Life Cycle Cost Analysis and Value Engineering and their Usage in the United Arab Emirates: A Case Study of Residential Buildings in Al Ain

تحليل تكاليف دورة الحياة والهندسة القيمة و استخدامتها في دولة الإمارات العربية المتحدة: دراسة حالة من بنايات سكنية في العين

by

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Abstract

Anxiety of succeeding a business is uncertainty to any stakeholder. Therefore appropriate strategical planning based on financial assessment is essential, strictly speaking for long-term planning. Accordingly, life cycle cost analysis is a proper financial technique to evaluate all pertinent costs to a project during its lifetime. Whereas value engineering allows project managers to look over new designs to select the best design that fulfils performance over function. The aim of this research is to compute the life cycle cost and apply the concept of VE on residential buildings in Al Ain, UAE over life cycle of 35 years.

An explanatory mixed method was followed through collecting data for new and old residential buildings in Al Ain. New buildings have less than 10 years old and was constructed using new appliances and finishes. Old buildings that have more than 10 years old and constructed poor quality and non-energy saving appliances. Old buildings' data was collected from a survey conducted by asking property owners. After that a quick comparison between buildings in Al Ain and in the UK was conducted.

LCCA was computed from cradle to grave, which includes three main phases: initial phase, operation phase and demolition phase. Initial phase contains design and construction costs. Operation phase consists of electricity, water, maintenance and replacement costs. Demolition phase includes only the cost of demolition and any associated cost. All costs were collected now except initial cost. Therefore, initial cost was uplifted to current value. Interviews were conducted to evaluate how the concept of value engineering was improved and applied efficiently at the market.

Results show that initial cost for new buildings in Al Ain is more than initial cost for old buildings due to the change in requirements and regulations and the change in raw materials prices. Results found that initial cost for buildings in Al Ain and the UK are so close. In addition, initial cost is the most sensitive value to change in input. Interest rate came at the second place in the sensitivity analysis. Moreover, it has been recommended applying value engineering to save in electricity cost, the main contributor in operation cost.

المُلخـــص

القلق من نجاح العمل يعد من شيء مجهول لأي صاحب مصلحة ، لذلك فإن التخطيط الاستراتيجي المناسب القائم على التقييم المالي أمر ضروري ، و بمعنى أدق التخطيط على المدى البعيد. وبناء على ذلك، فإن تحليل تكاليف دورة الحياة يعد تقنية مالية مناسبة لتقييم جميع التكاليف ذات الصلة بالمشروع خلال دورة حياة المشروع. في حين أن الهندسة القيمة تسمح لمديري المشاريع النظر في تصاميم جديدة لاختيار أفضل تصميم يلبي أداء أكثر من وظيفة. الهدف من هذا البحث هو حساب تكلفة دورة الحياة وتطبيق مفهوم الهندسة القيمة على المباني السكنية في العين، الإمارات العربية المتحدة على مدى دورة الحياة المكونة من 35 عاما.

وقد اتبعت الطريقة التفسيرية المختلطة من خلال جمع بيانات المباني السكنية الجديدة والقديمة في العين. المباني الجديدة التي لديها أقل من 10 سنوات، و التي قد شيدت باستخدام الأجهزة والتشطيبات الحديثة. أما المباني القديمة هي التي لديها أكثر من 10 سنوات، وشيدت باستخدام نوعية رديئة من الأجهزة غير الموفرة للطاقة. تم جمع بيانات المباني القديمة من استطلاع أجري على أصحاب العقارات. وبعد ذلك أجريت مقارنة سريعة بين المباني في العين والمملكة المتحدة.

تحليل تكاليف دورة الحياة تم حسابها من المهد إلى اللحد، والتي تتضمن ثلاث مراحل رئيسية: المرحلة الأولية، مرحلة التشغيل ومرحلة الهدم. المرحلة الأولية تحتوي على تكاليف التصميم والبناء. أما مرحلة التشغيل تتكون من تكاليف الكهرباء والمياه والصيانة والاستبدال. أما مرحلة الهدم لا تشمل سوى تكلفة الهدم وأي تكلفة مرتبطة به. جميع هذه التكاليف جمعت في الوقت الراهن باستثناء التكلفة الأولية. لذلك، تم حساب التكلفة الأولية بناءً على قيمتها في الوقت الحالي. كما أجريت مقابلات لتقييم كيفية تحسين مفهوم هندسة القيمة وتطبيقها بكفاءة في السوق.

تُظهر النتائج أن التكلفة الأولية للمباني الجديدة في العين أكثر من التكلفة الأولية للمباني القديمة ، و ذلك بسبب التغيرات التي حدثت في المتطلبات واللوائح الحكومية وكذلك بسبب التغير في أسعار المواد الخام. و أثبتت النتائج أن التكلفة الأولية للمباني في العين والمملكة المتحدة متقاربة جداً. وبالإضافة إلى ذلك، قد وجد أن التكلفة الأولية هي التكلفة الأكثر حساسية للتغيير في المدخلات. وجاء معدل الفائدة في المرتبة الثانية في تحليل اختبار حساسية المتغيرات. وعلاوة على ذلك، فقد أوصي بتطبيق هندسة القيمة لمساعدة في التوفير في تكلفة الكهرباء التي تعد المساهم الرئيسي في تكلفة التشغيل.

Student’s ID: 2014143007

Acknowledgment

Say, "O my Lord! advance me in knowledge." Qur'an

Abu Hurairah (May Allah be pleased with him) reported: The Messenger of Allah said, "Allah makes the way to Jannah easy for him who treads the path in search of knowledge."[Muslim]. Hadith

First of all, I praise God for guiding me to search of knowledge, providing me the power to challenge all life difficulties' to write this dissertation and granting me the capability to proceed successfully. This thesis appears in its current form due to the assistance and guidance of several people.

I would like to express my deep thankfulness to my supervisor **Prof. Abid Abu-Tair** for the useful comments, remarks and engagement through the learning process of this master. I would like to thank him for his extreme patience. Furthermore, I would like to thank **Dr. Abdelhalim Boussabaine** for his effective guidance and contribution to my topic.

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List of Abbreviations

AADC	Al Ain Distribution Company
ADCE	Abu Dhabi Commercial Engineering Services
ADDC	Abu Dhabi Distribution Company
AIRR	Adjusted internal rate of return
BIM	Building information modelling
CC	Construction costs
DARE	decision alternative ratio evaluation system
DC	Demolition cost
DR	Discount Rate
DSS	Decision support system
DSW	Day–Stout–Warren
EC	electricity cost
EUAB	Equivalent Uniform Annual Benefit
EUAC	Equivalent Uniform Annual Cost
FAST	function analysis system technique
FC	future cost
GDP	Gross domestic product
HVAC	Heating, ventilating, and air conditioning
IC	Initial Cost
IRR	Internal Rate of Return
ISO	International Organization Standard
KB	Knowledge base
LCA	Life cycle assessments
LCC	Life cycle costing
LCCA	Life cycle cost analysis
LCE	Life cycle energy
LED	light-emitting diode
M&RC	maintenance and replacement cost

List of Symbols

A	Annual amount or annuity
B_j	the annual net benefit in year i.
BUA	Built-up area
C	investment cost
$C_{CM\&T}$	construction materials and testing costs
C_E	costs of energy
CL&OH	labors and overhead costs
C_M	maintenance cost
C_{MF}	machinery fuel costs
C_U	use stage cost
C_W	water and wastewater cost
d	number of days
DE	demolition energy
EBEi	initial embodied energy
EBEr	maintenance or recurring embodied energy
F	Future Value
G	Uniform gradient amount
G+1	Buildings consist of ground and first floor
G+2	Buildings consist of ground and first and second floors
G+3	Buildings consist of ground and first, second and third floors
G+4	Buildings consist of ground and first, second, third and fourth floors
i	interest rate
LCE_b	total life cycle energy demand of the residential building,
$LCEE_b$	total embodied energy of the building (initial and recurrent embodied energy),
$LCEE_{if}$	life cycle embodied energy of infrastructures,
$LCOPE_b$	life cycle primary operational energy of the building
$LCTE_b$	life cycle transport energy demand of users in the building
M	maintenance cost

m	number of months
n	Number of compounding periods or asset life
N	Number of Samples
OPE	operating energy per year
P	Present value
$\mathbf{P_D}$	developer's profits
R	replacement cost
S	Salvage rate or resale value

CHAPTER 1: INTRODUCTION

1.0. Introduction

Life cycle cost analysis (LCCA) is new and old technique. It has been used for decades and until moment, it is an ambiguous technique that makes many companies unable to apply it in their organizations. Life cycle cost analysis is an economic technique that assists in economic decision-making. This method allows professionals to study and predict all pertain cost during the life cycle of the project.

Therefore, the aim of this research is to calculate the life cycle cost as a financial technique by applying net present value (NPV) method along with applying value engineering upon residential buildings in Al Ain city in the United Arab Emirates. In addition, this research compares between two types of residential buildings new and old buildings in Al Ain. After that, the results for new buildings were compared to similar buildings in the UK. Furthermore, sensitivity analysis was applied in order to find out the most sensitive factor during the life cycle of the project.

The research is organized into seven chapters. The first chapter describes the introduction, followed by the literature review, in chapters two until to chapter four. Literature review discusses the life cycle cost analysis, financial analysis and LCCA models and methods and value engineering. In chapter five, methodology will be discussed. Chapter six, shows the results and discussion. Finally, chapter seven presents the conclusion and the researcher recommendations.

Chapter two aims to figure out the of the guidelines for the literature review, which proposes the effect of life cycle cost analysis and value engineering on buildings in Al Ain City in the United Arab Emirates (UAE). The history of LCC was discussed in this chapter. Moreover, detailed definition for LCC was presented from different point of view. In order to understand the need, importance and LCC applications, examples of failed and successful projects were discussed. On the other hand, drawbacks and disadvantages for LCC were also illustrated.

Chapter two presents all the life cycle patterns such as life cycle assessments (LCA), life cycle energy (LCE) and life cycle cost (LCC). Key features for each pattern were discussed. In addition, this chapter collected the combination of (LCC and LCA) and

(LCC and LCE). Similarly, key features and applications for each combination were introduced. At the end of chapter two, life cycle process was explored in order to understand the life cycle for a construction project and to predict and extract all pertain costs for each cycle.

Chapter three aims to give a comprehensive account to the importance of economics and its effect on construction costs. National economy of the country contributes in critical financial analysis that directly influences computing life cycle costing. Economic components like interest rate, discount rate and inflation have immense influence on analysis. Methods of LCCA such as net present value, annual uniform cost, internal rate of return and payback method is explored. Then, LCC models were presented in brief. Furthermore, procedures of LCCA, sensitivity analysis, reliability and risk management are generally illustrated.

Chapter four represents value engineering. Definition of value engineering, need, importance, advantages and disadvantages were discussed. In addition, number of projects that applied value engineering were illustrated. Also, value engineering phases, steps and functions were presented.

Chapter five purposes to organize the research methodology of this dissertation to study analyse and evaluate buildings due to their life cycle cost using the net present value and value engineering. An explanatory mixed method of quantitative and qualitative methods were adapted in this research. This chapter explains all data sources, assumptions and all pre-data analysis. In addition, chapter five illustrates step by step the LCCA procedures which are defining objectives, alternatives and constraints, determining basic assumptions, combining cost data, calculating LCCA and preparing results and make final decision.

Chapter six illustrates the life cycle cost analysis results for all data. LCCA for new buildings in Al Ain, LCCA for old buildings in Al Ain, detailed comparison between new and old buildings in Al Ain based on initial cost, operation cost and net present values. After that LCC for new buildings in Al Ain were compared to another LCC study in the UK. Therefore, sensitivity analysis was examined to discover the most sensitive factor.

Results for the life cycle cost analysis for new buildings in Al Ain has shown that operation cost over 35 years is more than twice initial cost for (G+1), (G+2), (G+3) and (G+4) buildings. It has been noticed that the most expensive cost is electricity cost. Replacement cost was very small, it reaches 3 times its cost at year 30.

On the other hand, results for the life cycle cost analysis for old buildings in Al Ain has shown that initial cost to operation cost in old buildings is approximately 1 to 3 for (G+1) and (G+2) buildings and initial cost to operation cost is 1 to 2.5 for (G+3) and (G+4) buildings. Maintenance and water costs are so close to each other through the life cycle of 35 years.

A detailed comparison between new and old buildings in Al Ain based on initial cost, operation cost and net present value revealed that there is an extensive difference between new and old buildings in initial cost. That is because old buildings initial cost due to the change in raw materials' prices, labour costs and new requirements by new authorities.

It has been found that the comparison indicates that operation cost for new buildings is obviously higher than operation cost for old buildings. Electricity cost is the most effective cost in both new and old buildings during the lifetime operation cost. Although annual electricity cost for new buildings is less than the annual electricity cost for old buildings, the total operation cost for new buildings is more than old buildings through a life cycle of 35 years. That is because the decrease in tariff of electricity charge during the first twenty years from the old buildings' life, leads to decrease the total life cycle cost for old buildings.

The second comparison between Al Ain new buildings and the UK residential buildings indicated that initial cost for both are near to each other. Operation cost was difficult to compare due to the difference in methodologies. While it was found that electricity cost in the UK occupies 38% from the total operation cost. The other proportions of 33.3% for maintenance and transport, 16.3% for wastewater treatment and 12.3% for water cost. For demolition cost, houses in the UK are higher than buildings in Al Ain by 100%.

After that a sensitivity analysis was conducted for new buildings in Al Ain. It has been noticed that the rank of the highest slopes are for initial cost, interest rate, utility cost and maintenance and replacement cost in order for all types of buildings. The relative change in initial cost at -30% change in input varies from -15% to -17% and the relative change in initial cost at 30% change in input varies 11% to 13%. Initial Cost increases with the increase in change in input values.

Also, the relative change in interest rate at -30% change was found 11% for (G+1), (G+2) and (G+3) buildings and 10% for (G+4) buildings. the relative change in interest rate at 30% change was found constant at -11% for (G+1), (G+2) and (G+3) buildings and -10% for (G+4) buildings. Interest rate decreases with the increase in input value.

CHAPTER 2:
LITERATURE REVIEW

2.0. Overview

This chapter presents a novel method of evaluating buildings based on their life cycle costs and value engineering method. Life cycle costing as a methodology can be computed through different approaches. The life cycle cost analysis was performed by applying net present value technique in order to help project managers to decide whether the project is worthy to develop and invest or no and to distinguish between list of projects after ranking and compare between them. Sample of projects in Al Ain in the United Arab Emirates were examined through this technique.

2.0.1 Introduction

For several years, a great effort has been devoted to study and to manage projects in an effective and efficient way. It was and still a significant concern to all authorities, stakeholders and projects' developers. In order to manage projects in a successful manner, some conditions have to be achieved successfully. Venkataraman and Pinto (2008) set conditions of project success by controlling costs efficiency and developing and improving project's value. Davis (2016) has also recognized a technique of evaluating project success from a stakeholder point of view who judges the importance of project success dimension based on his own priority.

Similarly, Singh et al. (2011) has defined the golden triangle of cost, time and quality as paramount factors in construction industry. On the other hand, a new relationship between the golden triangle has been revealed by Gardiner and Stewart (2000) who motivate applying net present value (NPV) as a gauge of project success.

Therefore, the aim of this literature review is to propose the effect of life cycle cost analysis and value engineering on buildings in Al Ain City in the United Arab Emirates (UAE). The literature review is divided into three main sections. First section demonstrates life cycle cost definition, applications, need, importance, limitations and some previous applied examples in the UK and the UAE. The second section, illustrates the main financial analysis principles, methods, models and procedures. Also, sensitivity analysis, reliability, ranking alternatives, risk management were illustrated.

Finally, value engineering and its definition, advantages and disadvantages, phases and main functions were presented.

2.0.2 UAE in brief

The United Arab Emirates has unified and announced as an independent federal country on 2nd December 1970 under the lead of the late Sheikh Zayed bin Sultan Al Nahyan who struggled to cope all challenges to divert a desert to a developed country that relies on diversified economic sources. UAE is one of the richest countries in oil and gas inventory in the world and from its profits, an enormous development has been done (The Executive Council 2007).

This research studies the Emirate of Abu Dhabi and especially Al Ain, one of the biggest towns in the Emirate. Under the leadership of Sheikh Khalifa Bin Zayed Al Nahyan, President of the UAE and Ruler of Abu Dhabi who is continuing the wise vision of his father. In 2007, Abu Dhabi Policy Agenda saw the lights. It planned a comprehensive strategy for the emirate on the long-term and set the Abu Dhabi vision 2030. Furthermore, it allows the UAE to grow steadily, to mitigate depending on hydrocarbon sector in the gross domestic product of the emirate (GDP) (Abu Dhabi Council for Economic Development & Abu Dhabi Urban Planning Council 2007).

Abu Dhabi economic visions 2030 aims to be “a sustainable, diversified, high-value-added economy that encourages enterprises and entrepreneurship and well integrated in the global economy leading to better opportunities for all” (General Secretariat of the Executive Council, Department of Planning Economy in Abu Dhabi & Abu Dhabi Council for Economic Development 2008, p. 17).

Construction industry is one of the activities that contributes to the non-oil development and growth. The SCAD (Statistic Centre - Abu Dhabi 2016, p. 82) reported that “construction activity contributed 9.6% to the GDP in 2014”.

It is however important to study the buildings life cycle cost analysis in the UAE. Applying a long-term strategy will contribute in saving money. However, considering environment aspects will follow the UAE orientation and vision.

2.0.2.1.Buildings in the UAE

Buildings and constructions have been remodelled to meet the rapid progress of the country. Estidama is an organization that aims to build new sustainability framework to protect the environment of the UAE and to improve the quality of life. Estidama drives developers and designers to apply basic four pillars of environment, economic, social and cultural (Abu Dhabi Council for Economic Development & Abu Dhabi Urban Planning Council 2007).

2.0.2.2.Energy Consumption in the UAE

The energy consumption in the UAE was 111,685 GWH in 2014 and was 52,841 GWH in Abu Dhabi at the same year. The residential sector only consumed 15,535 GWH in 2014, 29% from the total energy consumption in Abu Dhabi (United Arab Emirates - Ministry of Energy 2014).

Indeed, the UAE has ranked twenty fourth on the world in energy consumption, while the UAE has ranked the thirteenth on the world in the energy production, which means that the UAE has different sources of energy production not only from oil and gas production, but also from solar production (U.S. Energy Information Administration 2015). A relationship between economy and energy in the UAE was scrutinized by Sweidan (2012) in order to decide whether the economy growth lead to more energy consumption or the increment in energy consumption reflects the country prosperity. A period from 1973 to 2008 was tested in two scales of short and long-term. Short-term showed a positive and bi-trend relationship between the country production and the energy consumption. While results on the long-term revealed that the plenty supply of oil from an oil exporter country stimulate consuming more energy.

2.0.3 Al Ain in brief

Al Ain has an arid climate most of the year. The air temperature is always above 40°C from April to October and reaches 50°C in June and July. However, the relative humidity at the same period decreases to the minimum because the arid weather and the typography of Al Ain, which does not have any, water surfaces (internal city in a desert)

(National Center of Meteorology & Seismology n.d.). Divisions of what projects were divided into three categories based on the building's typology as per UPC Al Ain vision 2030 (Abu Dhabi Urban Planning Council 2010). Therefore, we divided buildings in Al Ain into buildings up to 20 meters height (G+4) and buildings up to 15 meters height (G+3), (G+2) and (G+1) buildings up to 12 meters height as illustrated in Fig. (1). This, sub-dividing selected to allow us to compare results with different researches in different countries.

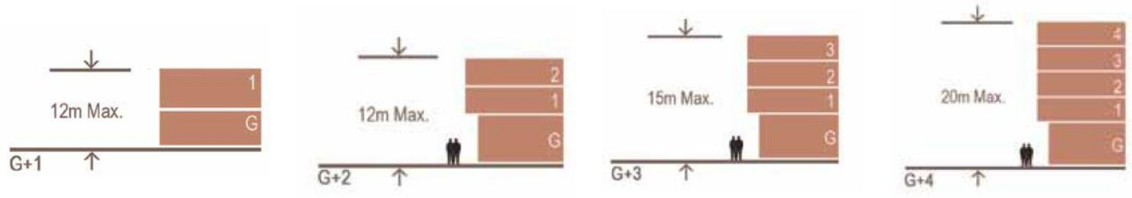


Figure 1 : Differences in Al Ain buildings' typology

(Abu Dhabi Urban Planning Council 2010, p. 3-5)

2.1. Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis has been gaining importance throughout the last few decades. The first enforcement of LCCA was on the mid of 1960s by the Logistics Management Institute in the U.S. who realised that decisions built on LCC at early phases has an obvious impact on future expenditures (Shtub, Bard & Globerson 2005); (Elmakis & Lisnianski 2006) & (Venkataraman and Pinto 2008).

2.1.1. LCCA definition

LCCA is a comprehensive financial technique that allows engineers, project managers, and cost analysts to study and evaluate all pertinent costs to a project during its lifetime. The project might be a product, system, building or any sequence processes through period of time with consideration of possible changes in economic factors over time.

The National Institute of Standards and Technology (1996, p.1-1) defined LCCA as it "is an economic method of project evaluation in which all costs arising from owning, operating, maintaining, and ultimately disposing of a project are considered to be potentially important to the decision".

Shtub, Bard and Globerson (2005, p.147) summarized the definition in "[the total cost of a product, structure, or system over its useful life". Predominantly, LCCA is useful technique to compare between costs of different alternatives that possess same specification and function.

2.1.2. Failed and successful cost management

Project cost management is risky and citical management because of the sensitivity of dealing with the golden tringle of cost, time and quality. In this section we will present a case study of failure cost management projects and some case studies of applied LCCA in projects.

