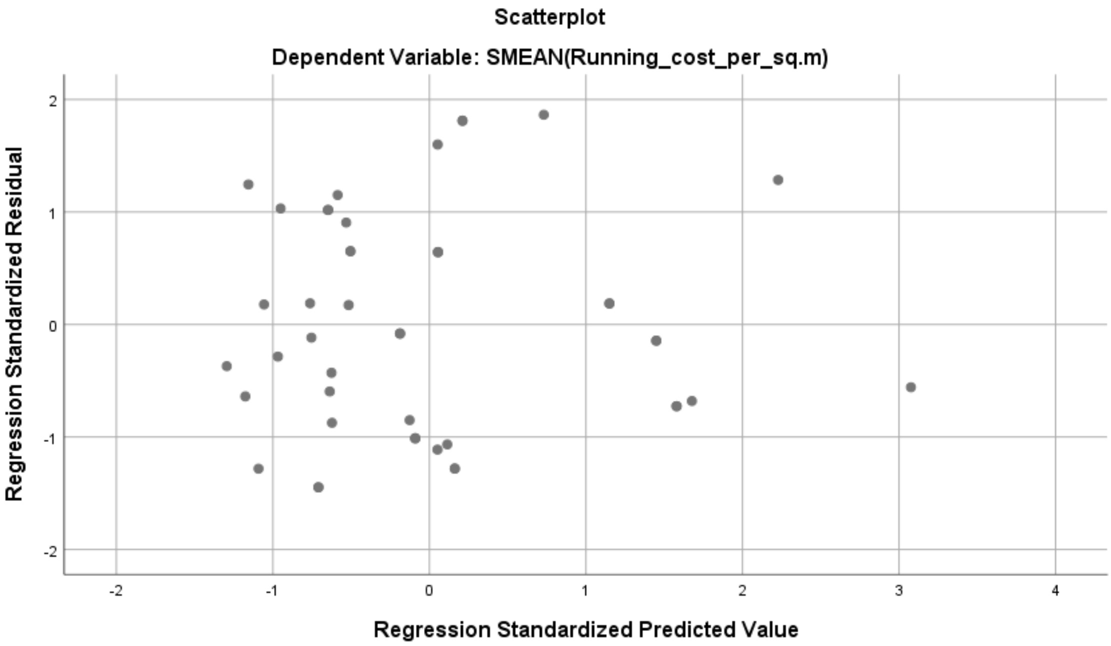
Charts

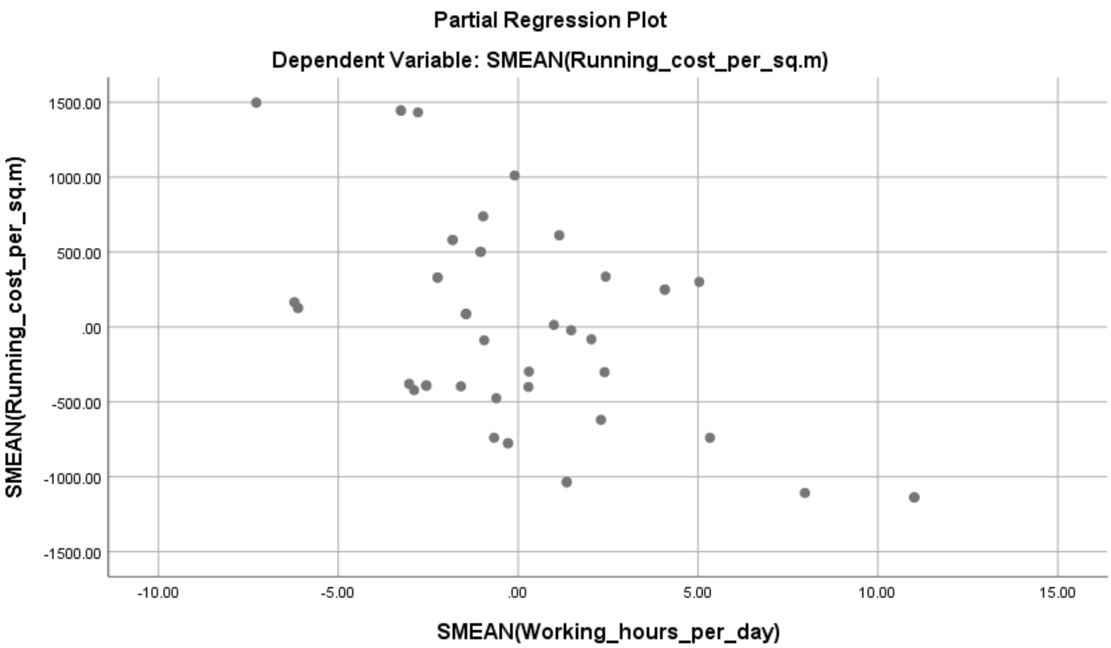


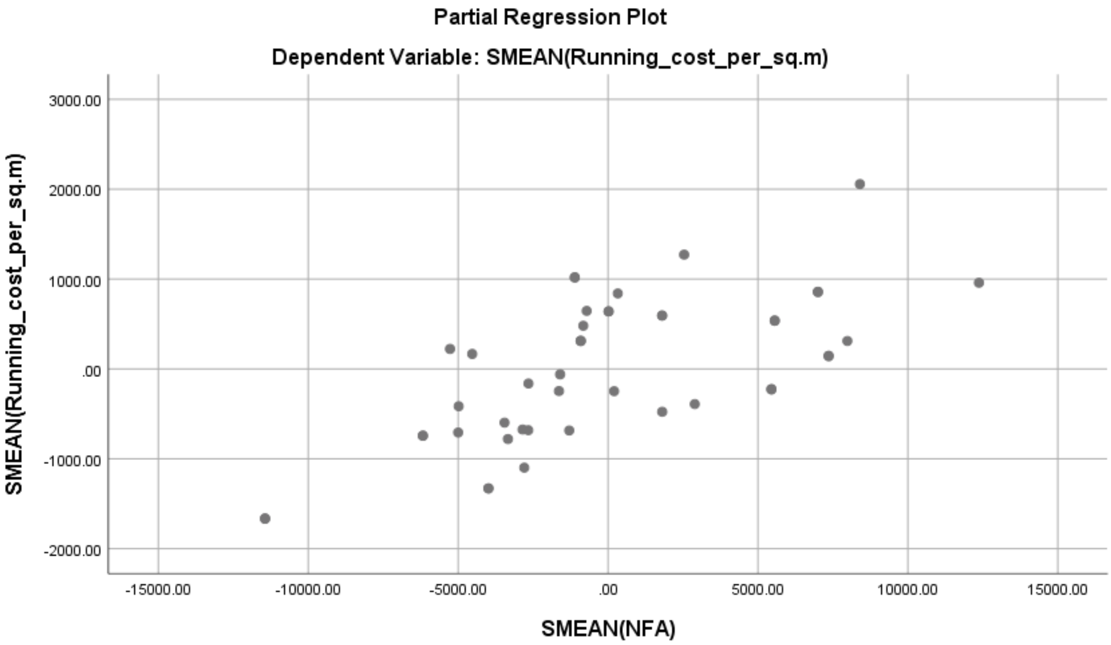
Histogram
Dependent Variable: SMEAN(Running_cost_per_sq.m)
Mean = -1.20E-15
Std. Dev. = 0.965
N = 45
Frequency
0
1
2
3
4
5
6
-2
-1
0
1
2
Regression Standardized Residual



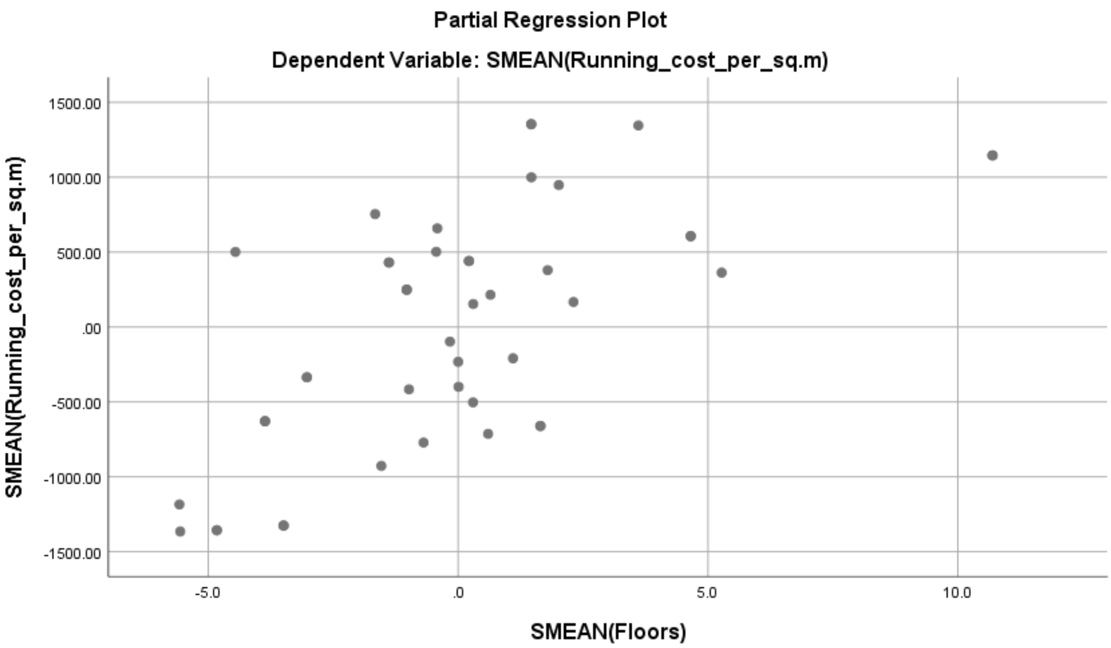
Normal P-P Plot of Regression Standardized Residual
Dependent Variable: SMEAN(Running_cost_per_sq.m)
Expected Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Observed Cum Prob