The failure case study is the "Central Artery/Tunnel (CA/T) project" or the "Big Dig" (Venkataraman and Pinto 2008, p.4). It is a massive highway project in the U.S. which consists of;

> "(1) an eight- to ten-lane underground expressway replacing the old elevated roadway, with a 14-lane, two-bridge crossing of the Charles River; and (2) extension of I-90 by building a tunnel that runs beneath South Boston and the harbor to Logan Airport (Venkataraman and Pinto 2008 , p.4)."

CA/T project oftentines failed to meet the scheduled date. It lasted for more than 20 years (1980s to 2006). On the other hand, the estimated cost for the project was $2.5 billion in 1983 and due to bad cost management, cost has reached to $14.63 billion in 2003. A Federal Audit of the project reported that uncontrollable costs were due to mistakes from contrators in their bids and the mismanagement from the project managers. The catastrophe in this project unfortunatelly did not stop after the enourmous collapse in cost and time, but it extended to non conformance works costs $108 million from the contractors due to structural bolt failures that killed commuters. The (CA/T) project is a raucous example to poor cost management and absence of real project management (Venkataraman and Pinto 2008).

On the other hand, Eno Center for Transportation & American Society of Civil Engineers (2014) reported that the “Port Authority of New York and New Jersey (PANYNJ) ” as an agancy has applied LCCA technique upon some of its projects. A project of Bay Runway at John F. Kennedy (JFK) International Airport and the George Washington Bridge applied LCCA in their repair. A saved cost of $140 million over 40 years and $100 million over 20 years have been recorded for the JFK bay runway replacement and for bridge repair respectively.

2.1.3. The need for LCCA

In recent years, research on life cycle costing has become very popular. While LCCA in capital or infrastucture investments is crucial and compulsory because LCCA is an efficient evaluation technique to measur benefits of projects on a long-term not only based on the initial cost (NIST 1995). Dhillon (2010) decided that LCCA is required because it helps in momentum competitors, shortage at the financial allowances, fluctuations in market rates espicially inflation rate, increments in operation and maintenance costs, working in precious products or sensitivity systems like manufacturing aircraft or developing military or space systems and consciousness raising to the importance of studying LCC. Besides, Kshirsagar, El-Gafy and Abdelhamid (2010) scrutinized LCCA in as asset management tool to prodict actual facility costs in buildings.

2.1.4. LCCA importance and applications

The importance of the LCCA settles in its value and applications. The main key feature of implanting LCCA is to assist in economic decision-making; by substantiating practically the projected reduction in future costs by determining the lowest life cycle costing.

A consensus is forming among experts that LCCA technique is the best technique to assist in making-decision. LCCA is important due its ability to support managers to measure the economic effect of their decisions. It has a significant effect on operation and construction stages, if decisions have been taken at early stages (Eisenberger, I. &

Lorden, G. 1977; Shtub, Bard & Globerson 2005 ; Ammar, Zayed & Moselhi 2013; Kulczycka & Smol 2016; Kim and Kang 2016).

Making decision is one of the most significant revenue from analysing life cycle costs. LCCA assists stakeholders and engineers in making decisions (Singh et al. 2011; Karim, Magnusson and Natanaelsson 2012; Park et al. 2014). Decision support system (DSS) mainly, consists of knowledge base (KB) and workshop (Naderpajouh & Afshar 2008). In order to build robust decisions, it is necessary to have knowledge about the theoretical and historical data of the project (Goh and Yang 2014).

This section reveals how LCCA contributes to decision making. The usefulness of applying LCCA is to;

a) compare between alternative (Shtub, Bard & Globerson 2005 & ASTM 2013); by trading off between different materials or systems to find the best economic design during the lifetime of the project (Eisenberger, I. & Lorden, G. 1977).

During a design and planning phase, Karim, Magnusson and Natanaelsson (2012) investigated life cycle cost analysis of three types of road barriers, which are concrete barrier, cable, and w-beam barriers. Researchers used an activity-based life cycle cost method by utilizing Monte Carlo Simulation. Although investment costs for concrete barriers are the highest, it shows the lowest LCC.

Seçer & Bozdağ (2011) applied LCCA technique to find out the most suitable seismic structural solution in respect to financial and technical sides for a five story X-braced steel building. Authors contrasted between three X-bracing configurations. Contrast built by accounting the entire cost estimate and base shear values in order to find the optimum earthquake damage cost compatible with the lowest initial costs during the designed life cycle.

b) improve energy conservation in projects and determine the efficient scale of investment (NIST 1996 and ASTM International 2013); by promoting building performance from all aspects like developing thermal performance, heating, ventilating, and air conditioning (HVAC) systems and replace inefficient equipment to high-efficient equipment ‘retrofitting’.

LCCA is professional technique in measuring the differences between retrofits that can improve building and energy efficiency and determine the minimum LCC approach (NIST 1996). LCCA participates in retrofitting approaches to allocate budget efficiently and select the most economic combination (ASTM International 2013).

Kim and Kang (2016) developed an integrated model to enforce cost optimization to energy saving designs in buildings at early stages to deduce the lowest LCC. This technique allows project managers to consider both energy simulation analysis and cost optimization method over examining different variables such as PV panel area ratio, skylight area ratio and roof insulation ratio and cost optimization model. Findings show that cost optimization model not only can contribute in reducing energy but also gives high indication to the best economic feasibility study.

Yildiz, Ozbalta and Eltez (2014) investigated various energy efficient measures that can reduce the total energy consumption in cold climates in Turkey. LCCA was adapted to estimate the best appropriate economic valuation case from alternatives that adopted payback method and NPV over life cycle of 20 years. Alternative that has the highest NPV case and the lowest payback period is the best feasible economic alternative.

In contrast, Boubekri (2012) argued that LCCA is not always the best solution to determine the best cost saving and energy solution when re-lamping for four-story compass of the University of Illinois at Urbana-Champaign was tested. Boubekri (2012) did not include a purchase cost at his study, which may contrast all results.

c) allocate investment efficiently or prioritize the allocation of insufficient funding (ASTM International 2013 & NIST 1996); by selecting the most economic level of investment and measuring the supplementary factors of economic performance based on LCCA. Ranking projects by computing saving-to-investment ratio (SIR) and adjusted internal rate of return (AIRR).

d) quantify environmental effect from a financial analysis; by combining life cycle cost analysis with life cycle assessment (LCA).

Approaches of LCCA and LCA are applied to build an easy tool for an economic analysis and to quantify environmental Impacts during project life cycle (Arpke & Hutzler 2005, Cited in Singh et al. 2011). The ideal usage of applying LCCA integrated with LCA is to find early solutions in planning stage and to assist in decision-making (Kulczycka & Smol 2016).

2.1.5. Disadvantages and limitations in LCCA

Research seems to agree that unavailability of information and scarcity in databases is an immense challenge. A key limitation in LCCA was the difficulties in collecting cost data as discussed by Ciroth 2009 Cited in Swarr et al. (2011). The main confrontation in cost database is that LCC pursues all associated costs through a life cycle, which needs a robust and detailed database. Furthermore, some of cost data are considered sensitive to some organizations. As well, data related to costs are affected particularly to market's rates, currency and time value.

Choi, Oh and Seo (2012) seemed to agree that scarcity of convenient databases and lack in reliability data Higham, Fortune and James (2015), increase the challenge in LCC calibration. Cuéllar-Franca and Azapagic (2014) overcame the unavailability of some data by considering sensitivity analysis into account to measure the influence of excluding these data in the study.

On the side of the local level, Afshari, Nikolopoulou and Martin (2014) faced a challenge in the UAE retrofit cost database. Due to the absence of UAE retrofit cost database, authors forced to consider US costs database provided by the National Residential Efficiency Measures Database as a guidance.

Moreover, Goh and Yang (2014) concluded that there were a general shortage in LCCA tools, practice and standard method. This view contrasts Higham, Fortune and James (2015) who concluded that standards were set, but there were lack of practicing standards by analysts.

Furthermore, Elmakis and Lisnianski (2006) LCCA from their point of view is expensive and time consuming to organize specialists from different departments in order to achieve successful LCCA. Also, Karim, Magnusson and Natanaelsson (2012) agree that LCCA spends time at the process.

Higham, Fortune and James (2015) put responsibility upon clients cost advisors and sustainability consultants as they were the main stimulant to apply LCC in the UK by restricting consultants with the short-termism budget. Furthermore, a shortage in realizing and consciousness that LCCA has advantages and benefits at early phase, contributes to rarely applying of LCCA (Higham, Fortune & James 2015). Researchers agreed that ambiguity of the benefits beyond applying LCC was a generic problem.

On the other hand, numerous authors support the need of organized and sufficient database subsidised by governments and official institution. Karim, Magnusson and Natanaelsson (2012) suggested that governments have to create their own systematic cost database in order to consolidate improving LCCA studies.

2.1.6. LCCA in Housing in Different Countries

This section presents the variety of applying life cycle costing by location or by countries. LCCA has been applied world widely in many countries, but we will spot more lights to LCCA in the United Kingdom (UK) and the United Arab Emirates (UAE).

2.1.6.1. LCCA in the UK

In the United Kingdom, Cuéllar-Franca and Azapagic (2014) conducted a research on three types of housing (detached, semi-detached and terraced) to evaluate its life cycle costs from a sustainable point of view. Construction industry has a significant effect on the UK economy, which participates by £90 billion (6.7%) in value added as reported by the BIS (Department for Business, Innovation and Skills 2013). The Office National of Statistics in the UK has weighted that construction output contributes to 5.9% of the total GDP of the country (Office National of Statistics 2016). Cuéllar-Franca and Azapagic (2014) derived that £27 billion per year are the life cycle cost for semi-detached houses in the UK and £20 billion per year for both detached and terraced houses. As a result, 67 billion per year or £3,360 billion is the total LCC for housing in the UK through 50 years life cycle (Cuéllar-Franca & Azapagic 2013).

Higham, Fortune and James (2015) have investigated whether the LCC is used at early phases in the UK domain construction as an estimation method. A questionnaire survey of 250 companies from leading cost consultants, architects, contractors and project management organizations were selected from 'Building Magazines'. Questionnaire findings show that LCC was rarely applied as an estimation tool in early phases. A prominent gap between practice and standards in applying LCC at early stage was proved in the UK construction industry.

2.1.6.2. LCCA in the UAE

In the United Arab Emirates, Afshari, Nikolopoulou and Martin (2014) conducted a research on a life-cycle analysis of energy efficiency retrofits in Abu Dhabi, concentrating on the air-conditioning as significant ingredient in the electricity load. Analysis compares differences by employing a comprehensive research-oriented forward model of building energy by using Energy Plus. Subsequently, a simulation is prepared to quantify assorted retrofits and estimation of the prospective CO_2 emissions produced from each alternative. Eventually, Authors applied a life cycle analysis that includes carbon emissions and cost. Findings of a Marginal Abatement Cost Curve (MACC) can contribute in decision making at design stage by prioritizing between alternatives during its lifetime.

2.1.6.3. LCCA in Turkey

In Turkey, Cetiner and Edis (2014) looked at the use phase at their study, considering that huge energy consumption is escalating at this phase that leads to enormous environmental and economic effects. This research aimed to scrutinize the possible retrofits onto residential buildings and to contrast between alternatives based on their environmental, economic and performance sustainability effect. Although, authors presented simple technique to facilitate comparing alternatives, they excluded air conditioning from their energy consumption.

2.2. Life Cycle Patterns

This section explains three patterns of analysis that takes into account the product or the system of life cycle. The most common patterns were selected which are life cycle assessment (LCA), life cycle energy (LCE) and life cycle costing (LCC). A brief summary of each pattern were discussed.

Analyzing buildings and considering the long term of life play a vital role from financial aspect, energy saving and environmentally aspect. That is why many researchers have paid attention to not only study the economical side but also to understand another factor. Cabeza et al. (2014) presented LCA, LCE and LCCA by location and amount of published studies on a world map as shown in Fig. (2).

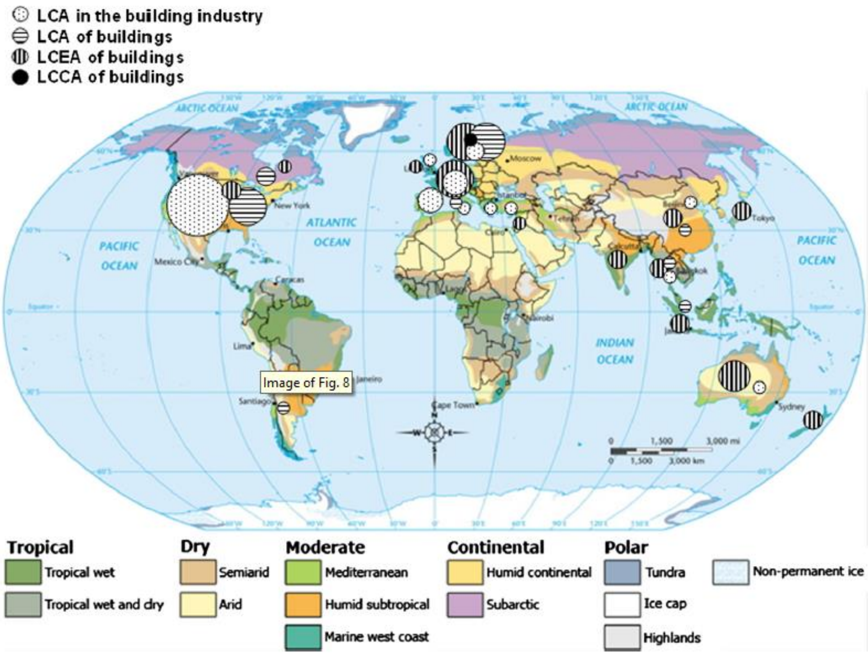


Figure 2: Distribution of LCA, LCE and LCCA by location and amount of published studies

(Cabeza et al. 2014, p. 413)

2.2.1. Life cycle assessment (LCA)

Life cycle assessment is a technique that concerned to environment issues and its related effect on a product, system or any process. LCA is a “cradle-to-grave” process because it is particularly evaluate and study materials and energy over the life cycle (ISO/DIS 15686-5.2 2016). LCA can be used to estimate and quantify greenhouse gas (GHG) emissions over the whole phases (Shin and Cho 2015).

The International Organization Standard (ISO) classified LCA into four phases, which are “the goal and scope definition, inventory analysis, impact assessment, and interpretation” (ISO:14040 2006, p.7). These phases were translated in a framework as shown in Fig. (3).

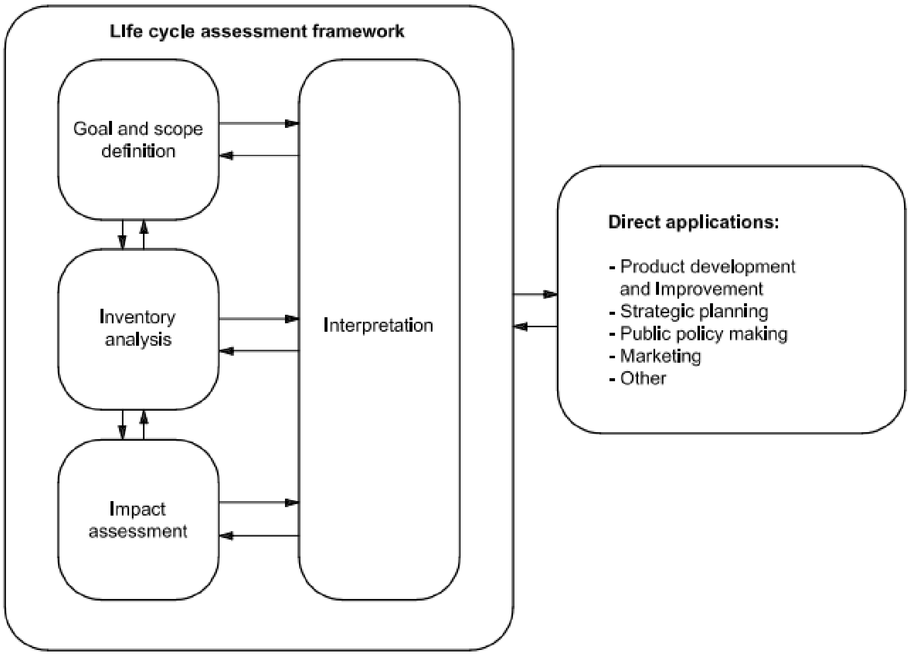


Figure 3: LCA framework
(ISO:14040 2006, p.8)

Singh et al. (2011) conducted a review of LCA applications particularly in building construction. An organized LCA approach were studied to demonstrate LCA applications for construction materials and technique appraisal, associated database and software tools. In addition, areas of development, challenges and future works were explored.

Cabeza et al. (2014) have also deeply developed Singh et al. (2011) review. Then a comprehensive LCA study conducted after classifying buildings into three categories, which are residential buildings, non-residential buildings and general civil engineering constructions. Furthermore, life cycle energy analysis and life cycle cost analysis for buildings were discussed from an environmental view. Finally, a detailed comparison of case studies collected in the review was conducted carefully.

2.2.2. Life cycle energy (LCE)

LCE is the assessment of all quantity of energy consumed in a project over its lifetime. Energy consumption starts from materials used in a project and its embodied energy comes after this material either by electricity or by fuel (Ramesh, Prakash & Kumar Shukla 2013). Then, energy consumed to operate the building includes all building operating equipment like lighting, cooling, heating, …etc. Later, maintenance cost is estimated to find the expected energy will be consumed during the building lifetime. Finally, energy consumed at demolition phase at the end of the project life mainly due to the fuel consumed by demolition machinery and by machines transported demolition waste.

Life cycle energy is expressed in Eq. (1) (Ramesh, Prakash & Kumar Shukla 2013, p.38). $\mathrm{LCE} = \mathrm{EBE_i} + \mathrm{EBE_r} + (\mathrm{OPE} * \text{building lifetime}) + \mathrm{DE}$………………….. Eq.(1)
where; EBEi = initial embodied energy,

EBEr = maintenance or recurring embodied energy,

OPE = operating energy per year and

DE = demolition energy.

Similarly, Stephan, Crawford and de Myttenaere (2012) adapted another equation to calculate the life cycle energy for residential buildings by dividing energy consumption into two scales. Building scale includes embodied and operation energy for the building and city scale which includes infrastructure and transport. Therefore, the total life cycle energy is the summation of all these factors as shown in Eq. (2) (Stephan, Crawford & de Myttenaere 2012, p. 595).

$LCE_b = LCEE_b + LCEE_{if} + LCOPE_b + LCTE_b$ ……………………….…………..Eq. (2)

where; LCE_b = total life cycle energy demand of the residential building,

$LCEE_b$ = total embodied energy of the building (initial and recurrent embodied energy),
$LCEE_{if}$ = life cycle embodied energy of infrastructures,
$LCOPE_b$ = life cycle primary operational energy of the building and
$LCTE_b$ = life cycle transport energy demand of users in the building.

Stephan, Crawford and de Myttenaere (2012) concluded that building size and journey distance are major factors influence upon the energy demand breakdown of embodied, operation and transport per cent. In addition, operation energy cost is estimated to exceed more than half percent of the total energy demand over a building lifetime.

2.2.3. Life cycle costing (LCC)

Life cycle costing was defined earlier at clause 2.2.1. This section introduces general components of life cycle costs that suit any project. These components or phases can be assigned partially or completely to meet different systems or projects. General phases of life cycle cost divided into five phases, which are (Shtub, Bard & Globerson 2005): conceptual design phase, advanced development and detailed phase, production phase, operation and maintenance phase, and divestment or disposal phase. Fig. (4) reflects the five phases and its relationship to project cost.

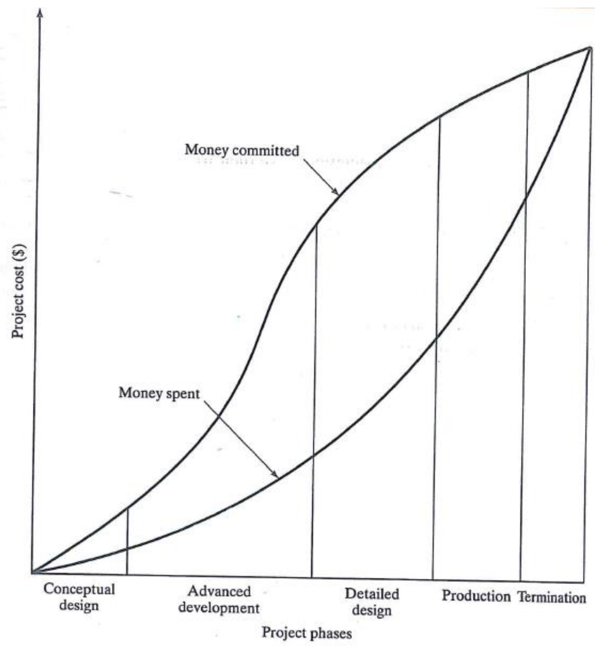


Figure 1.4 Relationship between project life cycle and cost.

Figure 4: Relationship between project life cycle and cost

(Shtub, Bard & Globerson 2005, pp. 9)

2.2.4. Life cycle cost (LCC) and life cycle assessment (LCA)

Several publications have appeared in combining between LCA and LCC to investigate economic and environmental impacts. Minne and Crittenden (2014) applied this combination in order to examine the impact of floor maintenance upon the total life cycle cost and environmental impact. As well, Cetiner and Edis (2014) relied on LCA and LCCA to decide between various retrofit alternatives in a residential building without deeply energy environmental assessment with respecting financial impact.

Kulczycka and Smol (2016) promoted various algorithm analysis connect LCA and LCCA which assist decision makers to adopt the most suitable project based on their available resources. In addition, Heijungs, Settanni and Guinée (2013) improved this integration by building LCC computation structure on the hypothesis of LCA. Another amalgamation conducted by Shin and Cho (2015) who applied building information modeling (BIM) to facilitate collecting information and to assess ease of apply LCA and LCCA in construction project at planning and design phases.