Scatterplot
Dependent Variable: SMEAN(Running_cost_per_sq.m)
Regression Standardized Residual
Regression Standardized Predicted Value
2
1
0
-1
-2
-2
-1
0
1
2
3
4


Partial Regression Plot
Dependent Variable: SMEAN(Running_cost_per_sq.m)
SMEAN(Running_cost_per_sq.m)
SMEAN(Working_hours_per_day)
1500.00
1000.00
500.00
.00
-500.00
-1000.00
-1500.00
-10.00
-5.00
.00
5.00
10.00
15.00



Partial Regression Plot
Dependent Variable: SMEAN(Running_cost_per_sq.m)
SMEAN(Running_cost_per_sq.m)
3000.00
2000.00
1000.00
.00
-1000.00
-2000.00
-15000.00
-10000.00
-5000.00
.00
5000.00
10000.00
15000.00
SMEAN(NFA)



Partial Regression Plot
Dependent Variable: SMEAN(Running_cost_per_sq.m)
SMEAN(Running_cost_per_sq.m)
1500.00
1000.00
500.00
.00
-500.00
-1000.00
-1500.00
-5.0
.0
5.0
10.0
SMEAN(Floors)

APPENDIX 06: SPSS output for index construction

```
REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /MISSING MEANSUBSTITUTION
  /STATISTICS COEFF OUTS CI(95) BCOV R ANOVA COLLIN TOL CHANGE ZPP
  /CRITERIA=PIN(.05) POUT(.10) CIN(95)
  /NOORIGIN
  /DEPENDENT Running_cost_per_sq.m
  /METHOD=ENTER Working_days_per_week Working_hours_per_day Age GIFA
NFA CA Height Floors
    Window_area WFR Occupancy Shape Type_of_structure
AttachedORDetached Q1_2014 Q2_2014 Q3_2014
    Q4_2014 Q1_2015 Q2_2015 Q3_2015 Q4_2015 Q1_2016 Q2_2016 Q3_2017
Q4_2018
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS DURBIN HISTOGRAM(ZRESID) NORMPROB(ZRESID)
  /CASEWISE PLOT(ZRESID) OUTLIERS(3)
  /SAVE PRED ZPRED ADJPRED MCIN RESID ZRESID SRESID SDRESID.
```

Regression - All commercial buildings (45)

Notes

Output Created		10-MAY-2020 00:36:46
Comments		
Input	Data	C:\Users\dgeek\Desktop\Hedonic index - All (45).sav
	Active Dataset	DataSet6
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	1005
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	For each variable used, missing values are replaced with the variable mean.

Syntax		REGRESSION /DESCRIPTIVES MEAN STDDEV CORR SIG N /MISSING MEANSUBSTITUTION /STATISTICS COEFF OUTS CI(95) BCOV R ANOVA COLLIN TOL CHANGE ZPP /CRITERIA=PIN(.05) POUT(.10) CIN(95) /NOORIGIN /DEPENDENT Running_cost_per_sq.m /METHOD=ENTER Working_days_per_week Working_hours_per_day Age GIFA NFA CA Height Floors Window_area WFR Occupancy Shape Type_of_structure AttachedORDetached Q1_2014 Q2_2014 Q3_2014 Q4_2014 Q1_2015 Q2_2015 Q3_2015 Q4_2015 Q1_2016 Q2_2016 Q3_2017 Q4_2018 /SCATTERPLOT=(*ZRESID ,*ZPRED) /RESIDUALS DURBIN HISTOGRAM(ZRESID) NORMPROB(ZRESID) /CASEWISE PLOT(ZRESID) OUTLIERS(3) /SAVE PRED ZPRED ADJPRED MCIN RESID ZRESID SRESID SDRESID.
Resources	Processor Time	00:00:00.59
	Elapsed Time	00:00:01.34
	Memory Required	53184 bytes
	Additional Memory Required for Residual Plots	280 bytes
Variables Created or Modified	PRE_2	Unstandardized Predicted Value
	RES_2	Unstandardized Residual
	ADJ_2	Adjusted Predicted Value
	ZPR_2	Standardized Predicted Value
	ZRE_2	Standardized Residual
	SRE_2	Studentized Residual
	SDR_2	Studentized Deleted Residual
	LMCI_2	95% Mean Confidence Interval Lower Bound for Running_cost_per_sq.m
	UMCI_2	95% Mean Confidence Interval Upper Bound for Running_cost_per_sq.m

Descriptive Statistics

	Mean	Std. Deviation	N
Average running cost/sq.m	8.0820991	.80234781	540
Working days/week	1.7389889	.13496764	540
Working hours/day	2.1214844	.36098183	540
Operated yrs.	2.2598571	.90785421	540
Gross Internal Floor Area (sq.m)	10.2507200	.65372793	540
Net Floor Area (sq.m)	9.8235667	.65373426	540
Circulation Area (sq.m)	9.1941022	.65373652	540
Building height (m)	4.8311156	.68819883	540
Number of floors	2.3669178	.66566021	540
Window area (sq.m)	9.4611267	1.15360945	540
Window-to-Floor-Ratio	-1.1842644	.74825915	540
Occupancy	7.2431778	.97245628	540
Shape	.60	.490	540
Type of structure	.67	.472	540
Grouping of buildings	.76	.430	540
Q1_2014	.08	.277	540
Q2_2014	.08	.277	540
Q3_2014	.08	.277	540
Q4_2014	.08	.277	540
Q1_2015	.08	.277	540
Q2_2015	.08	.277	540
Q3_2015	.08	.277	540
Q4_2015	.08	.277	540
Q1_2016	.08	.277	540
Q2_2016	.08	.277	540
Q3_2017	.08	.277	540
Q4_2018	.08	.277	540

Correlations

		Average running cost/sq.m	Working days/week	Working hours/day	Operated yrs.	Gross Internal Floor Area (sq.m)	Net Floor Area (sq.m)	Circulation Area (sq.m)	Building height (m)	Number of floors	Window area (sq.m)	Window-to-Floor-Ratio
Pearson Correlation	Average running cost/sq.m	1.000	-.032	.020	.222	.541	.541	.541	.590	.581	.663	.066
	Working days/week	-.032	1.000	.728	-.174	.079	.079	.079	.076	.081	.047	.017
	Working hours/day	.020	.728	1.000	-.039	.192	.192	.192	.203	.219	.197	.089

	Operated yrs.	.222	-.174	-.039	1.000	.463	.463	.463	.501	.488	.278	.128
	Gross Internal Floor Area (sq.m)	.541	.079	.192	.463	1.000	1.000	1.000	.949	.945	.580	.103
	Net Floor Area (sq.m)	.541	.079	.192	.463	1.000	1.000	1.000	.949	.945	.580	.103
	Circulation Area (sq.m)	.541	.079	.192	.463	1.000	1.000	1.000	.949	.945	.580	.103
	Building height (m)	.590	.076	.203	.501	.949	.949	.949	1.000	.990	.595	.119
	Number of floors	.581	.081	.219	.488	.945	.945	.945	.990	1.000	.590	.113
	Window area (sq.m)	.663	.047	.197	.278	.580	.580	.580	.595	.590	1.000	.184
	Window-to-Floor-Ratio	.066	.017	.089	.128	.103	.103	.103	.119	.113	.184	1.000
	Occupancy	.102	-.004	.102	.384	.195	.195	.195	.328	.293	.170	.116
	Shape	.131	.129	.166	-.210	.029	.029	.029	.118	.053	-.043	.052
	Type of structure	.040	-.120	.122	.320	.202	.202	.202	.235	.225	-.238	.085
	Grouping of buildings	-.141	-.190	-.151	.053	-.196	-.196	-.197	-.205	-.185	-.048	.232
	Q1_2014	-.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2014	-.017	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2014	-.011	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2014	-.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2015	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2015	-.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2015	-.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2015	.007	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2016	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2016	.007	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2017	.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2018	.011	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Sig. (1-tailed)	Average running cost/sq.m	.	.229	.318	.000	.000	.000	.000	.000	.000	.000	.062
	Working days/week	.229	.	.000	.000	.034	.034	.034	.038	.030	.138	.348
	Working hours/day	.318	.000	.	.185	.000	.000	.000	.000	.000	.000	.020
	Operated yrs.	.000	.000	.185	.	.000	.000	.000	.000	.000	.000	.001
	Gross Internal Floor Area (sq.m)	.000	.034	.000	.000	.	.000	.000	.000	.000	.000	.008
	Net Floor Area (sq.m)	.000	.034	.000	.000	.000	.	.000	.000	.000	.000	.008
	Circulation Area (sq.m)	.000	.034	.000	.000	.000	.000	.	.000	.000	.000	.008
	Building height (m)	.000	.038	.000	.000	.000	.000	.000	.	.000	.000	.003
	Number of floors	.000	.030	.000	.000	.000	.000	.000	.000	.	.000	.004
	Window area (sq.m)	.000	.138	.000	.000	.000	.000	.000	.000	.000	.	.000
	Window-to-Floor-Ratio	.062	.348	.020	.001	.008	.008	.008	.003	.004	.000	.
	Occupancy	.009	.460	.009	.000	.000	.000	.000	.000	.000	.000	.003

	Shape	.001	.001	.000	.000	.250	.250	.250	.003	.109	.161	.115
	Type of structure	.179	.003	.002	.000	.000	.000	.000	.000	.000	.000	.024
	Grouping of buildings	.001	.000	.000	.108	.000	.000	.000	.000	.000	.135	.000
	Q1_2014	.461	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2014	.347	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2014	.397	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2014	.445	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2015	.481	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2015	.454	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2015	.479	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2015	.438	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2016	.408	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2016	.437	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2017	.416	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2018	.402	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
N	Average running cost/sq.m	540	540	540	540	540	540	540	540	540	540	540
	Working days/week	540	540	540	540	540	540	540	540	540	540	540
	Working hours/day	540	540	540	540	540	540	540	540	540	540	540
	Operated yrs.	540	540	540	540	540	540	540	540	540	540	540
	Gross Internal Floor Area (sq.m)	540	540	540	540	540	540	540	540	540	540	540
	Net Floor Area (sq.m)	540	540	540	540	540	540	540	540	540	540	540
	Circulation Area (sq.m)	540	540	540	540	540	540	540	540	540	540	540
	Building height (m)	540	540	540	540	540	540	540	540	540	540	540
	Number of floors	540	540	540	540	540	540	540	540	540	540	540
	Window area (sq.m)	540	540	540	540	540	540	540	540	540	540	540
	Window-to-Floor-Ratio	540	540	540	540	540	540	540	540	540	540	540
	Occupancy	540	540	540	540	540	540	540	540	540	540	540
	Shape	540	540	540	540	540	540	540	540	540	540	540
	Type of structure	540	540	540	540	540	540	540	540	540	540	540
	Grouping of buildings	540	540	540	540	540	540	540	540	540	540	540
	Q1_2014	540	540	540	540	540	540	540	540	540	540	540
	Q2_2014	540	540	540	540	540	540	540	540	540	540	540
	Q3_2014	540	540	540	540	540	540	540	540	540	540	540
	Q4_2014	540	540	540	540	540	540	540	540	540	540	540
	Q1_2015	540	540	540	540	540	540	540	540	540	540	540
	Q2_2015	540	540	540	540	540	540	540	540	540	540	540
	Q3_2015	540	540	540	540	540	540	540	540	540	540	540
	Q4_2015	540	540	540	540	540	540	540	540	540	540	540

Q1_2016	540	540	540	540	540	540	540	540	540	540	540
Q2_2016	540	540	540	540	540	540	540	540	540	540	540
Q3_2017	540	540	540	540	540	540	540	540	540	540	540
Q4_2018	540	540	540	540	540	540	540	540	540	540	540

Variables Entered/Removed[a]

Model	Variables Entered	Method
1	Q4_2018, Grouping of buildings, Shape, Window area (sq.m), Q3_2017, Q2_2016, Q1_2016, Q1_2014, Working days/week, Q2_2014, Q4_2015, Window-to-Floor-Ratio, Q3_2014, Operated yrs., Q3_2015, Q4_2014, Type of structure, Occupancy, Q2_2015, Net Floor Area (sq.m), Working hours/day, Number of floors, Building height (m)[b]	Enter

a. Dependent Variable: Average running cost/sq.m

b. Tolerance = .000 limit reached.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change
1	.775[a]	.601	.583	.51796334	.601

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	208.552	23	9.067	33.798	.000[b]
	Residual	138.436	516	.268		
	Total	346.988	539			

a. Dependent Variable: Average running cost/sq.m

b. Predictors: (Constant), Q4_2018, Grouping of buildings, Shape, Window area (sq.m), Q3_2017, Q2_2016, Q1_2016, Q1_2014, Working days/week, Q2_2014, Q4_2015, Window-to-Floor-Ratio, Q3_2014, Operated yrs., Q3_2015, Q4_2014, Type of structure, Occupancy, Q2_2015, Net Floor Area (sq.m), Working hours/day, Number of floors, Building height (m)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t
1	(Constant)	6.741	1.049		6.425
	Working days/week	.808	.274	.136	2.945
	Working hours/day	-.681	.107	-.306	-6.368
	Operated yrs.	-.065	.034	-.074	-1.909
	Net Floor Area (sq.m)	-.561	.139	-.457	-4.048
	Building height (m)	.568	.382	.487	1.489
	Number of floors	.222	.319	.184	.697
	Window area (sq.m)	.494	.030	.710	16.223
	Window-to-Floor-Ratio	-.047	.033	-.044	-1.440
	Occupancy	-.165	.038	-.200	-4.311
	Shape	.101	.073	.062	1.391
	Type of structure	.467	.067	.275	6.917
	Grouping of buildings	-.172	.065	-.092	-2.644
	Q1_2014	-.017	.109	-.006	-.153
	Q2_2014	-.051	.109	-.017	-.463
	Q3_2014	-.036	.109	-.012	-.326
	Q4_2014	-.021	.109	-.007	-.196
	Q2_2015	-.019	.109	-.006	-.171
	Q3_2015	-.012	.109	-.004	-.105
	Q4_2015	.012	.109	.004	.112
	Q1_2016	.021	.109	.007	.193
	Q2_2016	.013	.109	.004	.116
	Q3_2017	.019	.109	.007	.173
	Q4_2018	.023	.109	.008	.209

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation
1	Gross Internal Floor Area (sq.m)	-1026.962[b]	-1.515	.130	-.067
	Circulation Area (sq.m)	-636.698[b]	-1.272	.204	-.056
	Q1_2015	.[b]	.	.	.

Coefficient Correlations[a]

Model			Q4_2018	Grouping of buildings	Shape	Window area (sq.m)	Q3_2017	Q2_2016
1	Correlations	Q4_2018	1.000	.000	.000	.000	.500	.500
		Grouping of buildings	.000	1.000	.089	.031	.000	.000
		Shape	.000	.089	1.000	.130	.000	.000
		Window area (sq.m)	.000	.031	.130	1.000	.000	.000
		Q3_2017	.500	.000	.000	.000	1.000	.500
		Q2_2016	.500	.000	.000	.000	.500	1.000
		Q1_2016	.500	.000	.000	.000	.500	.500
		Q1_2014	.500	.000	.000	.000	.500	.500
		Working days/week	.000	.166	.110	.303	.000	.000
		Q2_2014	.500	.000	.000	.000	.500	.500
		Q4_2015	.500	.000	.000	.000	.500	.500
		Window-to-Floor-Ratio	.000	-.328	-.114	-.182	.000	.000
		Q3_2014	.500	.000	.000	.000	.500	.500
		Operated yrs.	.000	-.253	.314	-.020	.000	.000
		Q3_2015	.500	.000	.000	.000	.500	.500
		Q4_2014	.500	.000	.000	.000	.500	.500
		Type of structure	.000	.112	-.151	.545	.000	.000
		Occupancy	.000	.402	.538	-.025	.000	.000
		Q2_2015	.500	.000	.000	.000	.500	.500
		Net Floor Area (sq.m)	.000	.209	.493	-.016	.000	.000
		Working hours/day	.000	-.087	-.250	-.344	.000	.000
		Number of floors	.000	.001	.640	.114	.000	.000
		Building height (m)	.000	-.054	-.729	-.171	.000	.000
	Covariances	Q4_2018	.012	.000	.000	.000	.006	.006
		Grouping of buildings	.000	.004	.000	6.101E-5	.000	.000
		Shape	.000	.000	.005	.000	.000	.000

	Window area (sq.m)	.000	6.101E-5	.000	.001	.000	.000
	Q3_2017	.006	.000	.000	.000	.012	.006
	Q2_2016	.006	.000	.000	.000	.006	.012
	Q1_2016	.006	.000	.000	.000	.006	.006
	Q1_2014	.006	.000	.000	.000	.006	.006
	Working days/week	.000	.003	.002	.003	.000	.000
	Q2_2014	.006	.000	.000	.000	.006	.006
	Q4_2015	.006	.000	.000	.000	.006	.006
	Window-to-Floor-Ratio	.000	-.001	.000	.000	.000	.000
	Q3_2014	.006	.000	.000	.000	.006	.006
	Operated yrs.	.000	-.001	.001	-2.099E-5	.000	.000
	Q3_2015	.006	.000	.000	.000	.006	.006
	Q4_2014	.006	.000	.000	.000	.006	.006
	Type of structure	.000	.000	-.001	.001	.000	.000
	Occupancy	.000	.001	.001	-2.859E-5	.000	.000
	Q2_2015	.006	.000	.000	.000	.006	.006
	Net Floor Area (sq.m)	.000	.002	.005	-6.816E-5	.000	.000
	Working hours/day	.000	-.001	-.002	-.001	.000	.000
	Number of floors	.000	3.045E-5	.015	.001	.000	.000
	Building height (m)	.000	-.001	-.020	-.002	.000	.000

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Variance Proportions Working days/week
1	1	12.468	1.000	.00	.00
	2	1.000	3.531	.00	.00
	3	1.000	3.531	.00	.00
	4	1.000	3.531	.00	.00
	5	1.000	3.531	.00	.00
	6	1.000	3.531	.00	.00
	7	1.000	3.531	.00	.00
	8	1.000	3.531	.00	.00

	9	1.000	3.531	.00	.00
	10	1.000	3.531	.00	.00
	11	1.000	3.531	.00	.00
	12	.406	5.540	.00	.00
	13	.362	5.870	.00	.00
	14	.333	6.117	.00	.00
	15	.180	8.321	.00	.00
	16	.105	10.898	.00	.00
	17	.071	13.238	.00	.00
	18	.039	17.792	.00	.00
	19	.019	25.339	.00	.00
	20	.008	40.640	.01	.01
	21	.006	45.627	.00	.07
	22	.001	96.372	.05	.88
	23	.000	230.309	.92	.01
	24	.000	348.061	.02	.03

Casewise Diagnostics[a,b]