2.2.5. Life cycle cost (LCC) and life cycle energy (LCE)

Many researchers have proposed studying LCE and LCC. Afshari, Nikolopoulou and Martin (2014) applied LCCA in developing retrofits examined on buildings to measure the difference in energy consumption through a structured framework and energy simulation model. Similarly, Yildiz, Ozbalta and Eltez (2014) applied LCCA for each retrofit alternative to differentiate between energy saving retrofits.

In order to reduce LCE and LCCA, Hamelin and Zmeureanu (2014) developed an optimization method to decrease heating and cooling loads in buildings by minimizing LCE first and its corresponding LCC. As well, Kim and Kang (2016) developed an optimization method to evaluate energy saving techniques by applying LCCA as a feasibility tool to assess buildings at design stage.

2.3. Life Cycle Costing Process

Life cycle costing process or phases were tailored to meet different purposes. In construction projects, although each organization has its own phases and processes, there are main processes for all construction projects to drive the projects to success path. For instance, Elmakis and Lisnianski (2006) adapted life cycle phases to meet products or systems characteristics as shown in Fig. (5). However, Kim and Kang (2016) illustrated different cash flow of building life cycle phases as presented in Fig. (6). Also, Griffin 1993 cited in Dunston & Williamson (1999) who illustrated in Fig. (7) the relative costs of the life cycle phases.

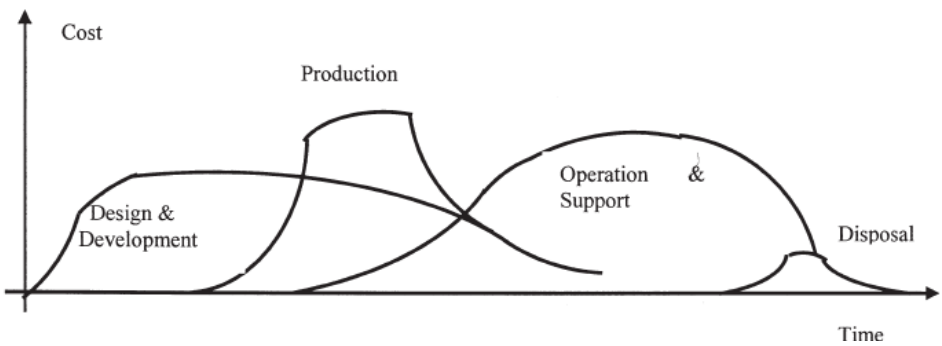


Figure 5: Different LCC phases of a product over time

(Elmakis & Lisnianski 2006, p. 6)

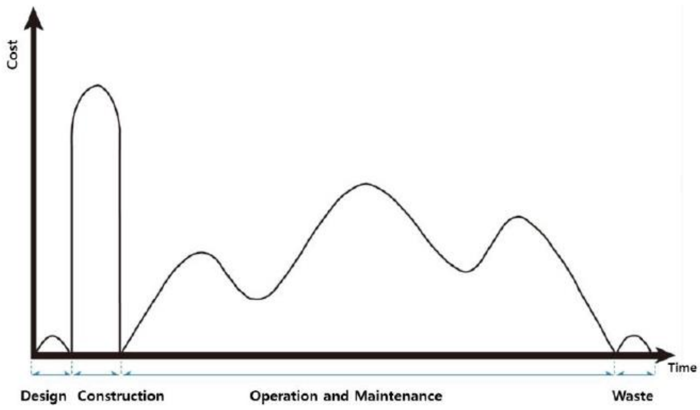


Figure 6: Life cycle phases of buildings over time

(Kim and Kang 2016, p.4)

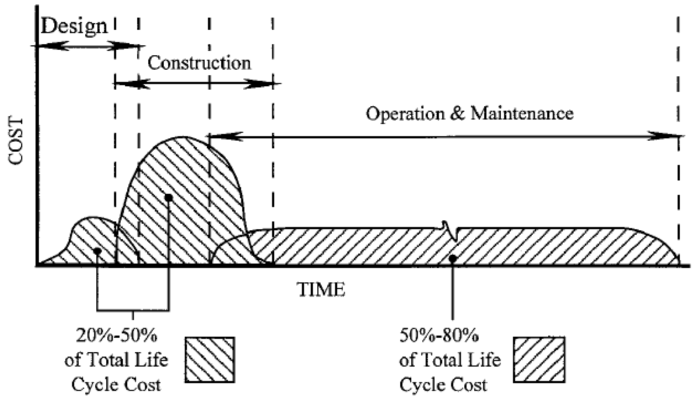


Figure 7: Life cycle costing phases

(Adapted from Griffin 1993 cited in Dunston & Williamson 1999)

In previous references it was observed that life cycle costing were organized into three prime categories, which are: initial cost, operation cost and demolition cost. Where operation cost contains utility costs and maintenance costs. Fig. (8) represents the life cycle costing organizational structure.

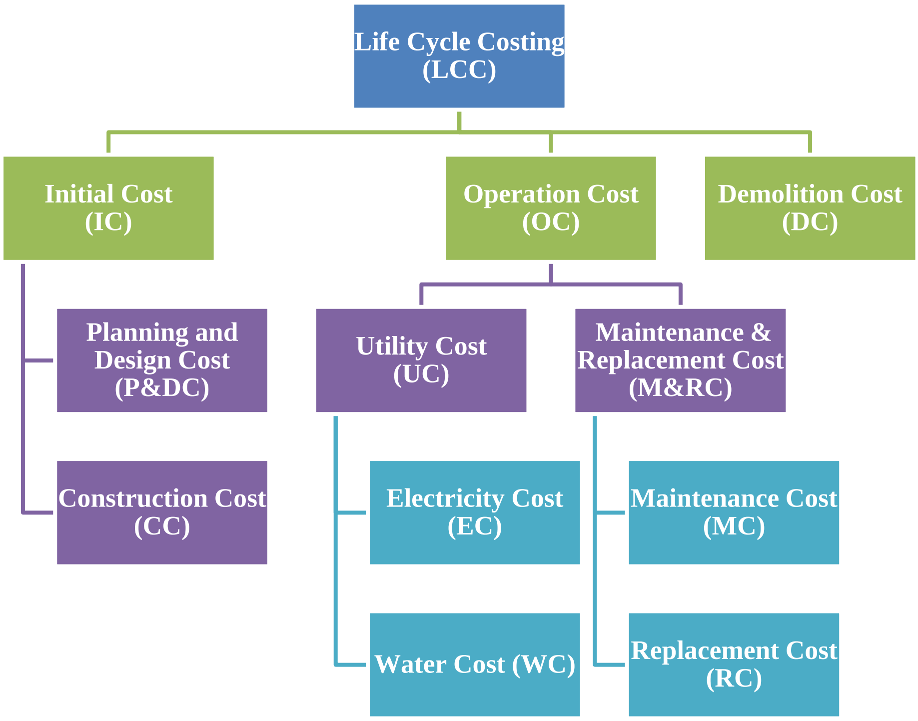


Figure 8: Organizational structure of a project life cycle costs

2.3.1. Initial Cost (IC)

Initial cost or capital cost is divided into two main categories, which are planning and design costs and construction costs. This stage consumes between 20% - 50% of the total time of the structure (Griffin 1993 cited in Dunston & Williamson 1999).

2.3.1.1. Planning and design costs (P&DC)

Design costs extracted from two fundamental phases which are conceptual design phase and advanced development and detailed design phase. Conceptual design phase include initial concept design and corresponding feasibility study, determining main configuration and selecting the suitable engineering system (Shtub, Bard & Globerson 2005). This stage allows clients and designers to select the best design from diverse design options. It also, configures the best engineering system that complies with regulation rules and requirements. However, feasibility study indicates the expected construction cost and the expected return cost of this investment. Shtub, Bard and Globerson (2005) illustrated that life cycle cost model can be used in this phase in order to underpin benefit-cost analysis. This phase exposed to large errors and uncertainties.

Advanced development and detailed design phase pertain to detailed design, process, planning and supporting all required documents to prepare project for production or construction phase. Detailed specifications, work breakdown structure and its related costs, detailed drawings, accurate costs, and labors allocation. Shtub, Bard and Globerson (2005) recommend applying accurate LCC in order to deduce precise estimate and support decisions in a proper manner.

2.3.1.2. Construction costs (CC)

Construction costs reflect production phase that includes executing the project, testing and commissioning. Cuéllar-Franca and Azapagic (2013) demonstrated that construction cost is the summation of construction materials and testing costs ($C_{CM\&T}$), labors and overhead costs ($C_{L\&OH}$), machinery fuel costs (C_{MF}) and developer's profits (P_D) as illustrated in Eq. (3).

$$C_C = C_{CM\&T} + C_{L\&OH} + C_{MF} + P_D \quad \ldots\ldots(3)$$

Moreover, Cuéllar-Franca and Azapagic (2013) demonstrated that the key players in this phase are in order; labour costs (52%) and construction material costs (35%) such as bricks and concrete.

2.3.2. Operation costs and maintenance costs (O&MC)

This phase is the longest phase, it reflects the expected service lifetime of the project. Griffin 1993 cited in Dunston & Williamson (1999) assumed that operation phase would consume 50% - 80% approximately from the total time of the structure. This phase includes costs required to operate, repair and maintain the project. For instance, energy cost, labour costs, spare parts and transportation cost (Shtub, Bard & Globerson 2005). The main contributors in this phase are: energy consumption cost (40%) and maintenance cost (23%) (Cuéllar-Franca & Azapagic 2013). Eq. (4) presented by Cuéllar-Franca and Azapagic (2013) illustrated that costs of 'use stage' (C_U) considers costs of energy (C_E), water and wastewater (C_W) and maintenance (C_M). Taking into account the economic histories of homogeneous buildings is paramount to assess the worth of associated costs in operating phase (Zeynalian, Trigunarsyah & Ronagh 2013).

$C_U = C_E + C_W + C_M$ ……………………………………………………….……Eq. (4)

After studying the effect of 'running phase' Cuéllar-Franca and Azapagic (2013) deduced that operation and maintenance phase represented more than 50% of the total life cycle costs and energy costs contributes in almost half of this cost.

2.3.3. Demolition cost (DC)

Termination phase is the end of the project's life after long operation period and useless or so expensive maintenance. Cuéllar-Franca and Azapagic (2013) segregated this cost in details and concluded that majority of termination costs extracted from labour costs to demolish the project.

CHAPTER 3:
FINANCIAL ANALYSIS AND LCCA METHODS AND MODELS

3.0. Overview

This chapter aims to give a comprehensive account to the importance of economics and its effect on construction costs. Economic components like interest rate, discount rate and inflation have immense influence on analysis. Methods of LCCA such as net present value, annual uniform cost, internal rate of return and payback method is explored. Then, LCC models are presented in brief. Furthermore, procedures of LCCA, sensitivity analysis, reliability and risk management are generally illustrated.

3.1. Financial Analysis Principles

This section deals with economic factors that have enormous effect on analysis and it is related to the economy of the country. From year to year and from country to country, inflation, interest and discount rate are fluid.

3.1.1. Time Value Money

Evaluating projects over time has additional ambit by considering the value of money over time. The value of money now is not the same from ten years ago. It is paramount to consider same value of money in computing costs incurred at different intervals. In this context, the most critical parameters are time (duration of life) and interest rate (Shtub, Bard & Globerson 2005).

Common economic analysis symbols and terms (Hastak 2015, p. 81);

$P \ = Present\ value$

$F \ = Future\ value$

A = Annual amount or annuity

G = Uniform gradient amount

n = Number of compounding periods or asset life

$i = Intrest\ rate$

$S = Salvage\ value$

Formula Name	Operation	Symbol	Formula
Single Payment			
Compound Amount, Eq.(5)	P to F	(F/P, i%, n)	$F = P\ (1+i)^n$
Present Value, Eq.(6)	F to P	(P/F, i%, n)	$P = F\ (1+i)^{-n}$
Uniform Series			
Sinking Fund, Eq.(7)	F to A	(A/F, i%, n)	$A = F\ [\frac{i}{(1+i)^n - 1}]$
Capital Recovery, Eq.(8)	P to A	(A/P, i%, n)	$A = P\ [\frac{i(1+i)^n}{(1+i)^n - 1}]$
Compound Amount, Eq.(9)	A to F	(F/A, i%, n)	$F = A\ [\frac{((1+i)^n - 1)}{i}]$
Equal Series Present Value, Eq.(10)	A to P	(P/A, i%, n)	$P = A\ [\frac{((1+i)^n - 1)}{(\ i * (1+i)^n)}]$
Gradient Series			
Arithmetic Uniform Gradient Present Value, Eq.(11)	G to P	(P/G, i%, n)	$P = G\ [\frac{((1+i)^n - i * n - 1)}{(\ i^2\ (1+i)^n)}]$

Table 1: Standard formulas for economic analysis

(Hastak 2015, p. 81)

3.1.2. Interest Rate (i)

Interest rate is "the rate of which a company is charged in the capital markets for borrowing funds to finance capital projects, such as through sales of corporate bonds" (Hastak 2015, p. 80). Interest rate depends on two paramount factors: lender's long-term anticipation and expecting risk that may occur after lending the capital. Accordingly, interest rate can reflect the risk of lending the capital by summing inflation rate on long period and the rate of risk of the lender regarding a particular borrower (Hastak 2015).

3.1.3. Discount Rate (DR)

Discount rate is an interest rate that deals with future in order to calculate expected future cost or cash flow (Hastak 2015).

Discount rate is a vital component in the life cycle cost analysis Goh and Yang (2014).

Kshirsagar, El-Gafy & Abdelhamid (2010) tested sensitivity analysis corresponding to variance amounts of discount rates that proved that it has no effect on recurring costs and vice versa has a significant effect on non –recurring costs.

3.1.4. Inflation

Inflation rate is the reduction in purchasing power of dollar from year to year (Hastak 2015). Boussabaine and Kirkham (2004) monitored the risk of inflation rate if it were set extremely high or low than the expected future costs, which may show misleading results.

3.1.5. Rate of Return (ROR)

Rate of return depends on a hurdle rate that decides the decision of investing a project or in quick comparing between alternatives. This rate is calculated from the schematic cash flows. The higher ROR values more than the hurdle rate, the best chances to invest in a project (Hastak 2015).

In order to measure the profitability of any investment, return of investment (ROI) or it and return of asset (ROA) should be computed. ROI refers to the effectivity of the project. However, ROA is considered as an evaluation tool to measure the project's performance (Hastak 2015).

Buys, Bendewald and Tupper (2011) concurred that LCCA appears more efficient in energy consumption more than payback technique. Consistent to this Hastak (2016), who confirms that payback technique is inaccurate due to unconsidered cash flows, benefits and costs beyond the payback period.

3.1.6. Net Profit Margin

Net profit margin is defined as a fraction of net income over a total revenue of the project as shown in Eq. (12) (Hastak 2015, p.25). Net Income is calculated after considering taxes and execluding exceptional items.

$$Net\ Profit\ Margin = \frac{Net\ Income}{Total\ Revenue} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (12)}$$

3.1.7. Return of Asset (ROA)

Return of asset is simply the return income of the project, which reflects the reality of whether the investment is worthy or no. Eq. (13) and (14) represents the ROA (Hastak 2015, p.25).

$$Return\ of\ Assets = Net\ Profit\ Margin \times Asset\ Turnover \times 100\% \ldots \text{Eq. (13)}$$

where;

$$Asset\ Turnover = \frac{Total\ Revenue}{Total\ Assets} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (14)}$$

There are many economic analysis techniques, which are mainly used to contrast between diverse alternatives. Economic analysis techniques are “net present value, capitalized cost, annual cash flow analysis, rate of return analysis, benefit-cost ratio analysis and payback period” (Hastak 2015, p. 80). These techniques are evaluating the output of the investment with referring to time value of money except payback technique.

3.2. Methods of Life Cycle Cost

Hereafter, we will focus only on the most popular methods, which are net present value, equivalent uniform annual cost/benefit, rate of return, and benefit-cost ratio analysis.

3.2.1. Net Present Value (NPV)

Net Present Value is defined as a tool to measure “the value in today’s dollars of its implementation over the specified timeframe” (Buys, Bendewald & Tupper 2011, p.

543). Positive NPV means a profitable measure. Also, the lower NPV is desirable when considering cost only, but if benefit is considered, then the highest NPV is more preferable (Hastak 2015).

It is however, important to note some NPV features. Computing NPV facilitates understanding life cycle cost/benefits for each alternative (Afshari, Nikolopoulou & Martin 2014). It is used as a tool to compare between different alternatives (Kshirsagar, El-Gafy & Abdelhamid 2010; Ates 2015).

Gardiner and Stewart (2000) applied NPV as a control mechanism tool that can rank alternatives economically. In addition, instead of measuring project success by delivering projects on time, to budget and of the required quality, Gardiner and Stewart (2000, p. 254) suggested delivering project according to the "best achievable NPV and to the required quality".

NPV can be computed from investment cost (C), replacement cost (R), resale value (S), annually recurring value (A) and maintenance (M), repair and non-annually recurring cost as shown in Eq. (15), adapted from Kaufman and cited in Kshirsagar, El-Gafy and Abdelhamid (2010, p. 165):

$NPV = C + R - S + A + M$ ……………………………………..……………….Eq. (15)

The NPV is the best convenient method in construction industry when applying LCCA approach (Kshirsagar, El-Gafy & Abdelhamid 2010).

3.2.2. Equivalent Uniform Annual Cost (EUAC) or Benefit (EUAB)

This method is applied upon a comparison based on annual cash flow is required (Hastak 2015). Besides, Equivalent annual cost has the advantage of comparing alternatives that have various lifetimes (Ammar, Zayed & Moselhi 2013).

3.2.3. Internal Rate of Return (IRR)

Return of investment (ROI) it called also, internal rate of return (IRR) (Buys, Bendewald & Tupper 2011). Return of investment is a tool to express cash flow and investmen analysis in a monetary invested unit. Productive investment shows high ROI (Hastak 2015). ROI can be computed from Eq. (16) (Hastak 2015, p.25);

$$ROI = \frac{[\,(Profit = (\,Project\ Output) - Project\ Costs\ (Input)]}{Project\ Costs\ (Inputs)} = x\% \text{ ………………….. Eq. (16)}$$

The ROI is a rate of return used to compare profitability of investments. If the ROI is greater than the owner's stated discount rate, the measure is beneficial (Buys, Bendewald & Tupper 2011).

Kshirsagar, El-Gafy and Abdelhamid (2010) adapted a comparison between NPV, EUAC and IRR and explained the main purpose of each method, benefits and limitation. This comparison was used to decide the appropriate LCCA method.

3.2.4. Payback Method

Calculation of simple payback necessitates less effort than LCCA that has one additional step to compute business-as-usual costs at base time (Buys, Bendewald and Tupper 2011). Simple payback is calculated from Eq.(17) (Shtub, Bard & Globerson 2005):

$$Payback\ Period = \frac{initial\ investment\ (P)}{annual\ net\ undiscounted\ benefits(B_j)} \text{ ………………………Eq.(17)}$$

where, B_j is the annual net benefit in year i.

Drawbacks of applying payback method is basically due to discarding the condition of the product at the baseline which leads to other costs such as maintenance and replacement costs (Buys, Bendewald and Tupper 2011).

3.3. Life Cycle Cost Models

As stated by Farr (2011) and cited in Sloan et al. (2014), the trajectory of cost modelling is divided into mathematical model and simulation model. The framework of cost modelling is represented in Figure (9).

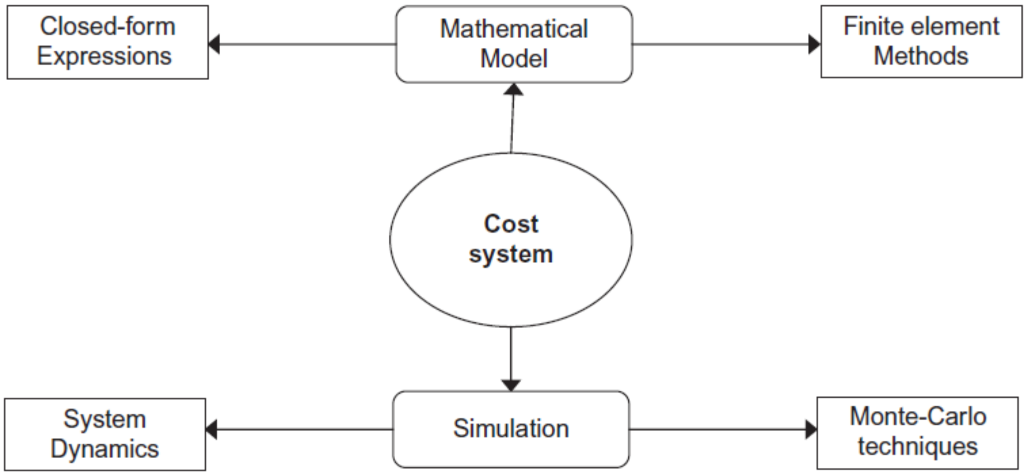


Figure 9: Paths to cost modelling

(Farr 2011, cited in Sloan et al. 2014)

3.3.1. Finite Element Algebric

Applying finite element technique in building and construction field is rarely employed although it contributes in hastening substantial and accurate analysis (Farr 2011, cited in Sloan et al. 2014).

Sloan et al. (2014) conducted a comparison between finite element method and Monte Carlo simulation analysis. Comparison affirms that cost values from both techniques are approximately same and relationships between parameters are approximate and not clear.

3.3.2. Monte Carlo Simulation Analysis

Monte Carlo simulation (MCS) is a technique that can dominate variables (Tesfamariam & Sanchez-Silva 2011), by investigating statistical characteristics (Choi, Oh & Seo 2012).

The equivalent uniform annual cost (EUAC) is calculated by implementing fuzzy-based LCC and simulation-based LCC models and results show consistent findings (Azeez, Zayed & Ammar 2013). Randomization is a key feature at Monte Carlo simulation technique that is pertain to discount rate (Sloan et al. 2014).

3.3.3. Fuzzy Based Life Cycle Cost Model

A fuzzy-based life cycle cost model manages vague and deficient knowledge of input data, which reflects the reality of any construction project (Ammar, Zayed & Moselhi 2013).