Case Number	Std. Residual	Average running cost/sq.m	Predicted Value	Residual
26	3.395	10.951	9.1923078	1.75829217
33	-3.183	6.293	7.9418038	-1.64860379
71	3.395	10.917	9.1584967	1.75870329
78	-3.182	6.260	7.9079927	-1.64819268
116	3.395	10.932	9.1733923	1.75830773
123	-3.183	6.274	7.9228882	-1.64868824
161	3.395	10.946	9.1876434	1.75825662
168	-3.183	6.289	7.9371393	-1.64863935
206	3.547	11.047	9.2090256	1.83747440
213	-3.155	6.325	7.9585216	-1.63392157
251	3.547	11.027	9.1902989	1.83710106
258	-3.155	6.305	7.9397949	-1.63439490
296	3.547	11.035	9.1975256	1.83707440
303	-3.155	6.313	7.9470216	-1.63442157
341	3.547	11.058	9.2212234	1.83707662
348	-3.155	6.336	7.9707193	-1.63441935
386	3.686	11.139	9.2300812	1.90921884
393	-3.125	6.361	7.9795771	-1.61837713
431	3.686	11.131	9.2216878	1.90921217
438	-3.125	6.353	7.9711838	-1.61838379
476	3.686	11.137	9.2278967	1.90920329

483	-3.125	6.359	7.9773927	-1.61839268
521	3.686	11.141	9.2318900	1.90920995
528	-3.125	6.363	7.9813860	-1.61838601

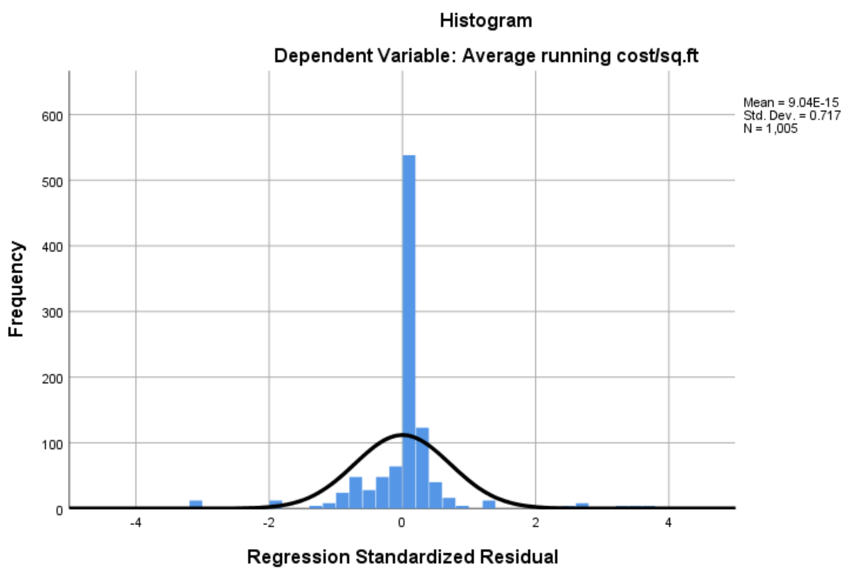
a. Dependent Variable: Average running cost/sq.m

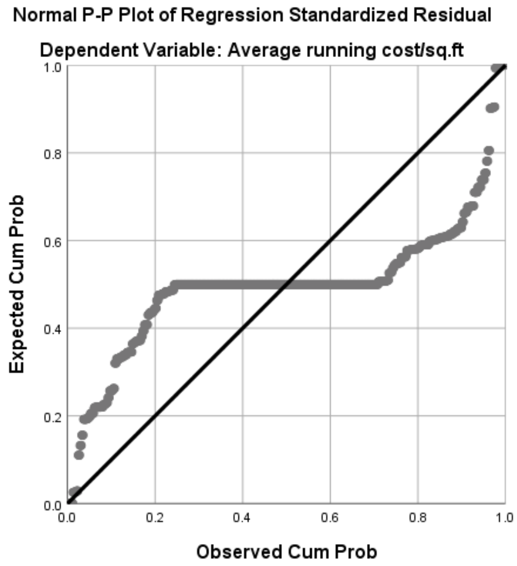
b. When values are missing, the substituted mean has been used in the statistical computation.

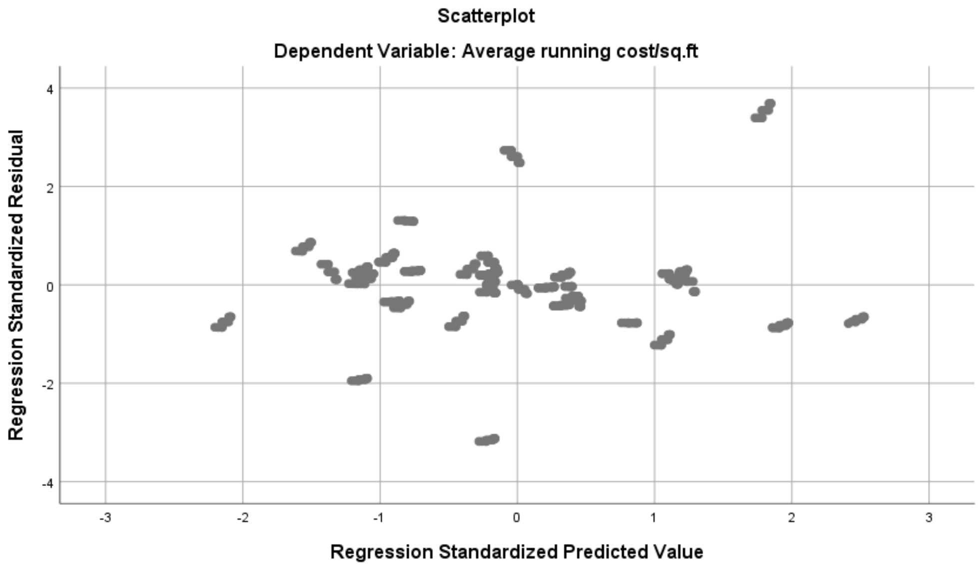
Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	6.7110691	9.6554041	8.0820991	.45576447
Std. Predicted Value	-2.204	2.529	.000	.733
Standard Error of Predicted Value	.022	.132	.069	.044
Adjusted Predicted Value	6.7419248	9.6699467	8.0826275	.45464747
Residual	-1.64868820	1.90921879	.00000000	.37132742
Std. Residual	-3.183	3.686	.000	.717
Stud. Residual	-3.271	3.793	.000	.736
Deleted Residual	-1.74131012	2.02148271	-.00052845	.39112889
Stud. Deleted Residual	-3.302	3.843	.000	.741
Mahal. Distance	.000	33.822	12.335	11.947
Cook's Distance	.000	.035	.001	.005
Centered Leverage Value	.000	.063	.023	.022

Charts





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NFA CA Height Floors
    Window_area WFR Occupancy Shape Type_of_structure
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AttachedORDetached Q1_2014 Q2_2014 Q3_2014
    Q4_2014 Q1_2015 Q2_2015 Q3_2015 Q4_2015 Q1_2016 Q2_2016 Q3_2017
Q4_2018
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  /CASEWISE PLOT(ZRESID) OUTLIERS(3)
  /SAVE PRED ZPRED ADJPRED SEPRED MCIN RESID ZRESID SRESID SDRESID.
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Regression - Office (22)

Notes

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	ADJ_2	Adjusted Predicted Value
	ZPR_2	Standardized Predicted Value
	ZRE_2	Standardized Residual
	SRE_2	Studentized Residual
	SDR_2	Studentized Deleted Residual
	SEP_2	Standard Error of Predicted Value
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	UMCI_2	95% Mean Confidence Interval Upper Bound for Running_cost_per_sq.m

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Descriptive Statistics

	Mean	Std. Deviation	N
Average running cost/sq.m	8.0261655	.66782834	264
Working days/week	1.7565364	.12907174	264
Working hours/day	2.2275364	.32488253	264
Operated yrs.	2.1498714	.84170195	264
Gross Internal Floor Area (sq.m)	10.2608500	.66930310	264
Net Floor Area (sq.m)	9.8337045	.66930160	264
Circulation Area (sq.m)	9.2042273	.66931637	264
Building height (m)	4.8522545	.67608400	264
Number of floors	2.3921318	.65499559	264
Window area (sq.m)	9.4034500	1.12619094	264
Window-to-Floor-Ratio	-1.2756955	.89748435	264
Occupancy	7.3240318	1.09283280	264
Shape	.68	.467	264
Type of structure	.64	.482	264
Grouping of buildings	.73	.446	264
Q1_2014	.08	.277	264
Q2_2014	.08	.277	264
Q3_2014	.08	.277	264
Q4_2014	.08	.277	264
Q1_2015	.08	.277	264
Q2_2015	.08	.277	264

Q3_2015	.08	.277	264
Q4_2015	.08	.277	264
Q1_2016	.08	.277	264
Q2_2016	.08	.277	264
Q3_2017	.08	.277	264
Q4_2018	.08	.277	264

Correlations

		Average running cost/sq.m	Working days/week	Working hours/day	Operated yrs.	Gross Internal Floor Area (sq.m)	Net Floor Area (sq.m)	Circulation Area (sq.m)	Building height (m)	Number of floors	Window area (sq.m)	Window-to-Floor-Ratio
Pearson Correlation	Average running cost/sq.m	1.000	.334	.332	.407	.559	.559	.559	.672	.653	.587	.184
	Working days/week	.334	1.000	.552	.186	.342	.342	.342	.363	.379	.282	.073
	Working hours/day	.332	.552	1.000	.350	.497	.497	.497	.487	.507	.517	.104
	Operated yrs.	.407	.186	.350	1.000	.430	.430	.430	.523	.481	.223	-.024
	Gross Internal Floor Area (sq.m)	.559	.342	.497	.430	1.000	1.000	1.000	.955	.954	.728	.234
	Net Floor Area (sq.m)	.559	.342	.497	.430	1.000	1.000	1.000	.955	.954	.728	.234
	Circulation Area (sq.m)	.559	.342	.497	.430	1.000	1.000	1.000	.955	.954	.728	.234
	Building height (m)	.672	.363	.487	.523	.955	.955	.955	1.000	.988	.724	.218
	Number of floors	.653	.379	.507	.481	.954	.954	.954	.988	1.000	.727	.181
	Window area (sq.m)	.587	.282	.517	.223	.728	.728	.728	.724	.727	1.000	.299
	Window-to-Floor-Ratio	.184	.073	.104	-.024	.234	.234	.234	.218	.181	.299	1.000
	Occupancy	.266	.056	.141	.300	.238	.238	.238	.373	.325	-.003	-.092
	Shape	.056	-.166	-.196	.046	-.199	-.199	-.199	-.146	-.244	.008	.340
	Type of structure	-.010	-.299	.139	.438	.014	.014	.014	.096	.051	-.298	-.119
	Grouping of buildings	-.103	-.145	-.214	-.063	-.109	-.109	-.109	-.091	-.064	.044	.392
	Q1_2014	-.007	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2014	-.022	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2014	-.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2014	-.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2015	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2015	-.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2015	-.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2015	.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2016	.014	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2016	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2017	.013	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

	Q4_2018	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Sig. (1-tailed)	Average running cost/sq.m	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
	Working days/week	.000	.	.000	.001	.000	.000	.000	.000	.000	.000	.118
	Working hours/day	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.045
	Operated yrs.	.000	.001	.000	.	.000	.000	.000	.000	.000	.000	.350
	Gross Internal Floor Area (sq.m)	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	Net Floor Area (sq.m)	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	Circulation Area (sq.m)	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	Building height (m)	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	Number of floors	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.002
	Window area (sq.m)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	Window-to-Floor-Ratio	.001	.118	.045	.350	.000	.000	.000	.000	.002	.000	.
	Occupancy	.000	.184	.011	.000	.000	.000	.000	.000	.000	.481	.068
	Shape	.183	.004	.001	.230	.001	.001	.001	.009	.000	.450	.000
	Type of structure	.437	.000	.012	.000	.411	.411	.411	.060	.203	.000	.026
	Grouping of buildings	.047	.009	.000	.154	.038	.038	.038	.070	.151	.237	.000
	Q1_2014	.454	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2014	.359	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2014	.399	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2014	.440	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2015	.485	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2015	.461	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2015	.482	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2015	.449	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2016	.409	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2016	.433	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2017	.415	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2018	.404	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
N	Average running cost/sq.m	264	264	264	264	264	264	264	264	264	264	264
	Working days/week	264	264	264	264	264	264	264	264	264	264	264
	Working hours/day	264	264	264	264	264	264	264	264	264	264	264
	Operated yrs.	264	264	264	264	264	264	264	264	264	264	264
	Gross Internal Floor Area (sq.m)	264	264	264	264	264	264	264	264	264	264	264
	Net Floor Area (sq.m)	264	264	264	264	264	264	264	264	264	264	264
	Circulation Area (sq.m)	264	264	264	264	264	264	264	264	264	264	264

Building height (m)	264	264	264	264	264	264	264	264	264	264	264
Number of floors	264	264	264	264	264	264	264	264	264	264	264
Window area (sq.m)	264	264	264	264	264	264	264	264	264	264	264
Window-to-Floor-Ratio	264	264	264	264	264	264	264	264	264	264	264
Occupancy	264	264	264	264	264	264	264	264	264	264	264
Shape	264	264	264	264	264	264	264	264	264	264	264
Type of structure	264	264	264	264	264	264	264	264	264	264	264
Grouping of buildings	264	264	264	264	264	264	264	264	264	264	264
Q1_2014	264	264	264	264	264	264	264	264	264	264	264
Q2_2014	264	264	264	264	264	264	264	264	264	264	264
Q3_2014	264	264	264	264	264	264	264	264	264	264	264
Q4_2014	264	264	264	264	264	264	264	264	264	264	264
Q1_2015	264	264	264	264	264	264	264	264	264	264	264
Q2_2015	264	264	264	264	264	264	264	264	264	264	264
Q3_2015	264	264	264	264	264	264	264	264	264	264	264
Q4_2015	264	264	264	264	264	264	264	264	264	264	264
Q1_2016	264	264	264	264	264	264	264	264	264	264	264
Q2_2016	264	264	264	264	264	264	264	264	264	264	264
Q3_2017	264	264	264	264	264	264	264	264	264	264	264
Q4_2018	264	264	264	264	264	264	264	264	264	264	264

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Q4_2018, Grouping of buildings, Window area (sq.m), Q3_2017, Q2_2016, Q1_2016, Q4_2015, Operated yrs., Shape, Q3_2015, Q2_2015, Q1_2015, Working days/week, Q4_2014, Q3_2014, Window-to-Floor-Ratio, Occupancy, Q2_2014, Working hours/day, Circulation Area (sq.m), Type of structure, Number of floors, Building height (m)[b]	.	Enter

a. Dependent Variable: Average running cost/sq.m

b. Tolerance = .000 limit reached.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change
1	.787[a]	.619	.583	.43142409	.619

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	72.626	23	3.158	16.965	.000[b]
	Residual	44.670	240	.186		
	Total	117.297	263			

a. Dependent Variable: Average running cost/sq.m

b. Predictors: (Constant), Q4_2018, Grouping of buildings, Window area (sq.m), Q3_2017, Q2_2016, Q1_2016, Q4_2015, Operated yrs., Shape, Q3_2015, Q2_2015, Q1_2015, Working days/week, Q4_2014, Q3_2014, Window-to-Floor-Ratio, Occupancy, Q2_2014, Working hours/day, Circulation Area (sq.m), Type of structure, Number of floors, Building height (m)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t
1	(Constant)	12.556	1.601		7.844
	Working days/week	.262	.382	.051	.688
	Working hours/day	-.188	.169	-.091	-1.113
	Operated yrs.	.108	.049	.136	2.182
	Circulation Area (sq.m)	-1.135	.203	-1.138	-5.583
	Building height (m)	.426	.647	.432	.659
	Number of floors	1.148	.562	1.126	2.043
	Window area (sq.m)	.135	.061	.228	2.231
	Window-to-Floor-Ratio	.091	.041	.123	2.220
	Occupancy	-.018	.068	-.029	-.258
	Shape	.245	.149	.171	1.645
	Type of structure	-.150	.142	-.108	-1.051
	Grouping of buildings	-.390	.093	-.261	-4.203
	Q2_2014	-.033	.130	-.014	-.257
	Q3_2014	-.019	.130	-.008	-.146
	Q4_2014	-.005	.130	-.002	-.036
	Q1_2015	.021	.130	.009	.161

Q2_2015	.003	.130	.001	.021
Q3_2015	.010	.130	.004	.076
Q4_2015	.034	.130	.014	.258
Q1_2016	.047	.130	.020	.365
Q2_2016	.039	.130	.016	.300
Q3_2017	.045	.130	.019	.348
Q4_2018	.049	.130	.020	.379

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation
1	Gross Internal Floor Area (sq.m)	520.990[b]	.292	.771	.019
	Net Floor Area (sq.m)	-846.351[b]	-.661	.509	-.043
	Q1_2014	.[b]	.	.	.

Coefficient Correlations[a]

Model			Q4_2018	Grouping of buildings	Window area (sq.m)	Q3_2017	Q2_2016	Q1_2016
1	Correlations	Q4_2018	1.000	.000	.000	.500	.500	.500
		Grouping of buildings	.000	1.000	.021	.000	.000	.000
		Window area (sq.m)	.000	.021	1.000	.000	.000	.000
		Q3_2017	.500	.000	.000	1.000	.500	.500
		Q2_2016	.500	.000	.000	.500	1.000	.500
		Q1_2016	.500	.000	.000	.500	.500	1.000
		Q4_2015	.500	.000	.000	.500	.500	.500
		Operated yrs.	.000	-.108	-.084	.000	.000	.000
		Shape	.000	.108	-.411	.000	.000	.000
		Q3_2015	.500	.000	.000	.500	.500	.500
		Q2_2015	.500	.000	.000	.500	.500	.500
		Q1_2015	.500	.000	.000	.500	.500	.500
		Working days/week	.000	.107	.607	.000	.000	.000
		Q4_2014	.500	.000	.000	.500	.500	.500
		Q3_2014	.500	.000	.000	.500	.500	.500
		Window-to-Floor-Ratio	.000	-.532	.033	.000	.000	.000
		Occupancy	.000	.402	-.240	.000	.000	.000
		Q2_2014	.500	.000	.000	.500	.500	.500
		Working hours/day	.000	.162	-.675	.000	.000	.000
		Circulation Area (sq.m)	.000	.413	-.046	.000	.000	.000