A structured approach for improving a model of VE computerized expert system was studied by Naderpajouh and Afshar (2008) which implements a fuzzy decision support system (DSS) at the evaluation phase by ranking ideas.

The Day–Stout–Warren (DSW) algorithm and vertex method were employed by Ammar, Zayed and Moselhi (2013) to improve LCC model to a fuzzy-based LCC. This technique allows depicting convex fuzzy set, by managing various numbers of α-intervals. This approach allows analysing LLC of any alternative by employing the equivalent uniform annual cost ($\mathrm{E\widehat{U}AC}$). Azeez, Zayed and Ammar (2013) slightly change in previous equations by neglecting salvage values (SV), not discounting annual costs ($\widehat{\mathrm{A}}\mathrm{C}$) and discounting future cost ($\widehat{\mathrm{F}}\mathrm{C}$) two times as a present value then along service life of the alternative.

3.4. LCCA Procedures

ASTM International (2013, p. 1) established “a procedure for evaluating the life-cycle cost (LCC) of a building or building system and comparing the LCCs of alternative building designs or systems that satisfy the same functional requirements”. Fig. (10) identifies simply the life cycle costing procedures.

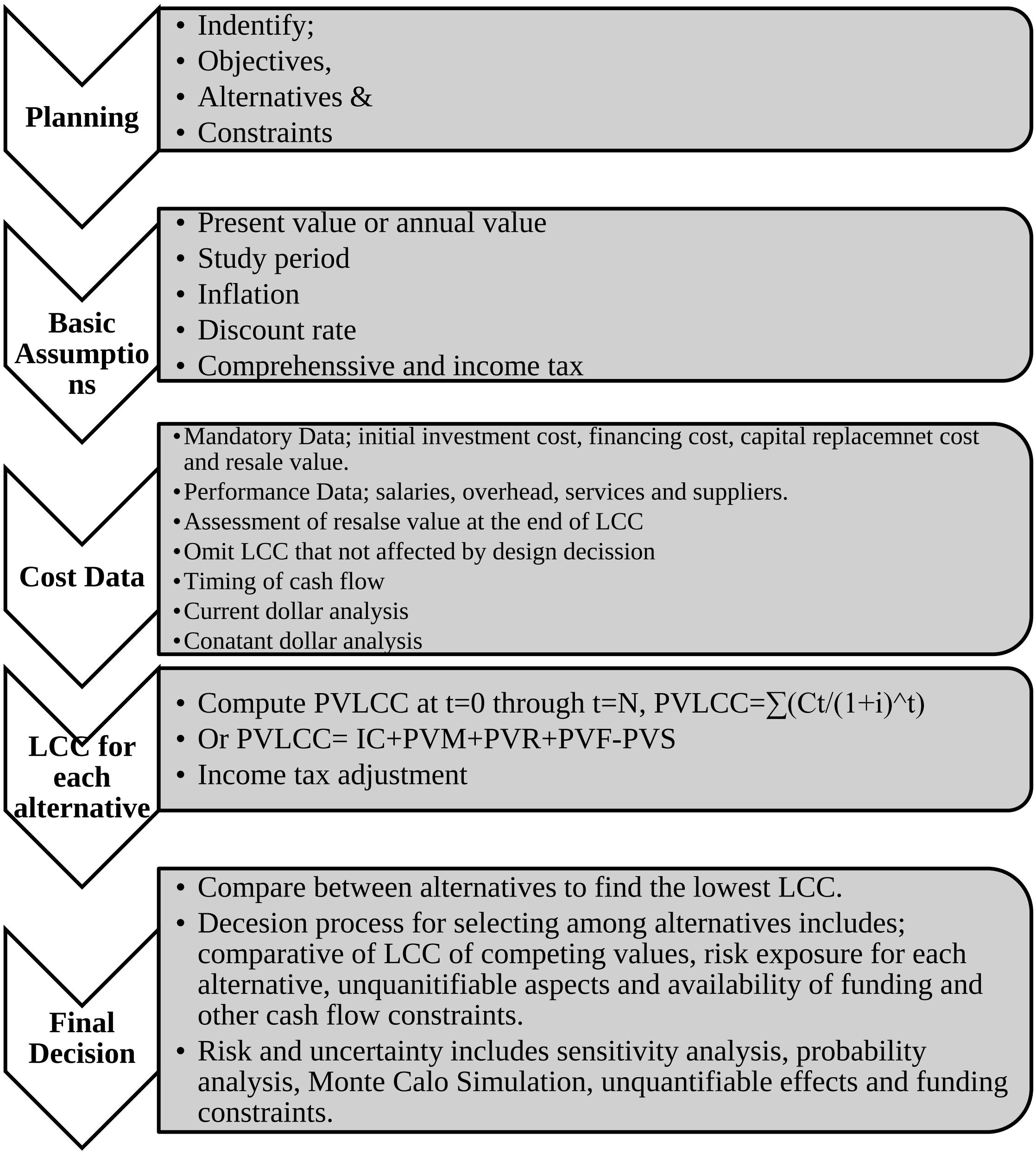


Figure 10: LCCA procedures

(Adapted from ASTM International 2013)

3.5. Life Cycle Cost Analysis Software and Applications

Shin and Cho (2015) applied LCCA in building information modelling (BIM) approach by following several steps. First step was pinpointing the aim of the study by generating and assessing alternatives that have same performance with minimal cost. Secondly, some important parameters were assumed such as analysis period, discount rate, initial cost, operation cost and other related costs and the required time for each stage. Thirdly, for each alternative, life cycle costs were counted. Finally, and in order to estimate the financial feasibility study, Shin and Cho (2015, p.2) computed some indices like “net saving, saving to investment ratio and payback period”.

Furthermore, Matlab as a computational program and Energy Plus as an energy simulation program were linked and used by Kim and Kang (2016) at an integrated LCC optimization technique that allows project managers to compare between buildings based on energy optimization model or cost optimization model.

3.6. Risk, Uncertainty and Reliability

3.6.1. Risk Management

Zeynalian, Trigunarsyah and Ronagh (2013) directed a research of apprising technical and mangerial expected failure risks over the life cycle of a typical two-story residential building in Iran. Taking into account all expected life cycle failure risks enhance the precision of risk analysis and management model results. In order to deffereniate between alternatives, Zeynalian, Trigunarsyah and Ronagh (2013) implemented Delphi Method to build a decission after conducting questionnaires for local experts. A structure of life cycle failure risks is represented in Fig. (11) (Zeynalian, Trigunarsyah and Ronagh 2013, pp. 54 cited in Pate-Cornell 1984).

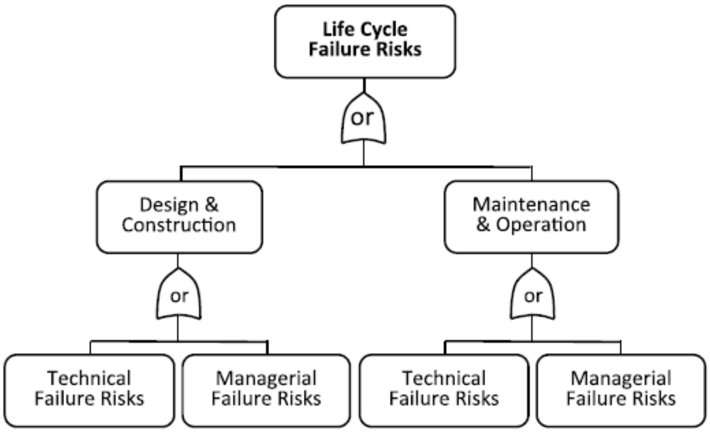


Figure 11: Fault structure of life cycle failure risks

(Zeynalian, Trigunarsyah and Ronagh 2013, pp. 54 cited in Pate-Cornell 1984)

3.6.2. Sensitivity Analysis

Sensitivity analysis is a study that aims to study the effect of variability of the main input parameters, which assist in realizing data evaluation. Tesfamariam & Sanchez-Silva (2011) have used a sensitive analysis to measure the effect of various building performance on LCC. Results of sensitive analysis show that construction quality has the most impact on LCC; however, plan irregularity was the lowest impact. Sensitivity analysis carried out by Aktas and Bilec (2012) to identify from the model's output, the greatest impact between variables. Shin and Cho (2015) concluded that sensitivity analysis reflects a reliability aspect to a study of LCCA.

Goh and Yang (2014) have applied LCCA in infrastructure project by investigating sustainability-related cost in highway investments and applying LCCA as a long-term financial strategy. They relied upon fuzzy analytical hierarchy process as a qualitative approach and LCCA as a quantitative approach to assist in making decision and analysing sensitivity parameters.

Kshirsagar, El-Gafy and Abdelhamid (2010) persued sensitivity analysis in order to keep track of selecting discount rate and its influence on LCCA outcomes. It was recommended to add sensitivity analysis after LCCA as an indicator to an obvious impact on LCCA results and accordingly decision making after that.

Azeez, Zayed and Ammar (2013) tested sensitivity analysis by applying Crystal Ball software. Results show that discount rate is the most sensitive parameter comparing to unit costs and service life. On the other hand, Karim, Magnusson and Natanaelsson (2012) realised that the most sensitive factors are the highest rank correlation coefficient.

A sensitivity analysis needs a quantity of trials and numbers to build a range of data for proper testing (Minne & Crittenden 2014). Minne and Crittenden (2014) studied the effect of considering maintenance during the use phase upon the life cycle of the residential flooring options of carpet, hardwood, linoleum, vinyl and ceramic. Study derived its results after looking for environmental and economic effects on various flooring types. It has been concluded that considering maintenance can create an environmentally and economically difference which leads to increase the expected performance and increasing the service life of the flooring.

3.6.3. Reliability

Elmakis and Lisnianski (2006) presented in Fig. (12) the relationships between costs and reliability over time. It has been noticed that reliability of acquisition cost is increased over time and the diverse happened in operation and support cost. The summation of acquisition curve and operation and support curve is the life cycle cost curve. The lowest LCC represents the optimal system reliability at the intersection of other two curves.

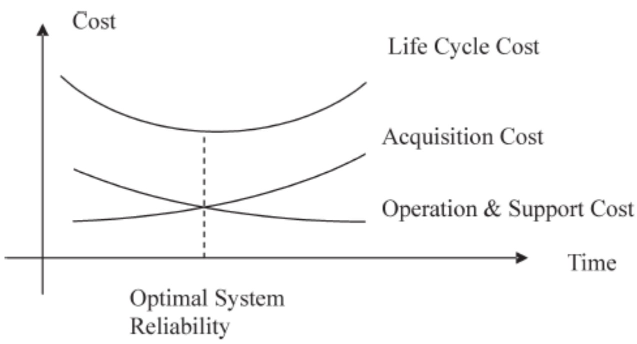


Figure 12: LCC of System reliability over time
(Elmakis & Lisnianski 2006, p. 7)

CHAPTER 4:
VALUE ENGINEERING

4.0. Overview

In 1960s, U.S. Government launched applying the earned value management as a monitor and control system to adjust project performance. They discovered the need of applying this system after the failure of U.S aircraft development, which led to a significant unexpected high cost and too long consumed time (Venkataraman and Pinto 2008).

4.1. Value Engineering (VE) Definition

Value engineering is defined as an organized and structured approach to increase project's performance through its life cycle with minimum costs. Analysis can promote process, design and construction projects, and business and administrative processes (International 2016). Also, it is defined as "a structured approach for identifying solutions that satisfy given needs with reduced costs" (Tang & Bittner 2014, pp. 130).

4.2. The need for VE and benefits

The best features at VE are its ability to solve problems by specialists and professionals VE team who incorporate to gather information and share skills, ideas and knowledge and expertise. In addition, VE helps stakeholders in making decisions (Tang & Bittner 2014).

4.3. VE Challenges

The significant importance of applying VE relies on function analysis and creativity generated by a numerous experts in many disciplines based on their construction experience, knowledge and engineering background (Naderpajouh & Afshar 2008; Kim, Lee & Hong 2016).

4.4. VE Case Studies

Kim, Lee and Hong (2016) applied VE technique in a roadway expansion project on a soft ground layer about 50 m thick in order to compare between cost-effective designs alternatives through an organized VE process. VE technique allows authors to examine alternatives based on cost saving, function improvement and value improvement toward original design.

In Singapore, Hwang, Zhao and Ong (2015) explored the crucial success factors for VM and estimated the potential risk factors by implementing value management (VM) in building projects. This investigation shows that VM implementation is proportional affected by the project size not nature or type. After a statistical survey collected from contactors besides, the VM success factors are ranked as follow; “communication and interaction among participant”, “clear and unambiguous objectives of VM” and in the third rank “appropriate risk allocation and management” and “education of VM” (Hwang, Zhao & Ong 2015, p.04014094-5). Furthermore, authors have ordered the most critical risk factors on VM implementation which are: “inadequate experience in VM,” “delay in approval and permits,” “communication risk,” “lack of commitment of project parties,” and “inability to adapt to changes” (Hwang, Zhao & Ong 2015, p. 04014094).

The Royal Commission in Jubail, Saudi Arabia applied value engineering to modify number of main roads for ornamentation goals. Eleven alternatives have been created at the creative phase after defining objectives at information phase and answering question at function phase. Due to several factors, alternatives were ranked and eliminated by applying an appraisal matrix. Results came up with the most suitable option and a saving $600,000 comparing to the original cost (Assaf, Jannadi & Al-Tamimi 2000).

4.5. VE Phases and Steps

Comprehensive valuation procedures are adopted by dividing value engineering job plans into three levels; pre-study, VE-study, and post-study. Pre-study or preparation stage covers gathering information, calibrating user needs and deciding targets. VE-study or analysis level includes analysing functions and extracting ideas. The final stage of post-study and execution stage consists of evaluating selections and analysing results (Choi, Oh & Seo 2012).

Tang and Bittner (2014) have developed a VE process consists of 7-steps which are; (1) collecting information, (2) shortening unnecessary functions, (3) creating solutions, (4) examining solutions, (5) electing and providing solutions, (6) displaying solutions and (7) observing the solution executing process. Authors have stated an encouragement tool to stimulate Contractors to apply VE technique, which is by sharing cost savings between Owner and Contractor.

VE job plan phases and tasks are described by Kim, Lee and Hong (2016) in Fig. (13).

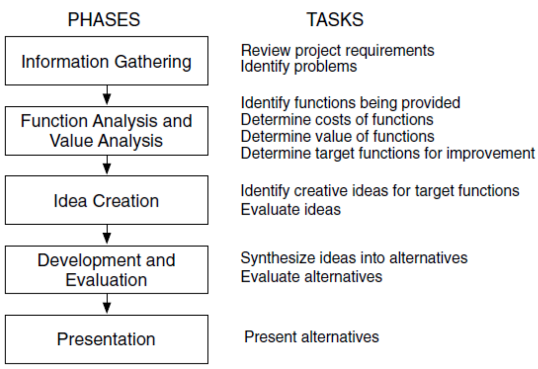


Figure 13: VE job plan phases and tasks

(Adopted from Kim, Lee & Hong (2016), pp. 05015014)

At the function analysis and value analysis phase, Kim, Lee and Hong (2016) applied function analysis system technique (FAST) to explain How-Why dimension to generate functions then select the basic functions. In addition, they implemented the decision alternative ratio evaluation system (DARE) law to set the value weight distribution. Function analysis system technique (FAST) can be used effectively during early VE sessions to classify project's functions (Naderpajouh & Afshar 2008).

4.6. VE Function

Value improvement is measured by function augmentation or cost reduction, or both, based on Eq. (18) (Dell'Isola 1973, 1997 & Lee et al. 2010 cited in Kim, Lee & Hong 2016, pp. 05015014):

$$\text{Value Improvement} = \frac{\Delta\,\text{Function}}{\Delta\,\text{Cost}} \quad \text{..Eq.(18)}$$

where, Δ Function = function differences to the original design, Δ Cost = cost differences to the original design.

The final decision in comparing between alternatives in order to examine value improvement was adopted by Kim, Lee and Hong (2016) based on Eq. (19).

$$\text{Value Improvement} = \frac{\text{Function Improvement (FI)}+100\%}{\text{Relative Cost Ratio (RC)}+100\%} \text{.....................................Eq. (19)}$$

where, function improvement and relative cost ratio are calculated from tables in Kim, Lee and Hong (2016) study.

The graph number (14), presented by Younker cited in Ren & Shan (2014, p. 2), indicates the relationship between costs and function. C_1 represents initial cost, C_2 represents costs of use stage. VE is applied by finding the minimum cost from the optimum point of function.

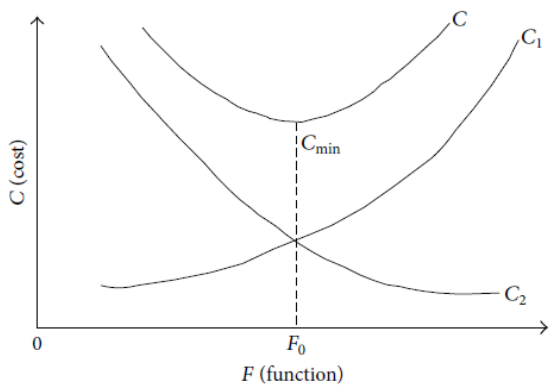


Figure 14: Relationship between function and cost

(Younker cited in Ren & Shan 2014, p. 2)

A structured approach for improving a model of VE computerized expert system was studied by Naderpajouh and Afshar (2008), using Borland Delphi 7.0, which implements a fuzzy decision support system (DSS) in the evaluation phase. This framework can be productive tool for construction problems that need hierarchical retrieved information from previous knowledge and look for contrasting between alternatives.

CHAPTER 5: METHODOLOGY

5.0. Overview

The purpose of this chapter is to organize the research methodology of this dissertation to study, analyse and evaluate buildings due to their life cycle cost using net present value and value engineering. These two concepts were extensively discussed at the literature review, which has been extracted from the latest academic journals and books. Literature review explores how LCCA and VE can be applied to assist stockholders and projects mangers in making decisions.

Based on the approach presented in literature review, the purpose of this research methodology are to (1) depict the applied research methodology, (2) illustrate the required data and available database for the analysis, (3) explicate the followed LCCA procedures in this research, (4) explain challenges, (5) describe the applied software, (6) analyse data by implementing LCCA approach, (7) compare LCC results, (8) and to test the validity of the results by applying sensitivity analysis.

5.1. Research Methodology

An explanatory mixed method was followed through collecting quantitative data before qualitative data in order to address and explain quantitative data efficiently and deliberately. In other words, mixed methods allow quantitative results to support qualitative results.

Quantitative method suits “deductive approaches” where “theory or hypothesis justifies the variables, the purpose statement, and the direction of the narrowly defined research questions” (Borrego, Douglas and Amelink 2009, p.54). Therefore, descriptive statistics, investigating variables relationships’ and applying the theory are the main objectives of adopting quantitative method. By same nature, this study examines different costs through the building life cycle. Qualitative method was used because it “focuses on smaller groups in order to examine a particular context in great detail” Borrego, Douglas and Amelink (2009, p.57).

This research aims to answer the following questions for comprehensive understanding and practicing LCCA and VE in projects.

- What is the average of the total life cycle cost for residential buildings in Al Ain per floor area?
- How far does the difference in LCC in Al Ain to UK?
- How LCCA can be calculated using Microsoft Excel 2010?
- What are the benefits of applying sensitivity analysis after the NPV?
- How can VE contribute in NPV?

5.2. Data and Data Base

Life cycle cost was calculated based on two different sets of data for new buildings and for old buildings. This study divides buildings life span into two categories. The first category describes 'New Buildings', with a current age of ten years or less. The second category represents 'Old Buildings', with a current age ranges between 20 – 30 years.

'New Buildings' data was collected from the databases of Abu Dhabi Commercial Engineering Services L.L.C. (ADCE) and Abu Dhabi Commercial Properties L.L.C. (ADCP) the partners of Abu Dhabi Commercial Bank (ADCB). The Author could access the databases after obtaining permissions easily from both departments because the Author works in the same organisation. Data was collected with preserving confidential information of publishing owners' names and projects' location and any identification data. Therefore, Author tailored the life cycle costing process based on the ADCE and ADCP procedures.

New buildings data includes building typology, number of units, detailed description of the units, plot area, residential area, built up area, evaluation date, start date of operation, initial cost, maintenance cost and income cost.

'Old Buildings' data was collected from a survey. A survey was conducted in order to collect a sufficient number of samples at the second category. A number of 32 local property owners were asked about their properties such as: building typology, number of residential units, building age, plot area, initial cost, maintenance cost, type of AC used, type of lighting used and the approximately income. As shown in Appendix I, a survey for 'old buildings' and the survey's results. Results were converted into numbers directly in order to start testing and analysing data. Property owners were asked either at the researcher workplace or from property owners known by researcher's father who lives in Al Ain for more than 30 years and knows many nationals who has assets. Survey questions were selected to be simple, clear and easy to understand. Thus, questions are created to be straightforward.

A sample of thirty projects is the minimum required number of samples that can draw the normal distribution (Chang, Huang & Wu 2006). For new buildings, a sample of 60 projects have been selected and examined from ADCE and ADCP databases. While, the second category only a sample of 30 projects were collected.

The economic service life of the residential investment buildings in Al Ain is approximately 30 to 35 years. We assumed that the service life of this study equals to 35 years. In past few decades, and due to the poor raw materials and workmanship the actual service life of buildings in the UAE was approximately from 20 to less than 30 years old only (Abdullah 2001).

The main required input data for LCCA are fundamental costs for building during its life cycle, building description, study period and some economic factors. Fundamental costs are expressed by initial cost (IC), operation cost (OC), and demolition cost (DC).

Initial or capital cost (IC) includes all costs required in design and construction phases. In design stage, it is required from the consultant to draw the concept design of the project and to do the advanced design. Advanced design includes obtaining all authorities approvals for all his schematic of architectural, structural, electrical and mechanical drawings.

Operation cost (OC) is associated with any cost required to operate the building. OC in our study is divided into utility cost (UC) and maintenance and replacement cost (M&RC). UC consists of electricity cost (EC) and water cost (WC). Facility management cost is already included in the maintenance cost. M&RC includes civil works, mechanical works, electrical works and replacement cost (RC). Table (2) shows the scheduled plan for the expected materials need to be replaced at a certain point in the life cycle of the residential building.

Demolition cost (DC) contains any costs related to demolition stage such as costs required for authorities approvals, department of transport fines due to occupied car parking, required equipment fees, demolition waste transport fees and contractor fees.

Expected Replacement Material	Replacement Year	Cost (AED)
Civil Works		
GRP lining for Water Tank	30	25,000
External Paints	15	50,000
Water Mixers	15	500
MEP Works		
Water heater	10	750
Booster pump	10	10,000
Transfer pump	10	10,000
DX units & DX units-compressor	15	4000

Table 2: Expected replacement materials

5.2.1. Dealing with missing data:

Before starting LCCA calculations, researcher reviewed all mislaid data and found that demolition cost, electricity cost, water cost and old building data were missing. In view of this, we explained how we worked out these data and prepared it for further analysis.

5.2.2. Demolition cost (DC)

Author could not find demolition cost in ADCE databases. Therefore, investigations and interviews were conducted. Author has asked 30 engineers who are working in contracting, consulting and project management. Interviews were important in this stage because we found that there are huge differences in pricing demolition as a lump sum price. Interviews were conducted at the Author’s work place. Contractors, consultants who have sufficient experience and working in Al Ain and project managers working in ADCE had been asked about the total approximate demolition cost.

Interviews with different parties show different point of view. Monawar – ADCE Project Manager – believes that the demolition cost priced at the bill of quantities is not reflecting the truth and it is a profit item to the main contractor. Monawar said “the main contractor assigns this task to a special demolition cost subcontractor who offers every single straw for selling. Indeed, some demolition subcontractors pay money to earn such project”.

From another point of view, some contractors shared Monawar opinion and agreed that demolition cost does not cost too much and it may cost solely the authorities fees. However, some contractors refused to admit to this theory and translated their high prices to the numerous requirements requested by authorities. Hussain – a Contractor – refers the high price to the exposure degree of risk. When the building is located at the city centre, it requires more safety requirements to secure high density of passengers. Excavation has a part of risk also, if any service line found underground. “Probable risk factors increase the demolishing cost, especially to buildings at the city centre” Hussain. In addition, occupying parking fees in the city centre costs daily more than low-density areas.

Finally, we calculated the average demolition cost for each building typology. For buildings (G+1), (G+2), (G+3) and (G+4) demolition cost equals approximately AED (25,000), (40,000), (80,000) and (100,000) respectively.

5.2.3. Electricity cost (EC)

Electricity cost is a cost that is consumed by each tenant. Therefore, ADCP does not have such information. Researcher estimated EC from assuming electricity consumption in the building based on the installed type of air conditioning system and lighting system. Therefore, from the approximate knowledge of electricity consumption, we estimated the electricity cost. RSB has announced that the most two contributors affecting the electricity consumption in the Emirate of Abu Dhabi are air conditioning and lighting with a percentage of 70% and (10-15)%, respectively (Regulation & Supervision Bureau 2016).

On the other hand, Al Awadi (2014) has developed a research to test the relationship between lighting and HVAC consumption in a federal or an office building in the UAE. The output of the study revealed that “each 1KWH of Lighting energy equal 3 KWH of HVAC energy consumptions” (Al Awadi 2014, p. 123).

In this regard, short interviews were conducted with mechanical and electrical project managers working in ADCE to ask about the actual electricity consumption for air conditioning and lighting systems in new and old buildings. For new buildings constructed under the supervision of ADCE, AbouMayye – Senior Electrical Engineer - said “the most common installed types of AC were mixed of split units, variable refrigerant flow (VRF) system and chillers”. We excluded chillers from our comparison based on Al Jamal – Senior Mechanical Engineer – recommendation because he advised that chillers have the lowest capacity and it will not be fare comparison with other types. However, we assumed that fluorescent lamps were installed for old buildings and light-emitting diode (LED) was installed for new buildings. From the interview conducted with MEP engineers in ADCE, a general assumption for AC and lighting consumptions were estimated as shown in Table (3).

	New Buildings		Old Buildings	
	Type	Average Rate of consumption	Type	Average Rate of consumption
Air Conditioning	VRF or Split units	65 w/h/m2	Window or Split units	100 w/h/m2
Lighting	LED	12 w/h/m2	Fluorescent Lamps	25 w/h/m2

Table 3: Electricity assumptions for AC and lighting in new and old buildings

(Al Jamal, Aboumayye & Alkhomos 2016)

Researcher calculated the electricity cost based on the tariff of charges published on 1st January, 2016 by the ADDC and AADC (Abu Dhabi Distribution Company & Al Ain

Distribution Company). Electricity unit cost of price per KWh is presented in Table (4). The government subsidies electricity consumption up to a specific limit (green consumption) after that supplies electricity in high rates (red consumption). In our study, we considered the actual cost of electricity for expatriates solely. Emirati citizens who live in the Emirate of Abu Dhabi are 536,741 people, while 1,443,837 people are non-citizens. The majority of population of around 75% in the Emirate of Abu Dhabi are non-citizens (Statistic Centre - Abu Dhabi 2016). Therefore, researcher assumed that all the tested residential units were for non-citizens or expatriates, as this represents the real costs of energy. To find the actual electricity cost with the minimum subsidizing by the government.

Customer	Property	New tariff (fls/KWh)	Average Daily Consumption (KWh/day)
National	Flat/Villa	5	Up to 30/400
		5.5	Over 30/400
Expat	Flat/Villa	21	Up to 20/200
		31.8	Over 20/200

Table 4: Electricity tariffs for Nationals and Expatriates in 2016

(Al Ain Distribution Company & Al Ain Distribution Company 2016)

On the other hand, researcher assumed that electricity cost would increase due to time by a specific electricity escalation rate. This rate has been calculated from the rates of 2014 to 2017. Electricity escalation rate is the slope of the average rate as shown in Table (5) and Fig. (15).

Electricity Escalation Rate				
Year	2014	2015	2016	2017
Up to limit (fls/KWh)	15	15	21	26.8
Over limit (fls/KWh)	15	21	31.8	30.5
Average (fls/KWh)	15	18	26.4	28.65

Table 5: Electricity escalation rates in Al Ain

(Al Ain Distribution Company & Al Ain Distribution Company 2016)

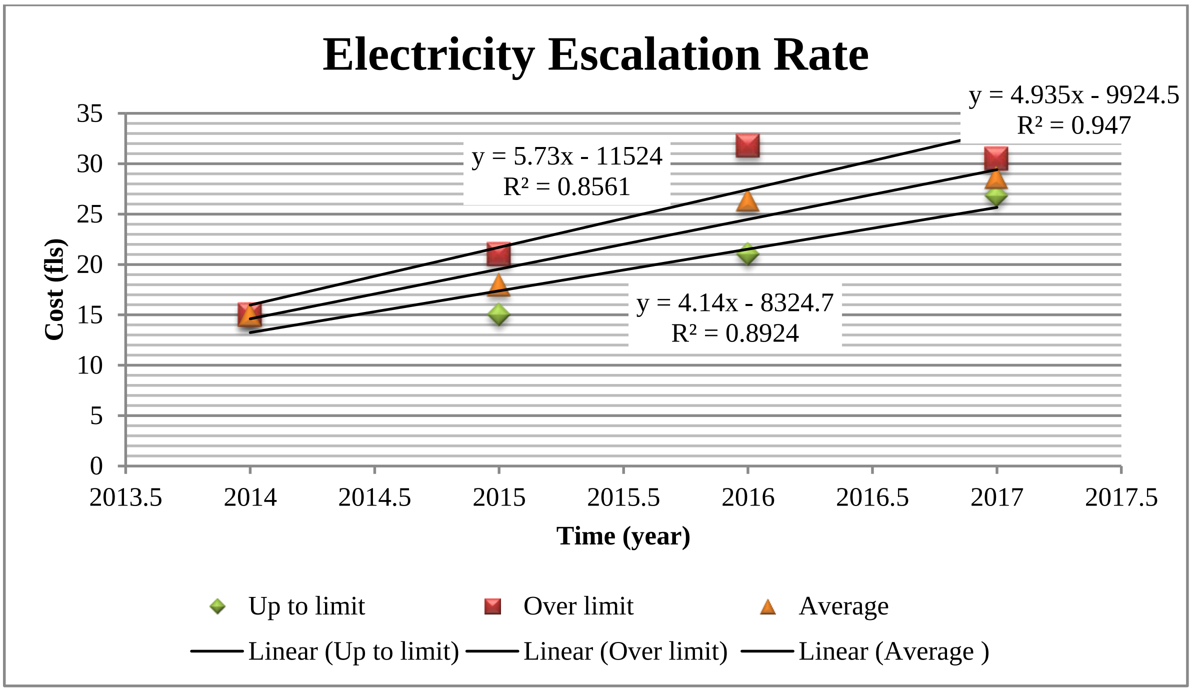


Figure 15: Electricity escalation rates in Al Ain

In order to compute the electricity consumption for each residential unit, we calculated electricity consumption based on the built up area and the electricity consumption. We calculated AC and lighting consumption from Eq. (20).

$$\text{AC/Lighting consumption}\left(\text{K.}\frac{\text{w}}{\text{yr}}\right) = (\text{Built Up Area}) * (\text{AC/Lighting cons.}) * (\text{No. of working hrs}) * 30.5\ \text{d} * 12\text{m} \quad \text{……Eq. (20)}$$

where: Built up Area = Gross Area in square meter, AC/Lighting cons. = Consumption estimated from Table (3), No. of working hours = Working hours agreed in Table (3), d = number of days and m= number of months.

After computing AC and lighting consumption from Eq. (20), we calculated the electricity cost from Eq. (21).

$$\text{Electricity Cost (AED)} = (\text{Green Consumption} * \text{Green tariff of charges}) + (\text{Red Consumption} * \text{Red tariff of charges}) \quad \text{……Eq. (21)}$$

5.2.4. Water cost (WC)

In order to estimate the approximate WC in a building, Researcher obtained information from the RSB assumptions for residential flats based on number of bedrooms in each unit (Regulation and Supervision Bureau, 2009). Table (6) shows the rounded water consumption per day. Based on the type of units in each building, we multiplied the rounded water consumption by the number of days at a year in order to calculate the total water consumption in Lit/year as shown in Eq. (22). After computing water consumption from Eq. (22), we calculated the electricity cost from Eq. (23).

$$\text{Water Consumption } \left(\frac{\text{Lit}}{\text{yr}}\right) = \text{ No. of Each type of Flats} * \text{Correspond Round Water Consumption} * 365 \quad ..\text{Eq. (22)}$$

$$\text{Water Cost (AED)} = (\text{Green Consumption} * \text{Green tariff of charges}) + (\text{Red Consumption} * \text{Red tariff of charges}) \quad \ldots\ldots\ldots\text{Eq. (23)}$$

Type of Unit	Rounded Water Consumption in Liter/Day
Residential Units	
1 Bedroom	500
2 Bedrooms	820
3 Bedrooms	1000
4 Bedrooms	1250

Table 6: Expected water consumption in residential units

(Regulation and Supervision Bureau, 2009)

Researcher calculated the water cost based on the tariff of charges published on 1st January, 2016 by the ADDC and AADC (Abu Dhabi Distribution Company & Al Ain Distribution Company). Water cost is shown in Table (7).

Customer	Property	Tariff (AED/1,000 liters)	Average Daily Consumption (liters/day)
National	Flat/Villa	1.70	Up to 700/7000
		1.89	Over 700/7000
Expat	Flat/Villa	5.95	Up to 700/5,000
		10.55	Over 700/5,000

Table 7: Water tariffs for Nationals and Expatriates in 2016

(Al Ain Distribution Company & Al Ain Distribution Company 2016)

Similarly, researcher assumed that water cost would increase due to time with by a specific water escalation rate. Rates were calculated based on published rates from 2014 to 2017. Water escalation rate is the slope of the average rate as shown in Table (8) and Fig. (16).

Water Escalation Rate				
Year	2014	2015	2016	2017
Up to limit (AED/1000Lit)	2.2	5.95	5.95	7.84
Over limit (AED/1000Lit)	2.2	5.95	10.55	10.41
Average (AED/1000Lit)	2.2	5.95	8.25	9.125

Table 8: Water escalation rates in Al Ain

(Al Ain Distribution Company & Al Ain Distribution Company 2016)

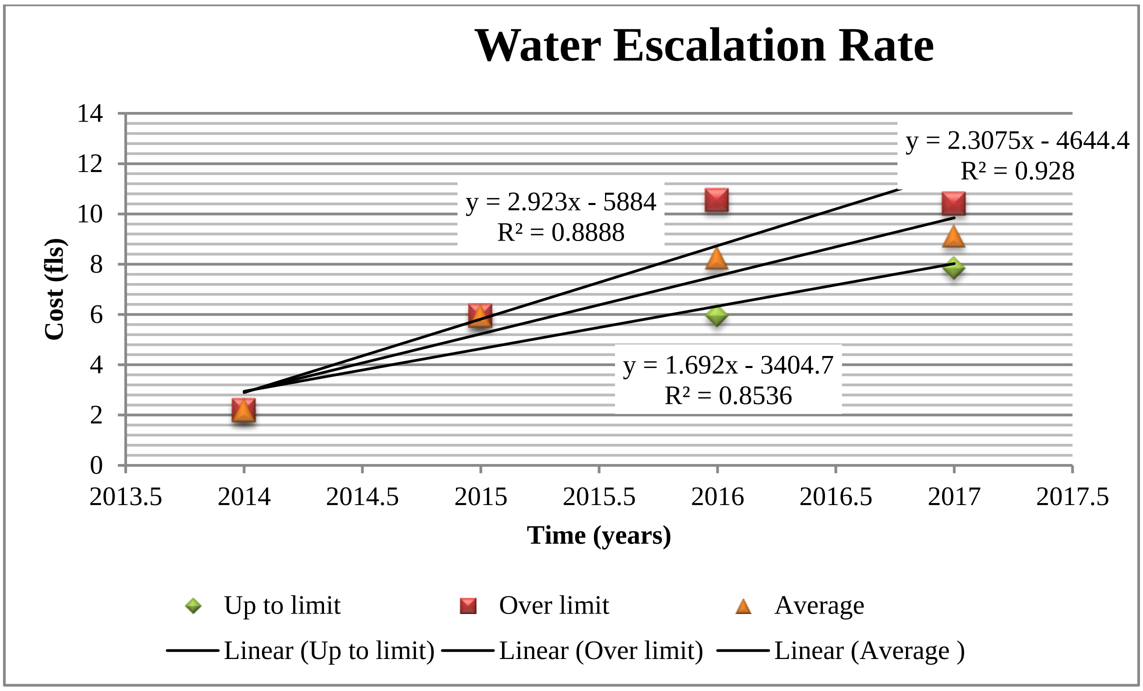


Figure 16: Water escalation rates in Al Ain

5.3. Life Cycle Cost Analysis Procedures

This section describes the LCCA procedures that were adapted from ASTM International (2013). The methodology of this research were applied the standard and followed same procedures that compatible to our case. LCCA procedures consist of main five steps, which are: classifying the study objective, alternatives and constraints assuming main assumptions in the study, combining all costs, computing life cycle costing and finally comparing LCCAs and decide the final decision. These procedures are illustrated in details in the following sections.

5.3.1. Define objectives, alternatives and constraints

The aim of this study is to study the total life cycle cost from 'cradle-to-grave'. This research examines new and old residential buildings in Al Ain, in the UAE. The 'Net Present Value' technique was selected to discount all costs to a present value cost then compile all these costs to find the total life cycle cost. After that researcher intents to emulate our results to a similar study in the UK.

This study will not deal with LCCA as a comparison tool to contrast between designs or material alternatives. In addition, no other type of buildings are included expect for residential use. Even retail or commercial units in the mixed used buildings were excluded from our study. Moreover, the effect of building location at the city is not considered. It is important also to know that no tax income fees were applied because the UAE government does not levy any taxes upon owning assets or investments.

5.3.2. Determine basic assumptions

General speaking, assumptions in an economic study has a notable influence and they were selected carefully. First of all, we assumed that the base time of this study is 2016 and the period of the study is 35 years for new buildings. Same study period is recommended to be applied at all LCCA comparisons (ASTM International 2013). For old buildings, it has been assumed that the average age of old buildings is twenty years. Therefore, researcher has calculated all costs before and after 20 years in order to calculate the NPV.

Secondly, some economic data are mandatory in the life cycle cost analysis like the general inflation rate and the discount rate. Based on ASTM International (2013) recommendation when no taxes are applied, it is easier to compute prices in a constant dollar. The second economic factor is discount rate. Calculating discount rate in our study is important to equal money spent at specified time in the future to money spent in today's prices. It is recommended to use the real discount rate when previous conditions are applied. The discount rate is calculated from the average interest rate of home loans for nationals offered from some of the national banks in the UAE. Thus, we found that the average interest rate is approximately 3.50% for nationals.

Thirdly, Author has calculated the average costs for each type of buildings in order to compute the sensitivity analysis for both new and old buildings.

5.3.3. Combined Cost Data

The paramount factor in compiling data is to combine data due to their right timing of cash flow. This research contains two types of cash flows; single cash flow and annual cash flow. Single cash flow occurs at a single point at the cash flow such as initial and demolition costs. While, annual or running cash flow occurs during a service lifetime such as maintenance costs, replacement costs, electricity cost and water costs.

5.3.4. Calculate LCCA

In order to calculate life cycle costs we converted each cash flow and cost to a present value and applied its suitable discount rate before summation all costs, as illustrated earlier in Eq. (6).

For single cash flow, and based on available databases, we uplifted the initial cost solely, while demolition costs are already collected according to the present value, so there is no need for adjustments. In addition, all running cost were computed at the current years and therefore no need to be discounted.

5.3.5. Compare LCCA and Make Final Decision

In this regard, we compared the LCC for new buildings with the LCC for old buildings in Al Ain, UAE over 35 years of economic service life. After that, another comparison were conducted between new buildings in the UAE and similar building in the UK. The lowest LCC shows the best preference.

ASTM International 2013 recommended not only to be aware of the lowest LCC, but also to beware of risk exposure, unquantifiable aspects and availability of cash flow constraints. Studying and determining risks and uncertainties are mandatory in comparing LCCAs from an investor point of view. It shows weak and hazard points in the investment.

Value engineering can be noticed after comparing results of old and new buildings. Especially, when comparing energy costs for new projects to old projects that used poor energy efficient appliances.

5.4. Sensitivity Analysis

ASTM International (2013) defined sensitivity analysis as “a test of the outcome of an analysis to alternative values of one or more parameters about which there is uncertainty”. Implementing sensitivity analysis in our research shows to the analysts what the most fundamental factors are. Some paramount factors can affect the results and guide the decision makers to the hot points in the analysis such as discount rates and study period. In addition, It helps decision makers to evaluate results based on level of sensitivity.

5.5. Applied software

All these data were gathered and analysed using Microsoft Excel 2010. A number of separated worksheets were prepared. Al Ain new and old buildings’ data were collected and prepared in two worksheets. A worksheet calculated initial cost, operation costs and demolition cost among the life cycle cost for each building. In addition, SPSS Statistics 17.0 which facilitates drawings histograms and normal distribution curves and analyses descriptive data in details.

5.6. Summary

This mixed research methodology strengthens the study because it mixes between quantitative and qualitative approaches with stressing on quantitative results as a priority of the study and qualitative results as a supplement to the research. This research assists project managers to calculate life cycle costing of projects and to apply value engineering that could expand project’s life span.

All costs required for computing the total life cycle cost were defined in this chapter in details. We applied the ASTM International (2013) as suits our case, data, and we applied all computational methods required for each case as recommended.

General speaking, initial and demolition costs are single present value. In our case we adjust only initial cost. While running cost like maintenance and utility costs were calculated as uniform present value.

CHAPTER 6:
RESULTS AND DESCUSSION

6.0. Overview

This section aims to present the results of this research. Results are described by analysing the life cycle cost for new buildings and old buildings in Al Ain. Then a comparison between new and old buildings was extracted. After that, a comparison between new buildings in Al Ain and similar study in the UK was prepared. In addition, sensitivity analysis for new buildings in Al Ain was examined. Finally, results and discussion were explored at the end of this chapter.

6.1. Pre-data Analysis

Buildings' samples are classified based on either building typology or types of units as shown in Fig. (17). As discussed earlier, buildings typology in Al Ain are categorized into buildings consist of ground floor and first or second or third or fourth floors and symbolized by (G+1), (G+2), (G+3) and (G+4) respectively. On the other hand, and in order to facilitate the types of units in Al Ain, we assumed that buildings are either apartments or villas.

Pre-data analysis is discussed in the sub-sections below by defining number of samples for each type of buildings as shown in Table (9). Then an induction about the average built up area for each type of buildings was discussed.

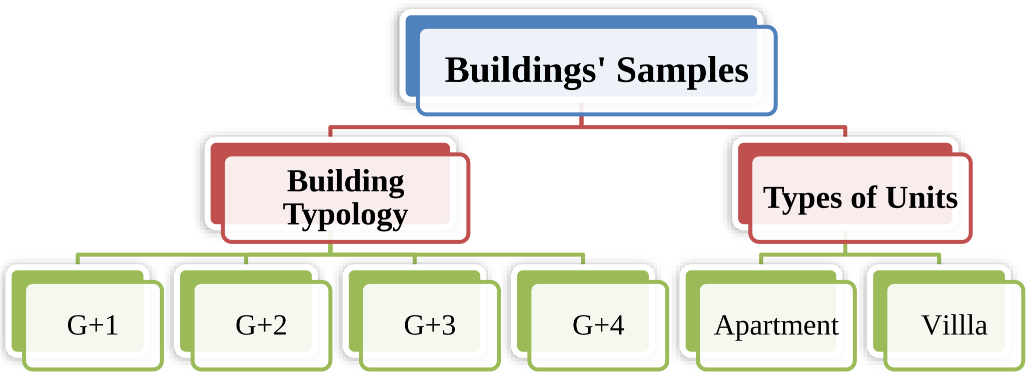


Figure 17: Categories of buildings' samples

6.1.1. Number of Samples (N)

Based on previous debate, new buildings data was extracted from ADCE and ADCP database. That is why we have 60 projects in this category. These samples were divided into 30, 4, 7 and 19 for (G+1), (G+2), (G+3) and (G+4) respectively. Therefore, we can say that (G+1) buildings indicates the best results. While (G+2) and (G+3) samples have very low number of samples and probability of error is more in these categories. However, (G+4) buildings do not reach to 30 samples, but at least can give reasonable indication better than (G+2) and (G+3) buildings.