	Type of structure	.000	-.039	.705	.000	.000	.000
	Number of floors	.000	-.109	-.235	.000	.000	.000
	Building height (m)	.000	-.047	.111	.000	.000	.000
Covariances	Q4_2018	.017	.000	.000	.008	.008	.008
	Grouping of buildings	.000	.009	.000	.000	.000	.000
	Window area (sq.m)	.000	.000	.004	.000	.000	.000
	Q3_2017	.008	.000	.000	.017	.008	.008
	Q2_2016	.008	.000	.000	.008	.017	.008
	Q1_2016	.008	.000	.000	.008	.008	.017
	Q4_2015	.008	.000	.000	.008	.008	.008
	Operated yrs.	.000	.000	.000	.000	.000	.000
	Shape	.000	.001	-.004	.000	.000	.000
	Q3_2015	.008	.000	.000	.008	.008	.008
	Q2_2015	.008	.000	.000	.008	.008	.008
	Q1_2015	.008	.000	.000	.008	.008	.008
	Working days/week	.000	.004	.014	.000	.000	.000
	Q4_2014	.008	.000	.000	.008	.008	.008
	Q3_2014	.008	.000	.000	.008	.008	.008
	Window-to-Floor-Ratio	.000	-.002	8.094E-5	.000	.000	.000
	Occupancy	.000	.003	-.001	.000	.000	.000
	Q2_2014	.008	.000	.000	.008	.008	.008
	Working hours/day	.000	.003	-.007	.000	.000	.000
	Circulation Area (sq.m)	.000	.008	-.001	.000	.000	.000
	Type of structure	.000	-.001	.006	.000	.000	.000
	Number of floors	.000	-.006	-.008	.000	.000	.000
	Building height (m)	.000	-.003	.004	.000	.000	.000

Collinearity Diagnostics[a]

				Variance Proportions	
Model	Dimension	Eigenvalue	Condition Index	(Constant)	Working days/week
1	1	12.458	1.000	.00	.00
	2	1.000	3.530	.00	.00
	3	1.000	3.530	.00	.00
	4	1.000	3.530	.00	.00
	5	1.000	3.530	.00	.00
	6	1.000	3.530	.00	.00
	7	1.000	3.530	.00	.00
	8	1.000	3.530	.00	.00
	9	1.000	3.530	.00	.00

	10	1.000	3.530	.00	.00
	11	1.000	3.530	.00	.00
	12	.537	4.815	.00	.00
	13	.375	5.762	.00	.00
	14	.237	7.250	.00	.00
	15	.174	8.458	.00	.00
	16	.099	11.211	.00	.00
	17	.068	13.579	.00	.00
	18	.027	21.642	.00	.01
	19	.016	28.109	.00	.00
	20	.005	52.434	.00	.12
	21	.004	56.202	.02	.00
	22	.001	119.272	.01	.70
	23	.000	285.384	.94	.15
	24	5.234E-5	487.884	.03	.02

Casewise Diagnostics[a,b]

Case Number	Std. Residual	Average running cost/sq.m	Predicted Value	Residual
15	3.422	9.472	7.9957224	1.47617755
37	3.421	9.438	7.9622997	1.47610028
59	3.422	9.453	7.9767588	1.47614119
81	3.421	9.467	7.9910088	1.47609119
103	3.260	9.423	8.0166906	1.40650937
125	3.258	9.404	7.9984088	1.40569119
147	3.258	9.411	8.0056315	1.40566846
169	3.258	9.435	8.0293270	1.40567301
191	3.098	9.380	8.0431588	1.33664119
213	3.098	9.371	8.0347679	1.33663210
235	3.098	9.378	8.0409679	1.33663210
257	3.098	9.382	8.0449679	1.33663210

a. Dependent Variable: Average running cost/sq.m

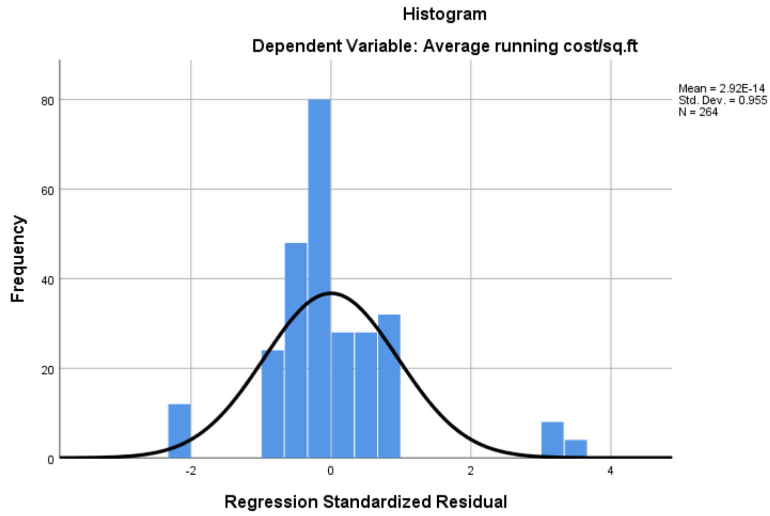
b. When values are missing, the substituted mean has been used in the statistical computation.

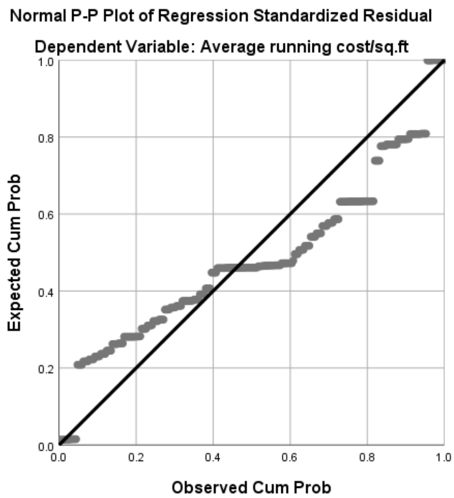
Residuals Statistics[a]

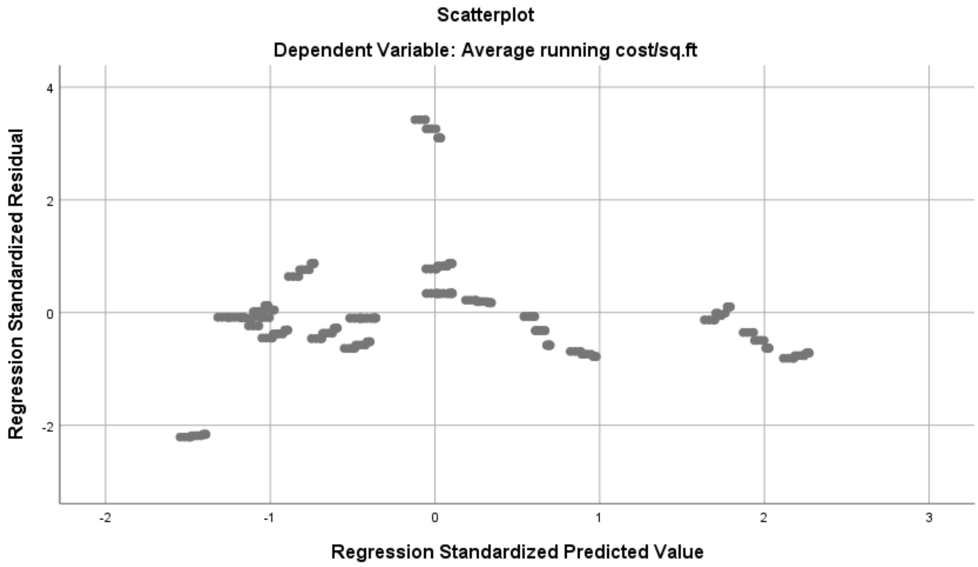
	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	7.2129965	9.2205114	8.0261655	.52549518
Std. Predicted Value	-1.547	2.273	.000	1.000
Standard Error of Predicted Value	.115	.147	.130	.010

Adjusted Predicted Value	7.3241963	9.2614698	8.0293815	.52717083
Residual	-.95325565	1.4761775 7	.00000000	.41212802
Std. Residual	-2.210	3.422	.000	.955
Stud. Residual	-2.335	3.566	-.004	1.001
Deleted Residual	-1.0644621 8	1.6038039 9	-.0032159 8	.45219507
Stud. Deleted Residual	-2.357	3.657	-.001	1.015
Mahal. Distance	17.549	29.740	22.913	3.766
Cook's Distance	.000	.046	.004	.010
Centered Leverage Value	.067	.113	.087	.014

Charts





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NFA CA Height Floors
    Window_area WFR Occupancy Shape Type_of_structure
AttachedORDetached Q1_2014 Q2_2014 Q3_2014
    Q4_2014 Q1_2015 Q2_2015 Q3_2015 Q4_2015 Q1_2016 Q2_2016 Q3_2017
Q4_2018
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Regression - Banks (17)

Notes

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	ZPR_1	Standardized Predicted Value
	ZRE_1	Standardized Residual
	SRE_1	Studentized Residual
	SDR_1	Studentized Deleted Residual
	SEP_1	Standard Error of Predicted Value
	LMCI_1	95% Mean Confidence Interval Lower Bound for Running_cost_per_sq.m
	UMCI_1	95% Mean Confidence Interval Upper Bound for Running_cost_per_sq.m

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Descriptive Statistics

	Mean	Std. Deviation	N
Average running cost/sq.m	8.2682417	.92414085	204
Working days/week	1.6523176	.07756122	204
Working hours/day	1.8230529	.06905236	204
Operated yrs.	2.6384438	.76418570	204
Gross Internal Floor Area (sq.m)	10.3455706	.58340608	204
Net Floor Area (sq.m)	9.9184118	.58342080	204
Circulation Area (sq.m)	9.2889529	.58341530	204
Building height (m)	4.9115824	.63888385	204
Number of floors	2.4290588	.62930553	204
Window area (sq.m)	9.6382176	1.17623858	204
Window-to-Floor-Ratio	-1.1696824	.59945305	204
Occupancy	7.1517471	.86040735	204
Shape	.41	.493	204
Type of structure	.65	.479	204
Grouping of buildings	.82	.382	204
Q1_2014	.08	.277	204
Q2_2014	.08	.277	204
Q3_2014	.08	.277	204
Q4_2014	.08	.277	204
Q1_2015	.08	.277	204
Q2_2015	.08	.277	204
Q3_2015	.08	.277	204

Q4_2015	.08	.277	204
Q1_2016	.08	.277	204
Q2_2016	.08	.277	204
Q3_2017	.08	.277	204
Q4_2018	.08	.277	204

Correlations

		Average running cost/sq.m	Working days/week	Working hours/day	Operated yrs.	Gross Internal Floor Area (sq.m)	Net Floor Area (sq.m)	Circulation Area (sq.m)	Building height (m)	Number of floors	Window area (sq.m)	Window -to-Floor-Ratio
Pearson Correlation	Average running cost/sq.m	1.000	-.081	-.067	-.051	.377	.377	.377	.385	.391	.864	-.021
	Working days/week	-.081	1.000	.818	-.252	.207	.207	.207	.086	.017	-.036	-.542
	Working hours/day	-.067	.818	1.000	-.292	.220	.220	.220	.094	.025	-.037	-.583
	Operated yrs.	-.051	-.252	-.292	1.000	.597	.597	.597	.500	.543	.058	.437
	Gross Internal Floor Area (sq.m)	.377	.207	.220	.597	1.000	1.000	1.000	.931	.917	.401	-.028
	Net Floor Area (sq.m)	.377	.207	.220	.597	1.000	1.000	1.000	.931	.917	.401	-.028
	Circulation Area (sq.m)	.377	.207	.220	.597	1.000	1.000	1.000	.931	.917	.401	-.028
	Building height (m)	.385	.086	.094	.500	.931	.931	.931	1.000	.988	.469	.018
	Number of floors	.391	.017	.025	.543	.917	.917	.917	.988	1.000	.449	.075
	Window area (sq.m)	.864	-.036	-.037	.058	.401	.401	.401	.469	.449	1.000	.032
	Window-to-Floor-Ratio	-.021	-.542	-.583	.437	-.028	-.028	-.028	.018	.075	.032	1.000
	Occupancy	.113	-.421	-.408	.569	.384	.384	.384	.516	.484	.409	.551
	Shape	.221	.099	.155	-.289	.328	.328	.328	.444	.370	.094	-.495
	Type of structure	-.039	-.171	-.216	.609	.455	.455	.455	.388	.417	-.100	.440
	Grouping of buildings	-.255	-.107	.210	-.243	-.464	-.464	-.464	-.576	-.542	-.406	-.147
	Q1_2014	-.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2014	-.018	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2014	-.013	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2014	-.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2015	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2015	-.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2015	-.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q4_2015	.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q1_2016	.012	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q2_2016	.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Q3_2017	.011	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

	Q4_2018	.012	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Sig. (1-tailed)	Average running cost/sq.m	.	.126	.171	.233	.000	.000	.000	.000	.000	.000	.384
	Working days/week	.126	.	.000	.000	.002	.002	.002	.112	.405	.304	.000
	Working hours/day	.171	.000	.	.000	.001	.001	.001	.091	.359	.301	.000
	Operated yrs.	.233	.000	.000	.	.000	.000	.000	.000	.000	.205	.000
	Gross Internal Floor Area (sq.m)	.000	.002	.001	.000	.	.000	.000	.000	.000	.000	.347
	Net Floor Area (sq.m)	.000	.002	.001	.000	.000	.	.000	.000	.000	.000	.347
	Circulation Area (sq.m)	.000	.002	.001	.000	.000	.000	.	.000	.000	.000	.347
	Building height (m)	.000	.112	.091	.000	.000	.000	.000	.	.000	.000	.402
	Number of floors	.000	.405	.359	.000	.000	.000	.000	.000	.	.000	.144
	Window area (sq.m)	.000	.304	.301	.205	.000	.000	.000	.000	.000	.	.327
	Window-to-Floor-Ratio	.384	.000	.000	.000	.347	.347	.347	.402	.144	.327	.
	Occupancy	.053	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	Shape	.001	.079	.013	.000	.000	.000	.000	.000	.000	.090	.000
	Type of structure	.291	.007	.001	.000	.000	.000	.000	.000	.000	.077	.000
	Grouping of buildings	.000	.064	.001	.000	.000	.000	.000	.000	.000	.000	.018
	Q1_2014	.463	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2014	.401	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2014	.429	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2014	.455	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2015	.489	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2015	.476	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2015	.489	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2015	.467	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q1_2016	.435	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q2_2016	.451	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q3_2017	.439	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
	Q4_2018	.432	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
N	Average running cost/sq.m	204	204	204	204	204	204	204	204	204	204	204
	Working days/week	204	204	204	204	204	204	204	204	204	204	204
	Working hours/day	204	204	204	204	204	204	204	204	204	204	204
	Operated yrs.	204	204	204	204	204	204	204	204	204	204	204
	Gross Internal Floor Area (sq.m)	204	204	204	204	204	204	204	204	204	204	204
	Net Floor Area (sq.m)	204	204	204	204	204	204	204	204	204	204	204
	Circulation Area (sq.m)	204	204	204	204	204	204	204	204	204	204	204

Building height (m)	204	204	204	204	204	204	204	204	204	204	204
Number of floors	204	204	204	204	204	204	204	204	204	204	204
Window area (sq.m)	204	204	204	204	204	204	204	204	204	204	204
Window-to-Floor-Ratio	204	204	204	204	204	204	204	204	204	204	204
Occupancy	204	204	204	204	204	204	204	204	204	204	204
Shape	204	204	204	204	204	204	204	204	204	204	204
Type of structure	204	204	204	204	204	204	204	204	204	204	204
Grouping of buildings	204	204	204	204	204	204	204	204	204	204	204
Q1_2014	204	204	204	204	204	204	204	204	204	204	204
Q2_2014	204	204	204	204	204	204	204	204	204	204	204
Q3_2014	204	204	204	204	204	204	204	204	204	204	204
Q4_2014	204	204	204	204	204	204	204	204	204	204	204
Q1_2015	204	204	204	204	204	204	204	204	204	204	204
Q2_2015	204	204	204	204	204	204	204	204	204	204	204
Q3_2015	204	204	204	204	204	204	204	204	204	204	204
Q4_2015	204	204	204	204	204	204	204	204	204	204	204
Q1_2016	204	204	204	204	204	204	204	204	204	204	204
Q2_2016	204	204	204	204	204	204	204	204	204	204	204
Q3_2017	204	204	204	204	204	204	204	204	204	204	204
Q4_2018	204	204	204	204	204	204	204	204	204	204	204

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Q4_2018, Grouping of buildings, Type of structure, Q3_2017, Q2_2016, Q4_2015, Working days/week, Q3_2015, Q3_2014, Shape, Q2_2014, Q1_2014, Q4_2014, Window area (sq.m), Q1_2015, Q2_2015, Operated yrs., Occupancy, Window-to-Floor-Ratio, Number of floors, Working hours/day, Gross Internal Floor Area (sq.m), Building height (m)[b]	.	Enter

a. Dependent Variable: Average running cost/sq.m

b. Tolerance = .000 limit reached.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change
1	.999[a]	.998	.998	.04305771	.998

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	173.036	23	7.523	4057.943	.000[b]
	Residual	.334	180	.002		
	Total	173.369	203			

a. Dependent Variable: Average running cost/sq.m

b. Predictors: (Constant), Q4_2018, Grouping of buildings, Type of structure, Q3_2017, Q2_2016, Q4_2015, Working days/week, Q3_2015, Q3_2014, Shape, Q2_2014, Q1_2014, Q4_2014, Window area (sq.m), Q1_2015, Q2_2015, Operated yrs., Occupancy, Window-to-Floor-Ratio, Number of floors, Working hours/day, Gross Internal Floor Area (sq.m), Building height (m)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	t
1	(Constant)	6.773	.160		42.232
	Working days/week	-1.908	.117	-.160	-16.359
	Working hours/day	8.842	.209	.661	42.281
	Operated yrs.	.795	.020	.657	40.102
	Gross Internal Floor Area (sq.m)	-.152	.038	-.096	-3.959
	Building height (m)	-5.954	.179	-4.116	-33.246
	Number of floors	4.354	.144	2.965	30.258
	Window area (sq.m)	1.143	.007	1.454	170.898
	Window-to-Floor-Ratio	.680	.013	.441	50.937
	Occupancy	-.567	.020	-.528	-28.206
	Shape	2.149	.029	1.147	74.806
	Type of structure	.669	.015	.347	45.194
	Grouping of buildings	-.937	.023	-.387	-40.404
	Q1_2014	-.055	.015	-.016	-3.720
	Q2_2014	-.089	.015	-.027	-6.053
	Q3_2014	-.074	.015	-.022	-4.995
	Q4_2014	-.060	.015	-.018	-4.031
	Q1_2015	-.029	.015	-.009	-1.968
	Q2_2015	-.048	.015	-.014	-3.265
	Q3_2015	-.041	.015	-.012	-2.775
	Q4_2015	-.017	.015	-.005	-1.171
	Q2_2016	-.008	.015	-.003	-.568

Q3_2017	-.002	.015	-.001	-.148
Q4_2018	.002	.015	.001	.122

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation
1	Net Floor Area (sq.m)	.[b]	.	.	.
	Circulation Area (sq.m)	.[b]	.	.	.
	Q1_2016	.[b]	.	.	.