On the other hand, the total number for old buildings is 32 projects. The majority of 14 projects are for (G+1) buildings whereas other types of buildings have 10 samples or less. We know that the number of samples is not enough to obtain reliable results, but collecting data for this category was a challenge for the Author. Table (9) shows all number of samples for new and old buildings in details.

	New Buildings	Old Buildings
G + 1	30	14
G + 2	4	5
G + 3	7	7
G + 4	19	6
Total	60	32

Table 9: Number of samples for new and old buildings in Al Ain

6.1.2. Built-up area (BUA)

BUA is defined as the overall horizontal area of slabs for all floors in a building construction and it is measured by square meters. BUA relies on the plot area and the regulation of each district or area at the city. As we explained earlier, each area has its own regulations and rules to determine the maximum allowable building’s height. As can be seen from Fig. (18), a histogram for each type of buildings is presented and includes the mean, the standard deviation and the number of samples for each type. Finally, the normal distribution curve was drawn to depict the BUA distributions.

Although, (G+1) buildings have well shape of normal distribution curve, it has a high standard deviation, which means that there is huge difference between high and low ranges of the BUA in this category. On the other hand (G+2) and (G+4) buildings have small standard deviations and means of 1460 m^2 and 2614 m^2. While (G+3) buildings have very discrete sample and it is not indicative. Author did not explain same graphs for the BUA for old buildings because BUA for old buildings were already estimated and deduced from new buildings data.

6.1.3. Number of bedrooms in each type of buildings

In order to estimate replacement cost in some items such as water heater and air conditioning units, number of units were estimated. We have assumed that the required number of water heaters and air condition from Eq. (24).

$No.of\ units = (n_1 B/R) * n_1 + (n_2 B/R) * n_2 + \cdots$ Eq. (24), where: $n_1 = No.of\ 1\ bedroom, n_2 = No.of\ 2\ bedrooms, B/R = bedroom.$

Number of units was estimated from the average units for all type of buildings as shown in Table (10).

	No. of 1 Bedroom	No. of 2 Bedrooms	No. of 3 Bedrooms	No. of 4 bedrooms	No. of Total units
G+1	1.60	8.43	1.17	0.10	11.30
G+2	-	-	2.75	2.00	4.75
G+3	10.00	6.40	2.40	0.40	18.00
G+4	6.50	9.13	0.81	-	16.44

Table 10: Number of units for each type of buildings

Built-Up Area Histograms for New Buildings

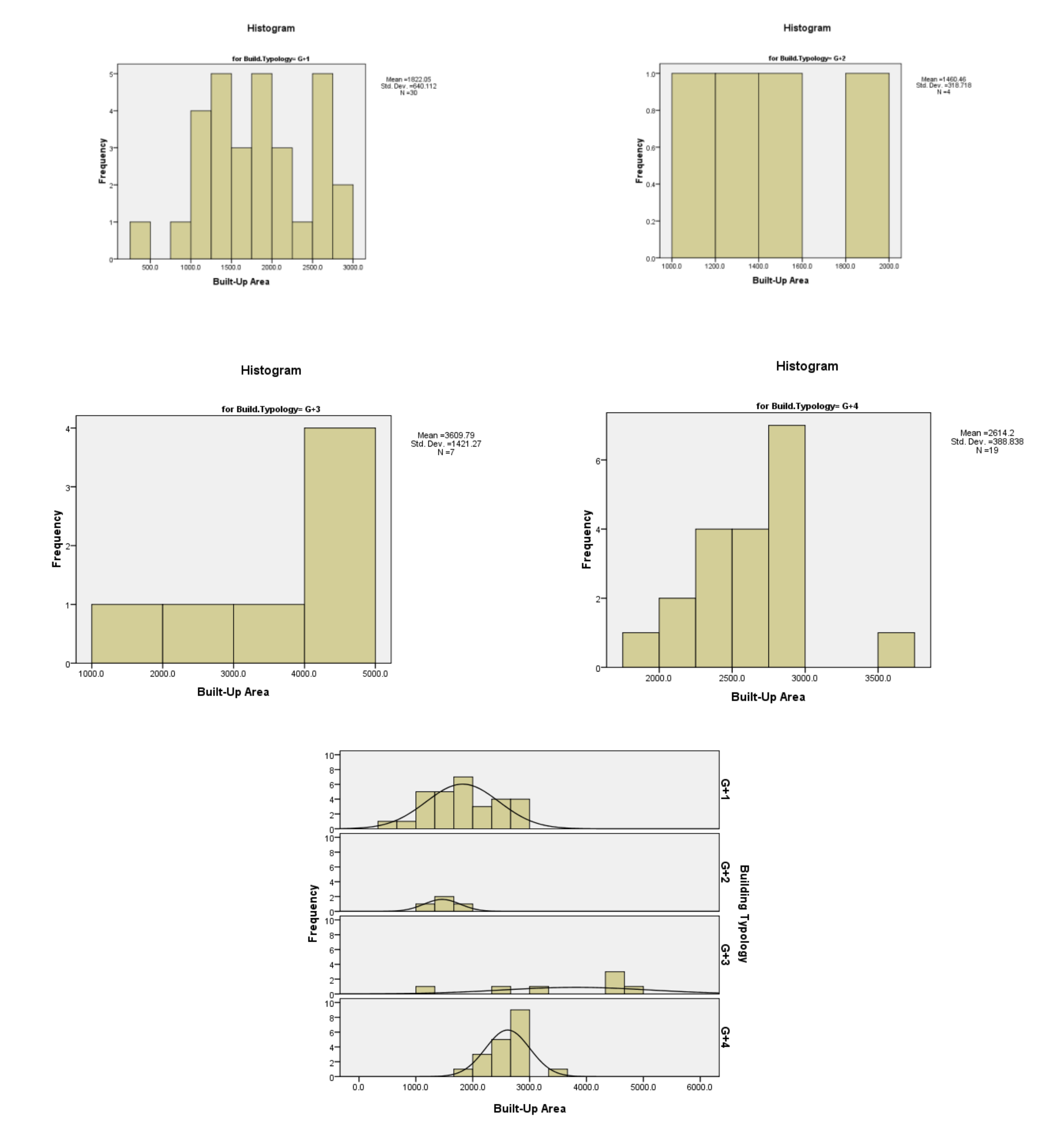


Figure 18: Built-Up Area histograms for new buildings for all building typologies

6.2. Life cycle cost for 'New buildings' in Al Ain

The concept of net present value and equation (6) has been applied in order to calculate the life cycle cost over a life cycle of 35 years for new residential buildings in Al Ain. LCC was computed based on initial cost, operation cost and demolition cost. The average of initial, maintenance, electricity, water and demolition cost for each type of buildings was calculated at the beginning. As well, replacement cost which was computed based on the estimated number of quantity and the corresponding prices. A worksheet for calculating the LCC and NPV for (G+1) buildings using Microsoft Excel 10.0 was prepared for this purpose as shown in Table (11). Likewise, similar sheet was prepared for (G+2), (G+3) and (G+4) buildings as presented in Appendix II.

LCC calculation for New Buildings in Al Ain for G+1

Input Values		No. of 1 BR	1.60	Inflation Rate	5.0%
G+1		No. of 2 BR	8.43	Interest Rate	3.50%
BUA	1,822.05	No. of 3 BR	1.17	Electricity Escalation rate	4.935%
		No. of 4 BR	0.10	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

(MC @ yr 5) (1+i)^(5yr)

	Rep. Yr	No. of Quant.	0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			3,108.91	-	-	-		-	-	-	-	-	-	-
Operation Cost					84.11	100.73	105.09	109.16	122.62	121.32	125.98	130.87	135.98	200.88
Maintenance Cost			-	-	0	12.47	12.47	12.47	12.47	15.92	15.92	15.92	15.92	15.92
Replacement Cost			-	-	-		-	-	9.21	-	-	-	-	59.55
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	22.37	-	-	-	-	-	-	9.21	-	-	-	-	11.75
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	5.49
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	5.49
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	22.37	-	-	-	-	-	-	-	-	-	-	-	36.83
Utilities Cost					84.11	88.26	92.62	96.69	100.95	105.40	110.07	114.95	120.06	125.41
Electricity Cost					66.77	70.06	73.52	77.15	80.96	84.95	89.14	93.54	98.16	103.00
Water Cost					17.35	18.20	19.10	19.54	19.99	20.45	20.93	21.41	21.90	22.41
Demolition Cost														
Total LCC			-	-	84.11	100.73	105.09	109.16	122.62	121.32	125.98	130.87	135.98	200.88
Total PV			3,108.91	-	81.27	94.04	94.79	95.13	103.25	98.69	99.02	99.38	99.77	142.41
Cumulative PV			3,108.91	3,108.91	3,190.17	3,284.21	3,379.00	3,474.12	3,577.37	3,676.06	3,775.08	3,874.46	3,974.23	4,116.64

Table 11: LCC for new buildings in Al Ain for (G+1) buildings …. Continue

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
151.32	157.19	163.32	169.75	248.92	189.14	196.52	204.25	212.34	300.97	236.86	246.16	255.90	266.11	301.22
20.31	20.31	20.31	20.31	20.31	25.92	25.92	25.92	25.92	25.92	33.09	33.09	33.09	33.09	33.09
-	-	-	-	72.44	-	-	-	-	80.15	-	-	-	-	24.43
-	-	-	-	27.44	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30.00	-	-	-	-	-	-	-	-	-	-
-	-	-	-	15.00	-	-	-	-	19.14	-	-	-	-	24.43
-	-	-	-	-	-	-	-	-	7.00	-	-	-	-	-
-	-	-	-	-	-	-	-	-	7.00	-	-	-	-	-
-	-	-	-	-	-	-	-	-	47.00	-	-	-	-	-
131.01	136.87	143.01	149.44	156.17	163.22	170.60	178.33	186.42	194.90	203.77	213.07	222.82	233.02	243.71
108.09	113.42	119.02	124.89	131.05	137.52	144.31	151.43	158.90	166.74	174.97	183.61	192.67	202.18	212.16
22.93	23.45	24.00	24.55	25.12	25.70	26.29	26.90	27.52	28.15	28.80	29.47	30.15	30.84	31.55
151.32	157.19	163.32	169.75	248.92	189.14	196.52	204.25	212.34	300.97	236.86	246.16	255.90	266.11	301.22
103.65	104.02	104.43	104.87	148.58	109.08	109.50	109.96	110.45	151.26	115.01	115.49	116.00	116.54	127.46
4,220.29	4,324.31	4,428.74	4,533.61	4,682.19	4,791.27	4,900.77	5,010.73	5,121.18	5,272.44	5,387.45	5,502.94	5,618.94	5,735.48	5,862.94

Table (11): LCC for new buildings in Al Ain for (G+1) buildings …. Continue

26	27	28	29	30	31	32	33	34	35	Total	Ratio to IC
-	-	-	-	-	-	-	-	-	-	2,877.46	
267.90	278.56	289.73	301.44	552.21	338.77	352.28	366.44	381.29	432.93	7,598.27	2.64
44.02	44.02	44.02	44.02	44.02	56.19	56.19	56.19	56.19	56.19	1,049.47	0.36
-	-	-	-	238.48	-	-	-	-	36.07	518.02	0.18
											-
-	-	-	-	71.17	-	-	-	-	-	105.41	
-	-	-	-	62.37	-	-	-	-	-	92.37	
-	-	-	-	28.26	-	-	-	-	36.07	136.40	
-	-	-	-	11.15	-	-	-	-	-	26.74	
-	-	-	-	11.15	-	-	-	-	-	26.74	
-	-	-	-	54.37	-	-	-	-	-	130.35	
223.88	234.53	245.71	257.42	269.71	282.59	296.09	310.25	325.10	340.68	6,030.79	2.10
208.94	219.25	230.07	241.42	253.34	265.84	278.96	292.73	307.17	322.33	5,584.08	1.94
14.94	15.29	15.64	16.00	16.37	16.75	17.13	17.53	17.93	18.35	446.70	0.16
					-	-	-	-	156.89	156.89	0.05
267.90	278.56	289.73	301.44	552.21	338.77	352.28	366.44	381.29	432.93	7,598.27	
109.53	110.03	110.58	111.16	196.74	116.62	117.16	117.75	118.38	129.87	6,557.95	2.28
5,429.66	5,539.69	5,650.27	5,761.43	5,958.17	6,074.78	6,191.95	6,309.70	6,428.08	6,557.95		

Table (11): LCC for new buildings in Al Ain for (G+1) buildings

In order to realize the weight of initial cost and other costs, costs over initial cost ratio was extracted from the above table. Herein below the weight of each cost to the initial cost ratio for all buildings typology is illustrated.

6.2.1. G+1 Buildings

As shown from Table (12) operation cost over 35 years is more than twice (2.71) initial cost in (G+1) buildings. Furthermore, initial ratio to utility cost is 1:2.22. For visual representation of the operation cost. Fig. (19) shows the running cost of operation cost over a life cycle of 35 years for new buildings. It has been noticed that the most expensive cost is electricity cost. Electricity cost is approximately 6 times over the water cost. As well, it is clear that maintenance cost does not have a notable weight through the lifetime of the project. Maintenance cost is so close to water cost. Also, replacement cost is almost zero unless some years. It was noticed that replacement cost at 30 years is 3 times more than the required replacement cost at year 15th.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	3,108.91	
Operation Cost	8,435.76	2.71
Maintenance Cost	1,006.68	0.32
Replacement Cost	514.03	0.17
Utilities Cost	6,915.04	2.22
Electricity Cost	5,949.88	1.91
Water Cost	965.16	0.31
Demolition Cost	89.12	0.03
Total PV	7218	2.32

Table 12: Weight of costs to initial ratio for (G+1) for new buildings

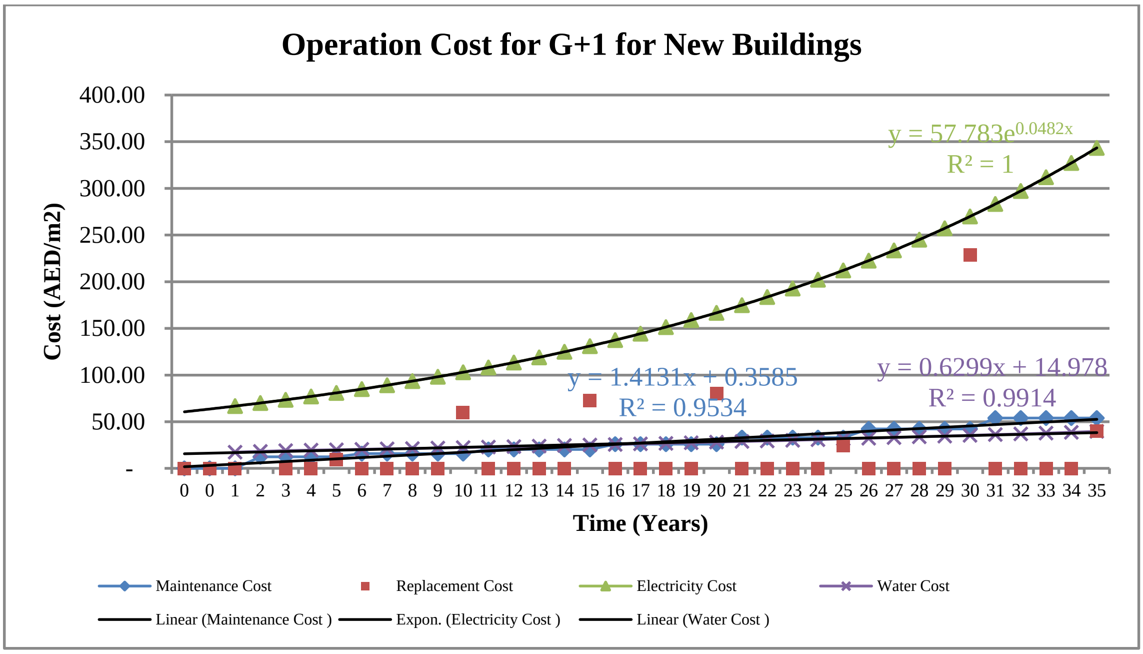


Figure 19: Operation cost for G+1 for new buildings

6.2.2. G+2 Buildings

Likewise, Table (13) presents the ratio of all costs to the initial cost. Ratio between initial to operation cost and initial to electricity cost are almost same. But, this type of buildings, electricity cost is more than water cost by 12 times. It has been shown at Fig. (20) that maintenance cost is almost twice water cost.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	2,877.46	
Operation Cost	7,598.27	2.64
Maintenance Cost	1,049.47	0.36
Replacement Cost	518.02	0.18
Utilities Cost	6,030.79	2.10
Electricity Cost	5,584.08	1.94
Water Cost	446.70	0.16
Demolition Cost	156.89	0.05
Total PV	7,598.27	2.64

Table 13: Weight of costs to initial ratio for (G+2) for new buildings

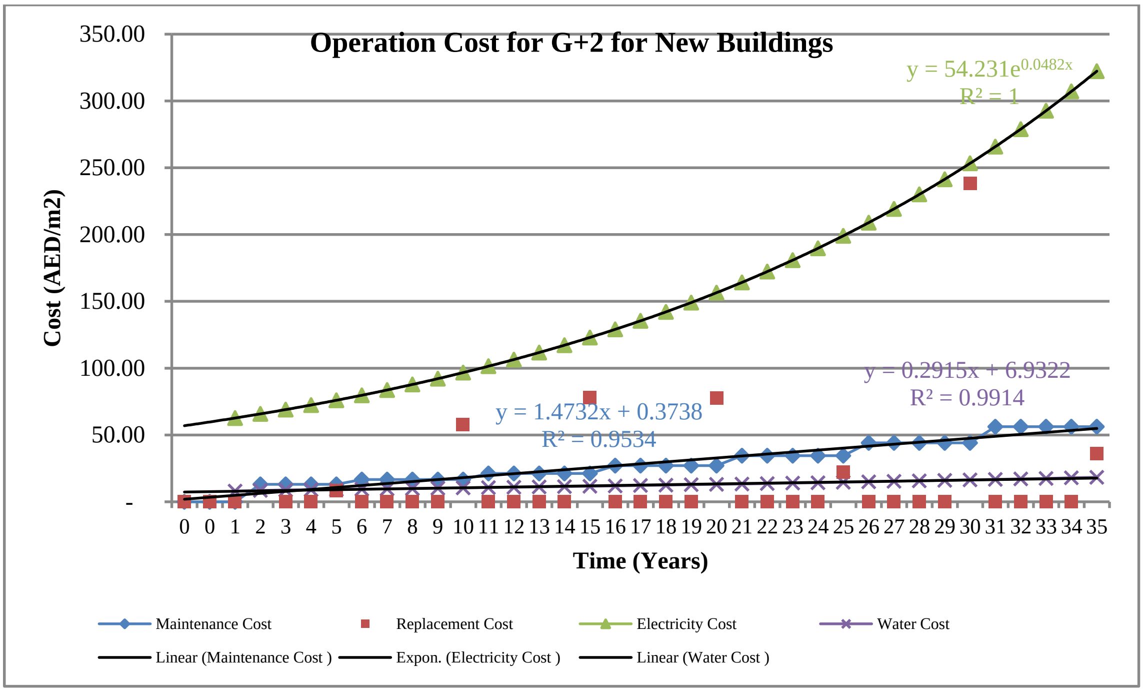


Figure 20: Operation cost for G+2 for new buildings

6.2.3. G+3 Buildings

In similar manner, Table (14) presents the ratio of initial cost to other costs. Once again, initial cost to operation cost is the same (1 to 2.71) and initial to utility cost is similar too. Nevertheless, electricity cost is more than water cost by approximately 9 times. As shown at Fig. (21), although maintenance cost is higher than water cost, the variance between these costs is decreased.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	2,956.79	
Operation Cost	8,023.86	2.71
Maintenance Cost	972.78	0.33
Replacement Cost	347.62	0.12
Utilities Cost	6,703.45	2.27
Electricity Cost	5,994.34	2.03
Water Cost	709.11	0.24
Demolition Cost	120.57	0.04
Total PV	6,858.82	2.71

Table 14: Weight of costs to initial ratio for (G+3) for new buildings

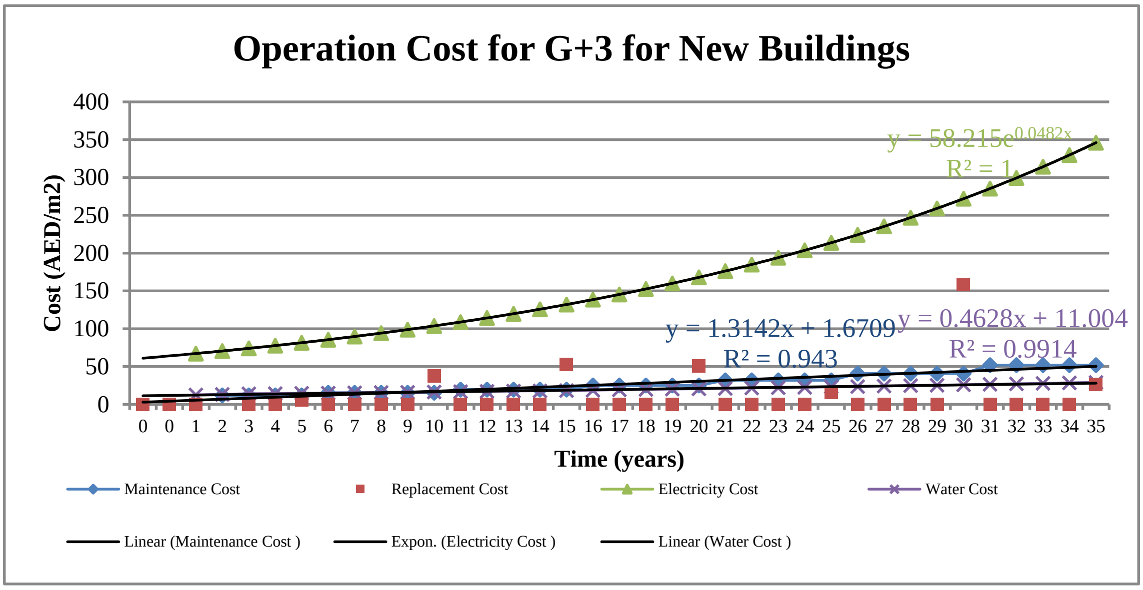


Figure 21: Operation cost for G+3 for new buildings

6.2.4. G+4 Buildings

Finally, Table (15) presents the ratio of initial cost to other costs. This type of buildings show that initial cost to operation cost is (1 to 2.17). Furthermore, ratio of initial to electricity cost is slightly decreased to be 1 to 1.76. In addition, electricity cost is approximately 7 times water cost as presented in Fig. (22).

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	3,884.00	
Operation Cost	8,439.84	2.17
Maintenance Cost	1,170.56	0.30
Replacement Cost	425.15	0.11
Utilities Cost	6,844.13	1.76
Electricity Cost	5,987.11	1.54
Water Cost	857.02	0.22
Demolition Cost	212.20	0.05
Total PV	7,991.39	2.06

Table 15: Weight of costs to initial ratio for (G+4) for new buildings

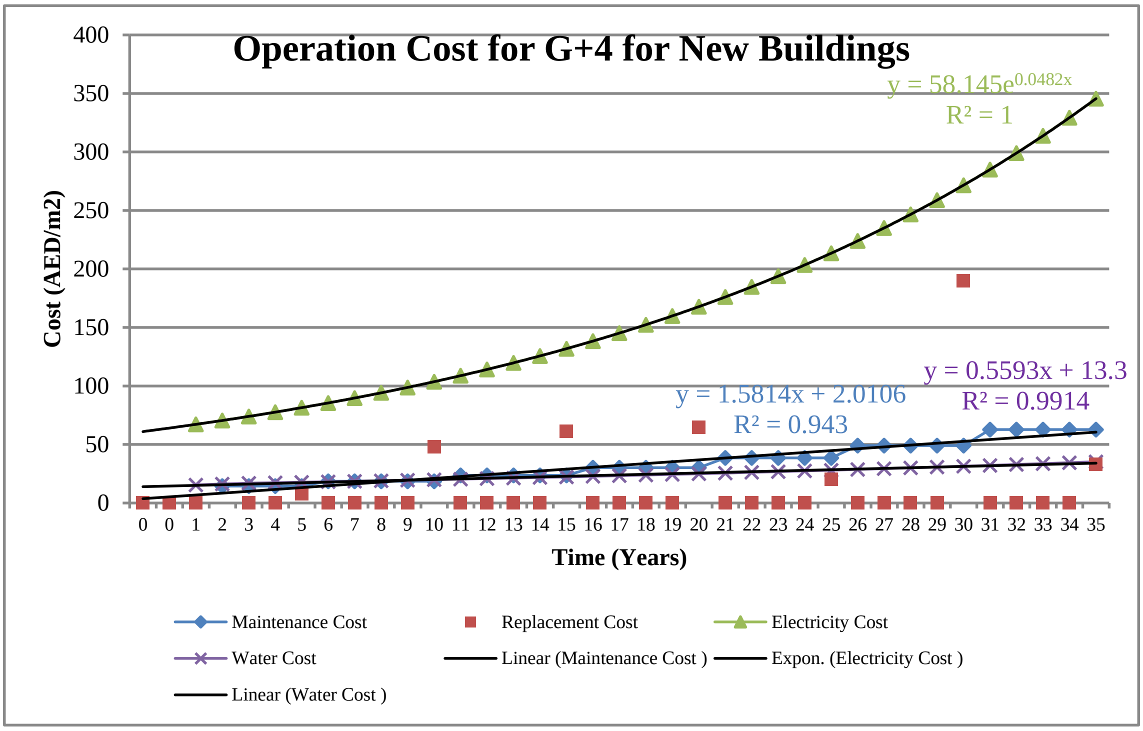


Figure 22: Operation cost for G+4 buildings

On the part of summarizing all costs associated to new buildings, Fig. (23) represents all costs for all types of new buildings in Al Ain. Moreover, Fig. (24) shows the breakdown of operation cost for the same buildings. It is obvious noted that electricity cost has the major impact on the operation cost during the life cycle cost for all buildings. In addition, Fig. (25) depicts the life cycle cost for all buildings typology. It has been found that (G+4) buildings has the highest cost. Following to that, costs for (G+1) buildings come at the second place. Although there is a variance between (G+4) and (G+1) for new buildings, there slopes are almost same. After that (G+3) and (G+2) buildings are closer to each other at the end.

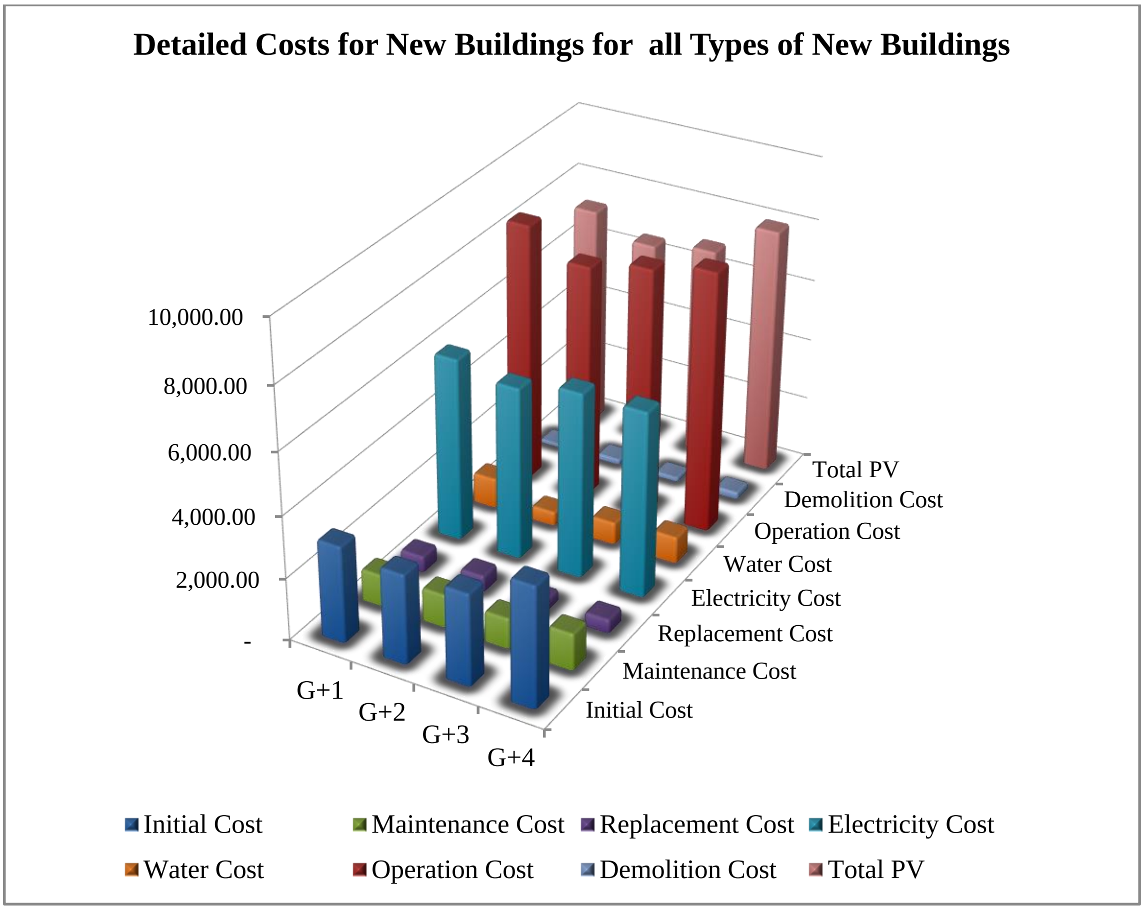


Figure 23: Breakdown for all LCC for all buildings typology

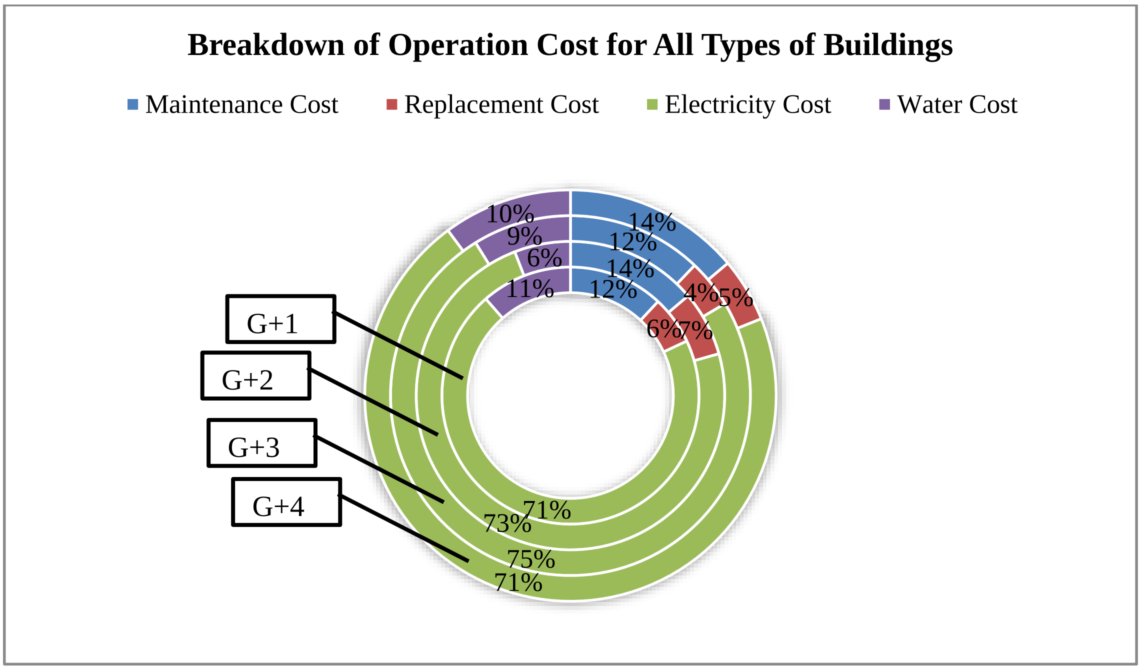


Figure 24: Breakdown for operation cost for all buildings typology

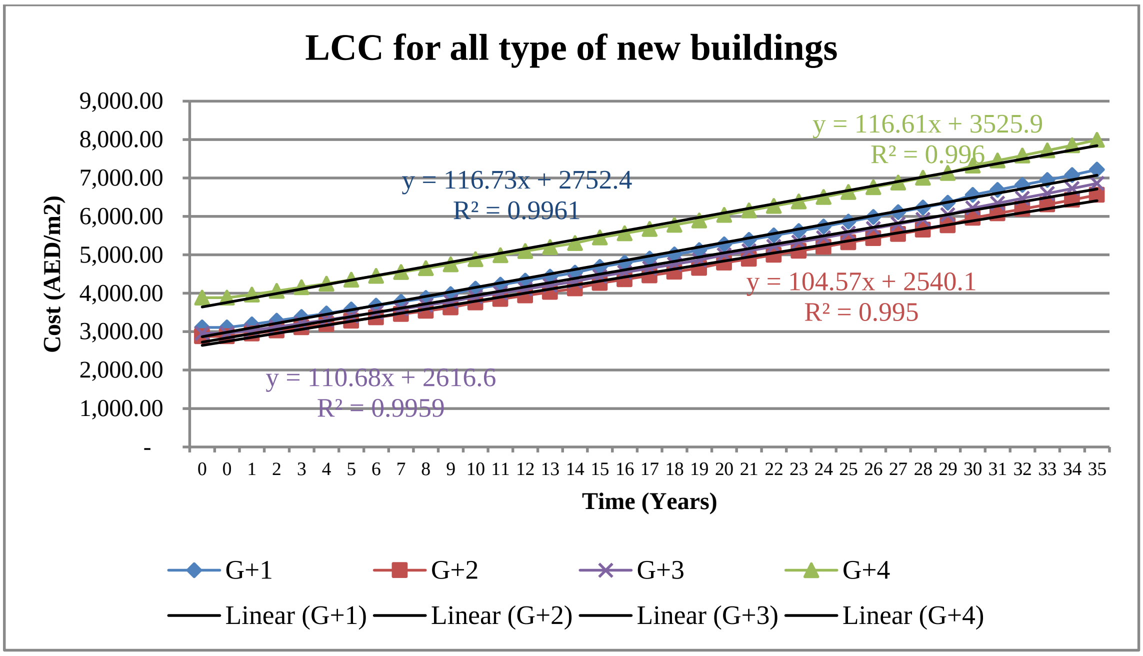


Figure 25: Life cycle cost for all buildings typology over a life cycle of 35 years

6.3. Life cycle cost for 'Old buildings' in Al Ain

Correspondingly, the explanation of life cycle cost and the net present value for old buildings in Al Ain is discussed below along with detailed explanation for each type of building. The full Excel sheet for LCC and NPV calculations were prepared and shown in Appendix III.

6.3.1. G+1 Buildings

As can be seen from Table (16) and Fig. (26), initial cost to operation cost in old buildings is approximately 1 to 3. The difference between water cost to electricity cost is almost 1 to 19. Maintenance and water costs are so close to each other through the life cycle of 35 years.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	1,736.60	
Operation Cost	5,168.61	2.98
Maintenance Cost	259.43	0.15
Replacement Cost	226.52	0.13
Utilities Cost	4,676.71	2.69
Electricity Cost	4,275.85	2.46
Water Cost	219.63	0.13
Demolition Cost	22.66	0.01
Total PV	4,322.61	2.49

Table 16: Weight of costs to initial ratio for (G+1) for old buildings

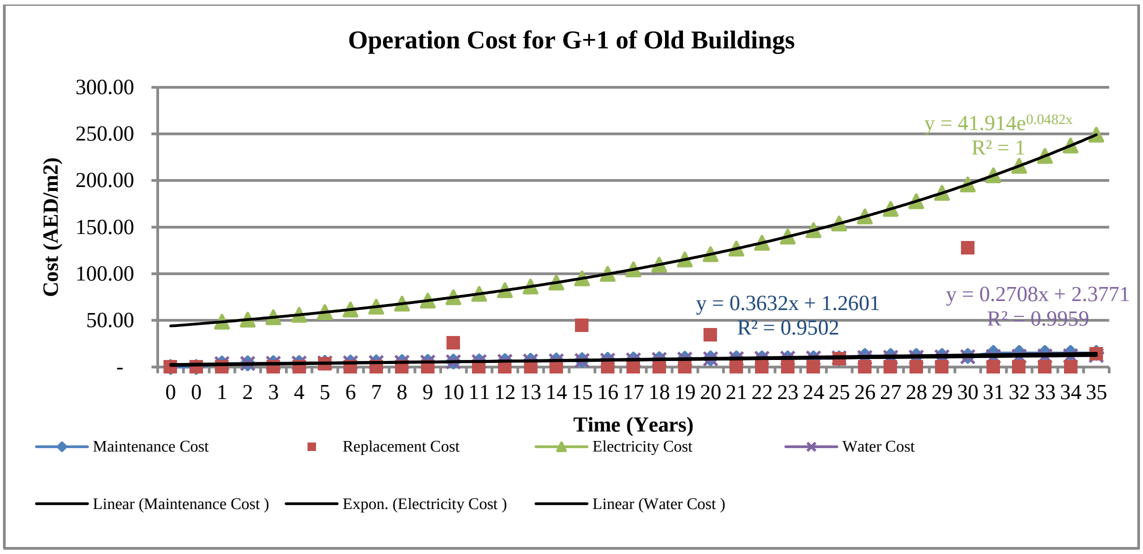


Figure 26: Operation cost for G+1 for old buildings

6.3.2. G+2 Buildings

From Table (17) and Fig. (27), it can be seen that initial to operation cost is 1 to 3 like (G+1) for old buildings. In addition, electricity cost also is more than water cost by 19 times same like G+1 for old buildings. Maintenance and water costs are so close to each other through the life cycle of 35 years.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	1,736.60	
Operation Cost	5,168.61	2.98
Maintenance Cost	259.43	0.15
Replacement Cost	226.52	0.13
Utilities Cost	4,676.71	2.69
Electricity Cost	4,275.85	2.46
Water Cost	219.63	0.13
Demolition Cost	22.66	0.01
Total PV	4,322.61	2.49

Table 17: Weight of costs to initial ratio for (G+2) for old buildings

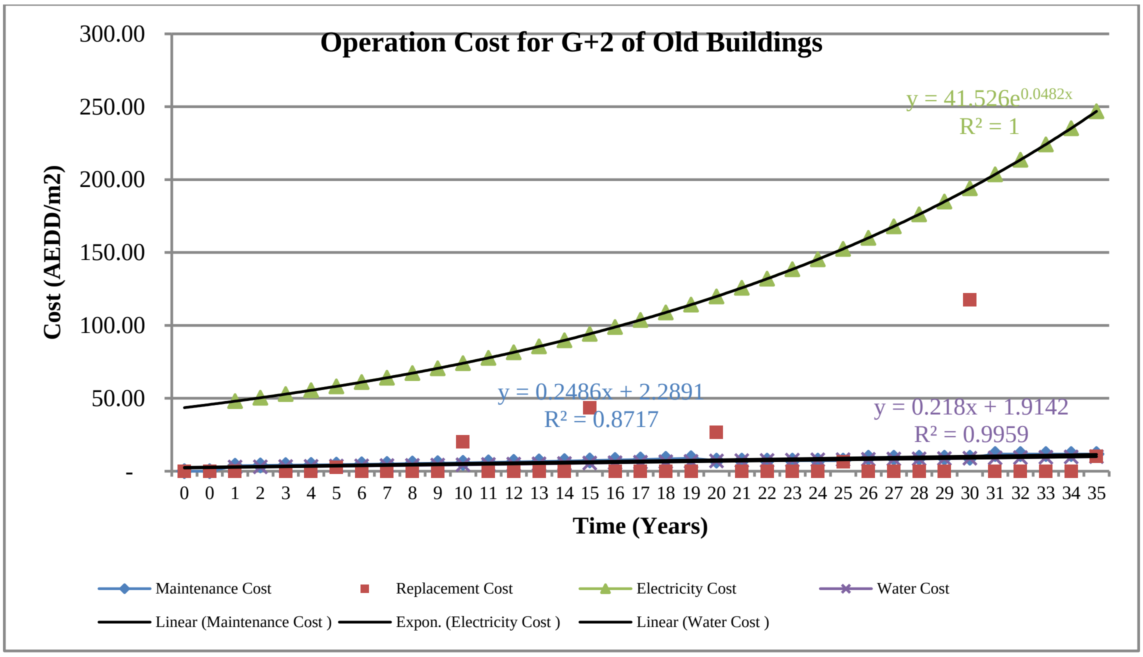


Figure 27: Operation cost for G+2 for old buildings

6.3.3. G+3 Buildings

The Table (18) and the Fig. (28) shows that there is a slight decrease in the ration between initial to operation cost which becomes for (G+3) old buildings 1 to 2.5 not 1 to 3. Although electricity cost is more than water cost, the ratio of water to electricity cost is decreased also and become 1 to 6 for G+3 old buildings instead of 1 to 19 for G+1 and G+2 old buildings. Although maintenance and water cost are close to each other, water cost is higher than maintenance cost for this type of old buildings.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	2,416.30	
Operation Cost	6,006.74	2.49
Maintenance Cost	409.48	0.17
Replacement Cost	352.67	0.15
Utilities Cost	5,237.19	2.17
Electricity Cost	4,335.08	1.79
Water Cost	696.68	0.29
Demolition Cost	58.00	0.02
Total PV	5,410.55	2.24

Table 18: Weight of costs to initial ratio for (G+3) for old buildings

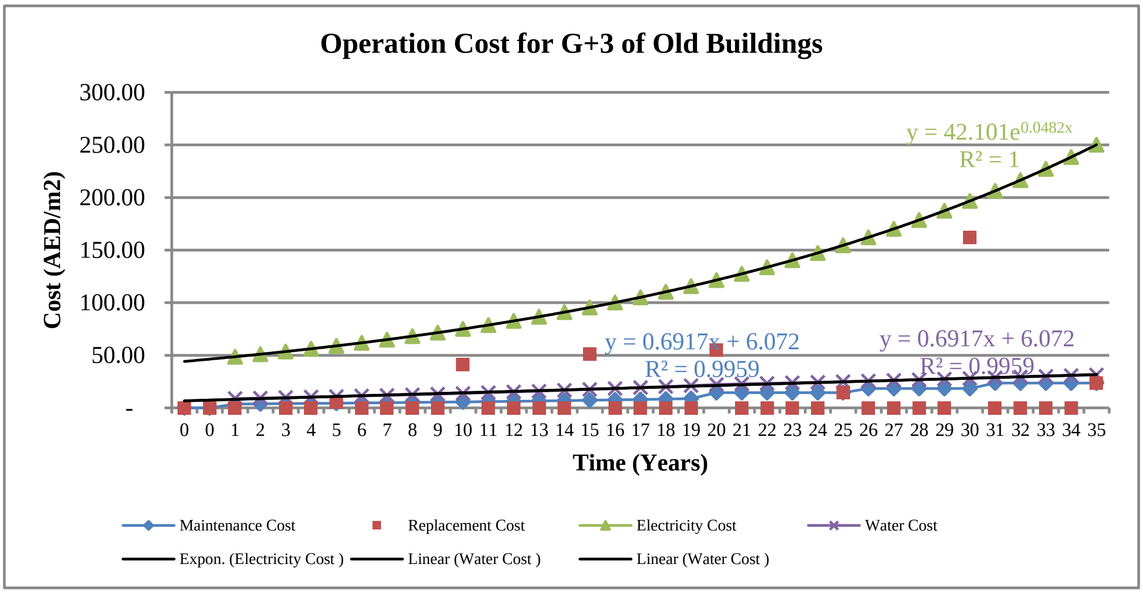


Figure 28: Operation cost for G+3 for old buildings

6.3.4. G+4 Buildings

Finally, the Table (19) and the Fig. (29) illustrate that initial to operation cost ratio equals 1 to 2.61 similar to G+3 old buildings. Moreover, electricity cost is more than water cost by 6 times similar to G+3 old buildings too. In the same manner maintenance and water cost are close to each other, water cost is higher than maintenance cost for this type of old buildings.