Coefficient Correlations[a]

Model			Q4_2018	Grouping of buildings	Type of structure	Q3_2017	Q2_2016	Q4_2015
1	Correlations	Q4_2018	1.000	.000	.000	.500	.500	.500
		Grouping of buildings	.000	1.000	-.722	.000	.000	.000
		Type of structure	.000	-.722	1.000	.000	.000	.000
		Q3_2017	.500	.000	.000	1.000	.500	.500
		Q2_2016	.500	.000	.000	.500	1.000	.500
		Q4_2015	.500	.000	.000	.500	.500	1.000
		Working days/week	.000	.375	-.076	.000	.000	.000
		Q3_2015	.500	.000	.000	.500	.500	.500
		Q3_2014	.500	.000	.000	.500	.500	.500
		Shape	.000	-.622	.623	.000	.000	.000
		Q2_2014	.500	.000	.000	.500	.500	.500
		Q1_2014	.500	.000	.000	.500	.500	.500
		Q4_2014	.500	.000	.000	.500	.500	.500
		Window area (sq.m)	.000	-.512	.548	.000	.000	.000
		Q1_2015	.500	.000	.000	.500	.500	.500
		Q2_2015	.500	.000	.000	.500	.500	.500
		Operated yrs.	.000	-.381	.241	.000	.000	.000
		Occupancy	.000	-.146	.317	.000	.000	.000
		Window-to-Floor-Ratio	.000	.055	-.227	.000	.000	.000
		Number of floors	.000	-.522	.601	.000	.000	.000
		Working hours/day	.000	-.857	.709	.000	.000	.000
		Gross Internal Floor Area (sq.m)	.000	.185	-.147	.000	.000	.000
		Building height (m)	.000	.531	-.600	.000	.000	.000
	Covariances	Q4_2018	.000	.000	.000	.000	.000	.000
		Grouping of buildings	.000	.001	.000	.000	.000	.000
		Type of structure	.000	.000	.000	.000	.000	.000

	Q3_2017	.000	.000	.000	.000	.000	.000
	Q2_2016	.000	.000	.000	.000	.000	.000
	Q4_2015	.000	.000	.000	.000	.000	.000
	Working days/week	.000	.001	.000	.000	.000	.000
	Q3_2015	.000	.000	.000	.000	.000	.000
	Q3_2014	.000	.000	.000	.000	.000	.000
	Shape	.000	.000	.000	.000	.000	.000
	Q2_2014	.000	.000	.000	.000	.000	.000
	Q1_2014	.000	.000	.000	.000	.000	.000
	Q4_2014	.000	.000	.000	.000	.000	.000
	Window area (sq.m)	.000	-7.932E-5	5.426E-5	.000	.000	.000
	Q1_2015	.000	.000	.000	.000	.000	.000
	Q2_2015	.000	.000	.000	.000	.000	.000
	Operated yrs.	.000	.000	7.062E-5	.000	.000	.000
	Occupancy	.000	-6.830E-5	9.450E-5	.000	.000	.000
	Window-to-Floor-Ratio	.000	1.717E-5	-4.481E-5	.000	.000	.000
	Number of floors	.000	-.002	.001	.000	.000	.000
	Working hours/day	.000	-.004	.002	.000	.000	.000
	Gross Internal Floor Area (sq.m)	.000	.000	-8.368E-5	.000	.000	.000
	Building height (m)	.000	.002	-.002	.000	.000	.000

Collinearity Diagnostics[a]

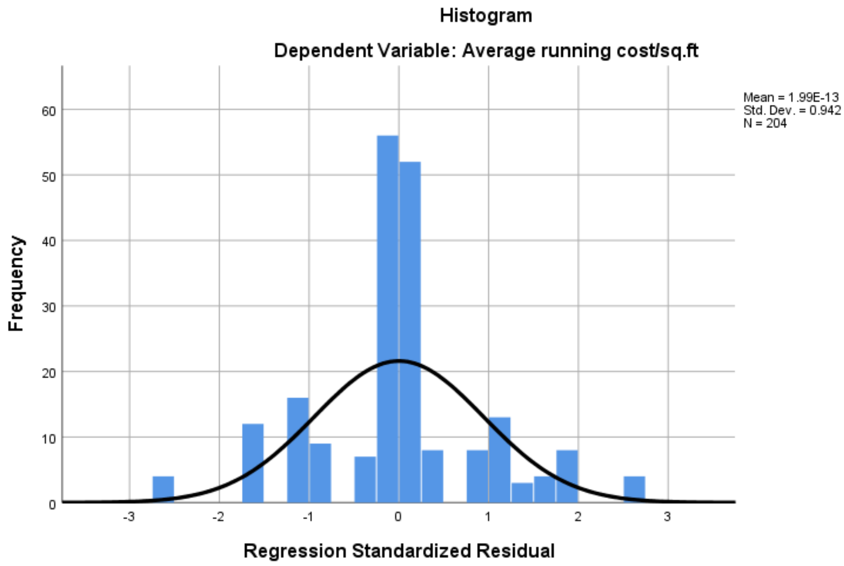
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Working days/week
1	1	12.508	1.000	.00	.00
	2	1.000	3.537	.00	.00
	3	1.000	3.537	.00	.00
	4	1.000	3.537	.00	.00
	5	1.000	3.537	.00	.00
	6	1.000	3.537	.00	.00
	7	1.000	3.537	.00	.00
	8	1.000	3.537	.00	.00
	9	1.000	3.537	.00	.00
	10	1.000	3.537	.00	.00
	11	1.000	3.537	.00	.00
	12	.698	4.232	.00	.00
	13	.387	5.683	.00	.00
	14	.186	8.199	.00	.00
	15	.089	11.847	.00	.00

16	.073	13.128	.00	.00
17	.030	20.346	.00	.00
18	.017	27.022	.00	.00
19	.008	40.166	.00	.00
20	.002	71.544	.00	.00
21	.000	160.586	.49	.11
22	.000	271.888	.11	.57
23	3.956E-5	562.297	.32	.19
24	9.040E-6	1176.309	.08	.12

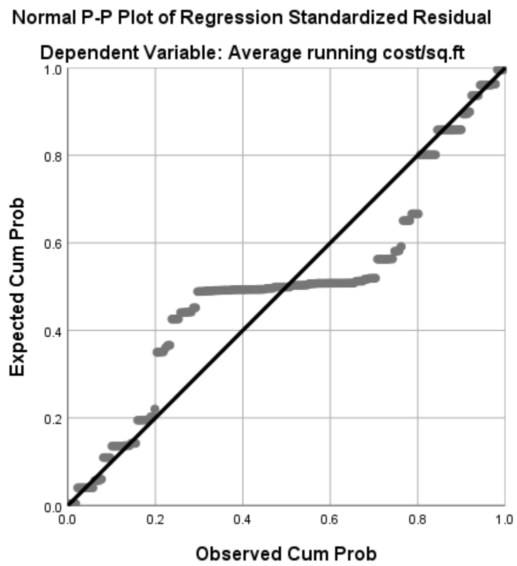
Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	6.3104453	11.0753536	8.2682417	.92325100
Std. Predicted Value	-2.121	3.040	.000	1.000
Standard Error of Predicted Value	.013	.016	.015	.001
Adjusted Predicted Value	6.3177862	11.0648937	8.2682417	.92326412
Residual	-.11416519	.11414657	.00000000	.04054517
Std. Residual	-2.651	2.651	.000	.942
Stud. Residual	-2.855	2.854	.000	1.006
Deleted Residual	-.13232784	.13230625	.00000000	.04627053
Stud. Deleted Residual	-2.913	2.913	.000	1.015
Mahal. Distance	18.409	26.868	22.887	4.232
Cook's Distance	.000	.054	.006	.011
Centered Leverage Value	.091	.132	.113	.021

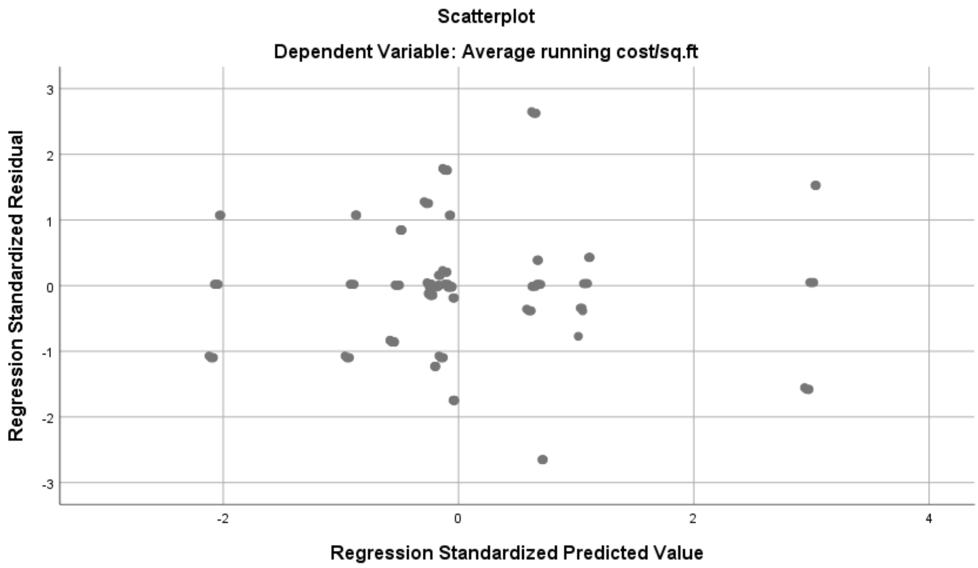
Charts



Histogram
Dependent Variable: Average running cost/sq.ft
Mean = 1.99E-13
Std. Dev. = 0.942
N = 204
Frequency
Regression Standardized Residual



Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Average running cost/sq.ft
Expected Cum Prob
Observed Cum Prob

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DATASET ACTIVATE DataSet7.
DATASET ACTIVATE DataSet7.

SAVE OUTFILE='C:\Users\dgeek\Desktop\Hedonic index - Office (22).sav'
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DATASET ACTIVATE DataSet6.
DATASET ACTIVATE DataSet6.

SAVE OUTFILE='C:\Users\dgeek\Desktop\Hedonic index - All (45).sav'
  /COMPRESSED.
DATASET ACTIVATE DataSet7.
DATASET CLOSE DataSet6.
DATASET ACTIVATE DataSet9.
DATASET CLOSE DataSet7.
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