Costs	Total cost over 35 years	Initial Cost to (X Cost) (Ratio)
Initial Cost	2,351.90	
Operation Cost	6,139.96	2.61
Maintenance Cost	572.45	0.24
Replacement Cost	323.94	0.14
Utilities Cost	5,234.57	2.23
Electricity Cost	4,335.08	1.84
Water Cost	694.18	0.30
Demolition Cost	37.79	0.02
Total PV	5,393.31	2.29

Table 19: Weight of costs to initial ratio for (G+4) for old buildings

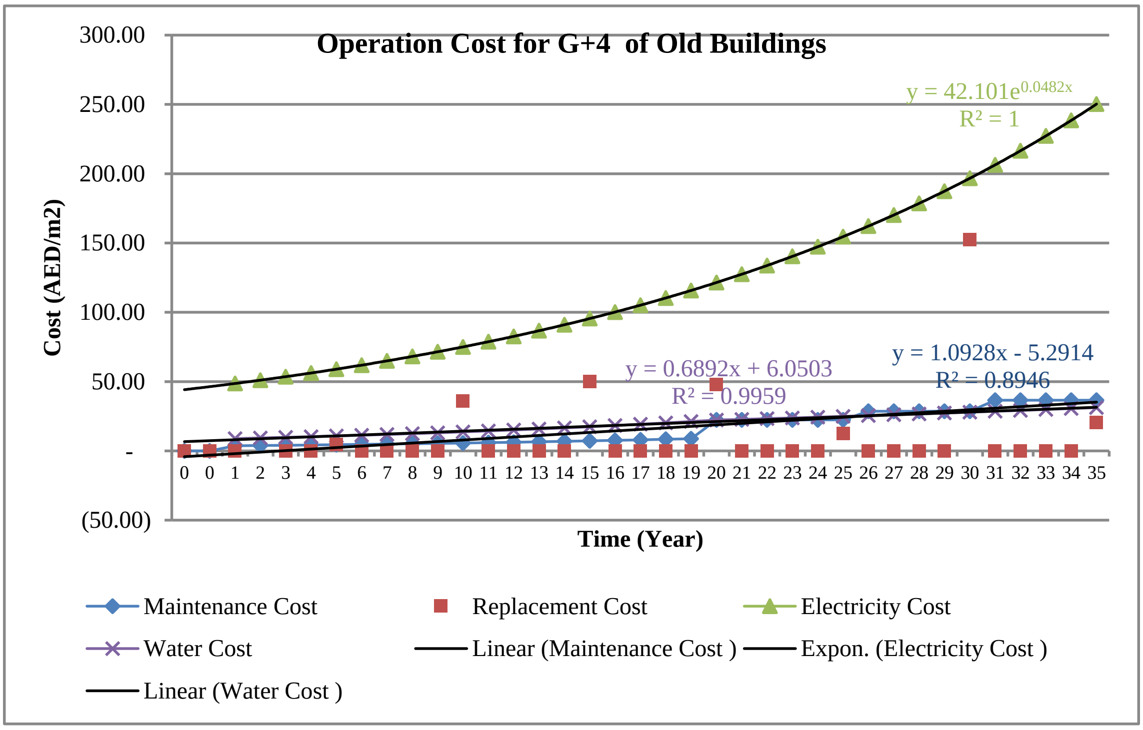


Figure 29: Operation cost for G+3 for old buildings

On the part of summarizing all costs associated to old buildings, Fig. (30) represents all costs for all types of old buildings in Al Ain. Moreover, Fig. (31) shows the breakdown of operation cost for the same buildings. It is noted again that electricity cost has the majority impact on the operation cost during the life cycle cost for all buildings. In addition, Fig. (32) depicts the life cycle cost for all buildings typology for old buildings. It has been found that (G+4) buildings has the highest cost. Following to that, costs for

(G+4) buildings come at the second place and it is so close to (G+3) buildings. After that there is a huge difference between (G+4) and (G+2) buildings. At the end (G+1) buildings is so close to (G+2).

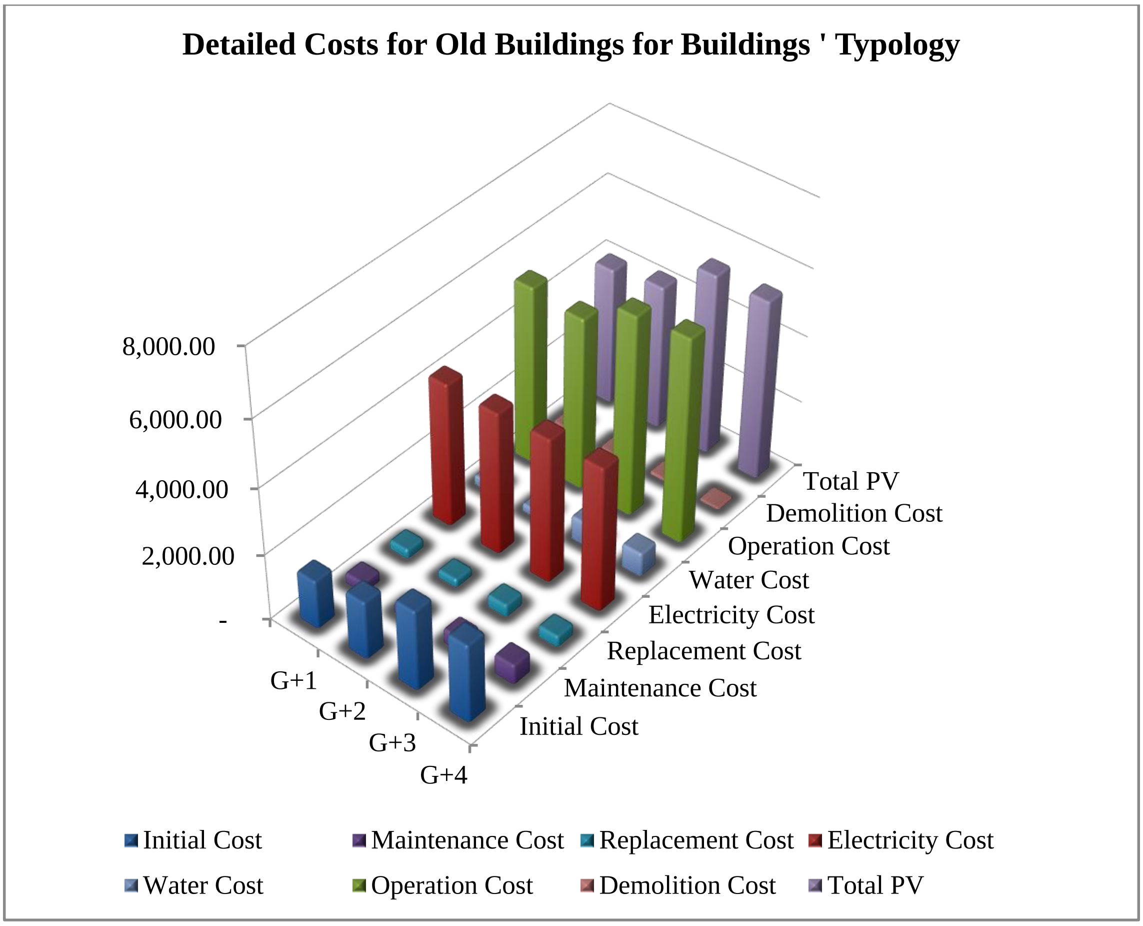


Figure 30: Breakdown for all LCC for all buildings typology

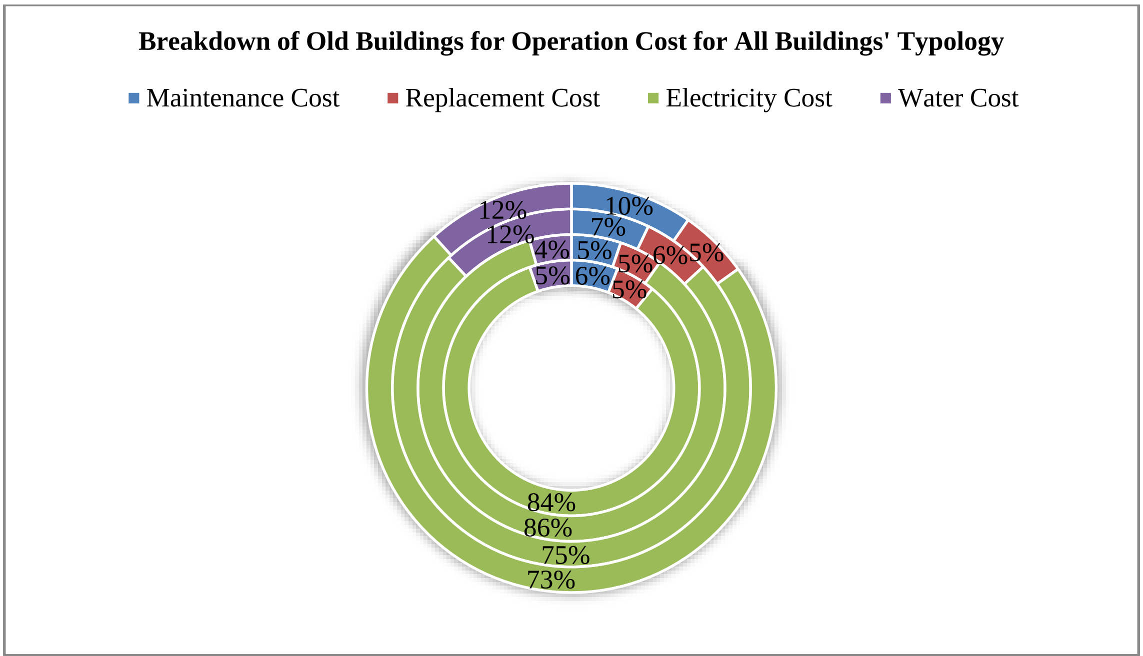


Figure 31: Breakdown for all LCC for all buildings typology

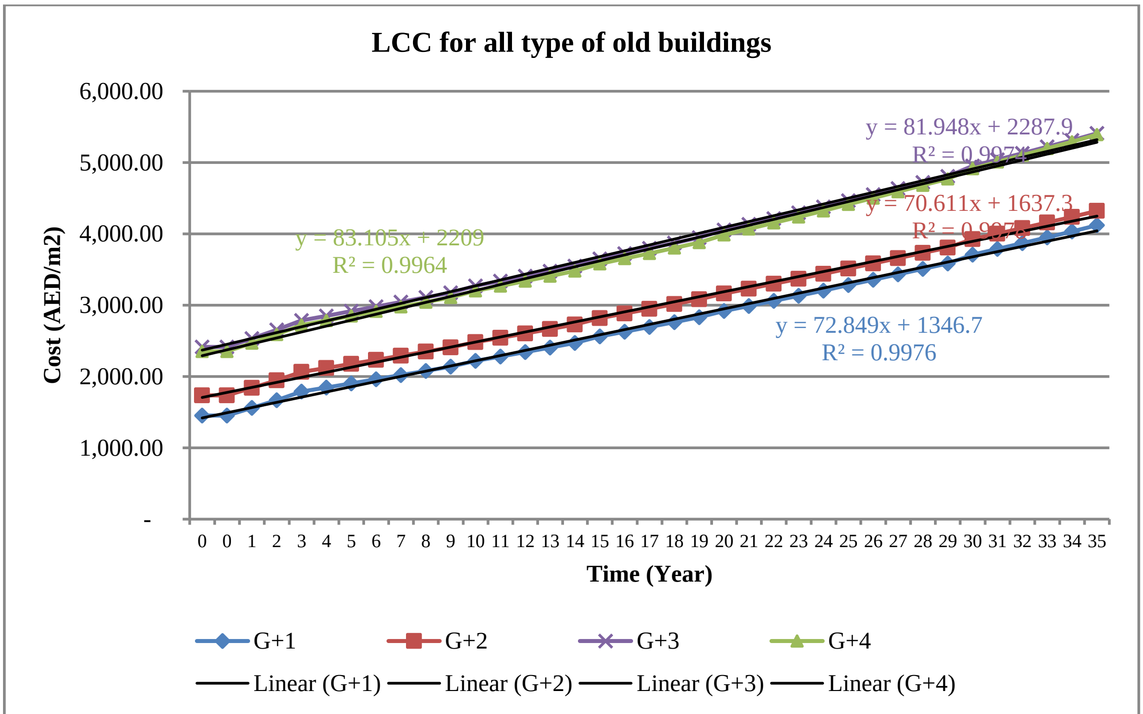


Figure 32: Life cycle cost for all buildings typology over a life cycle of 35 years

6.4. Comparison between ‘New buildings’ and ‘Old buildings’ in Al Ain

In this section a detailed comparison between new and old buildings in Al Ain was carried out.

6.4.1. Initial Cost (IC)

Initial capital cost as mentioned earlier includes design, planning and construction cost. In order to calculate the uplifted value for the initial cost Eq. (5) was applied. Table (20) presents initial cost comparison for new and old buildings for all types of buildings.

As can be seen below from Table (20) and Fig. (33), there is an extensive difference between new and old buildings in initial cost for (G+1) buildings. (G+1) New buildings cost almost 50% more than old buildings. The difference between new and old buildings decreases in (G+2) buildings and decreases more in (G+3) buildings until it increases again in (G+4) buildings. In general, the average difference between new and old buildings for all types of buildings equals 38%.

The increase in initial cost for new buildings can be demonstrated by the increase in prices in raw materials, labour cost, fuel and transportation, new requirements and regulations from new authorities such as Civil Defence, Department of Transport, …etc.

Building Typology	G + 1	G + 2	G + 3	G + 4
New Buildings (AED/m^2)	3,108.91	2,877.46	2,956.79	3,884.00
Old Buildings (AED/m^2)	1,453.60	1,736.60	2,416.30	2,351.90
Difference (Percentage)	53%	40%	18%	39%

Table 20: The average of initial cost for all types of buildings

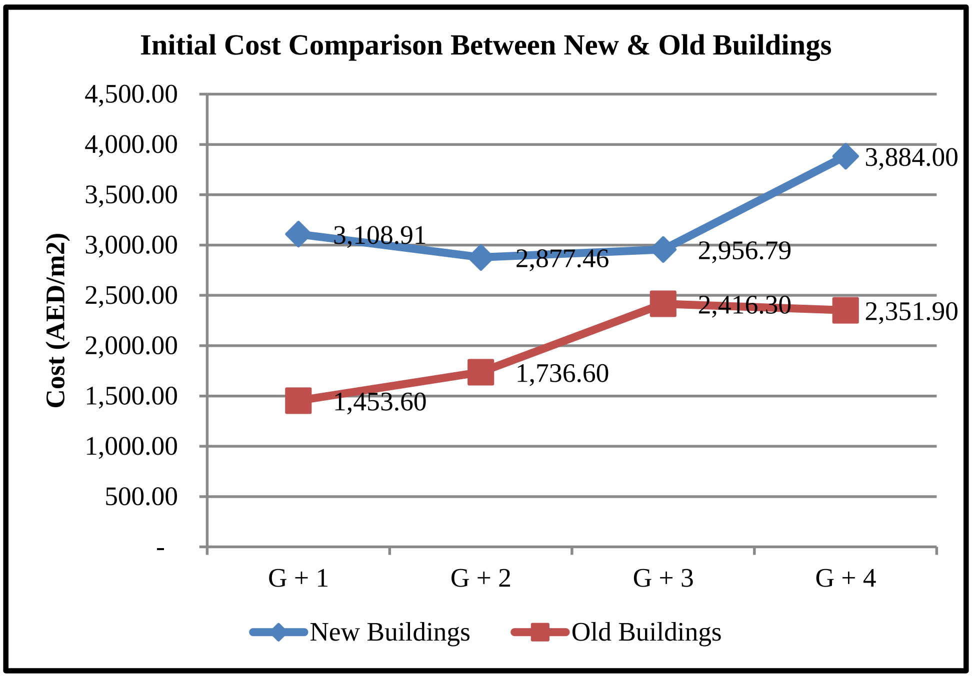


Figure 33: Initial cost comparison between new and old buildings for all types of buildings

6.4.2. Operation Cost (OC)

Operation cost includes maintenance and replacement costs and utility costs, which are electricity and water. Operation cost comparison between new and old buildings is referred at Table (21) and Fig. (34). The comparison indicates that operation cost for new buildings is obviously higher than operation cost for old buildings.

Building Typology	G + 1	G + 2	G + 3	G + 4
New Buildings (AED/m^2)	3,675.00	3,160.50	3,671.50	3,741.50
Old Buildings (AED/m^2)	4,233.25	4,194.05	4,252.15	4,252.15
Difference (Percentage)	-15%	-33%	-16%	-14%

Table 21: The average of annual operation cost for all types of buildings

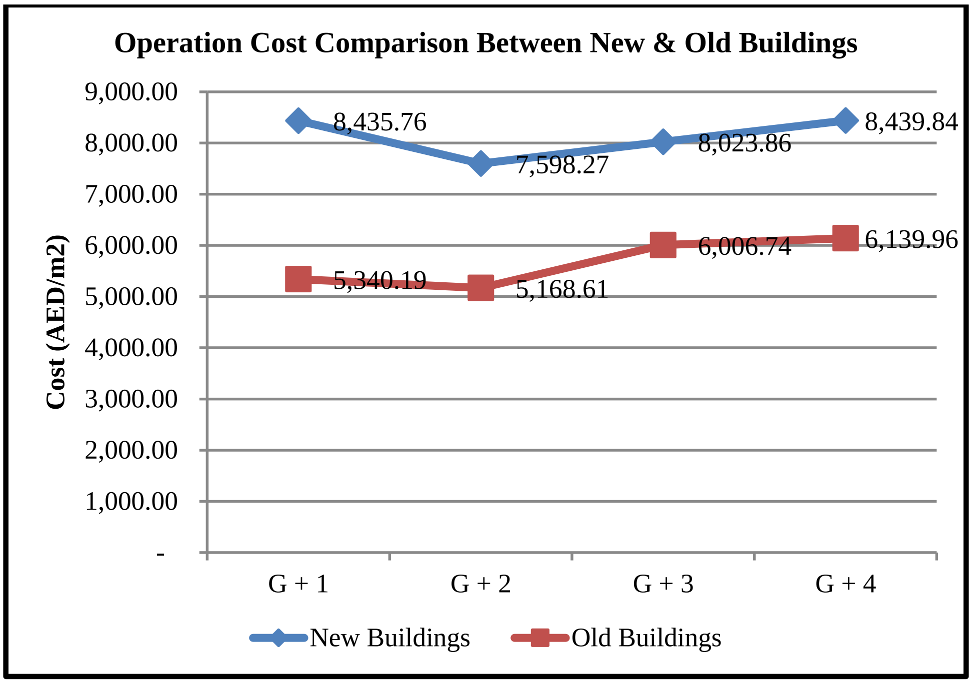


Figure 34: Operation cost comparison between new and old buildings for all types of buildings over 35 years

In order to investigate the reason of the huge variance between new and old buildings at the lifetime of operation cost of 35 years, Fig. (35) for new buildings and Fig. (36) for old buildings. Electricity cost is the most effective cost in both new and old buildings during the lifetime operation cost. Electricity cost in new buildings occupies about 72.5% from the total operation cost over 35 years. Likewise, electricity cost occupies 79.5% from the total life cycle cost of old buildings through 35 years.

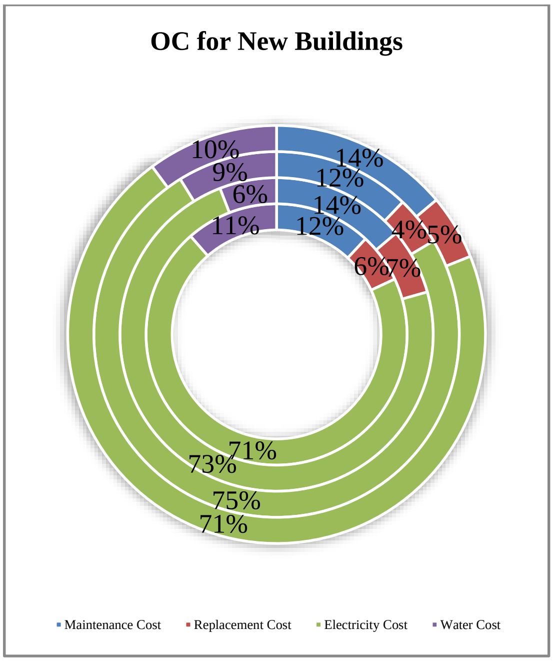


Figure 35: Breakdown of OC for New Buildings

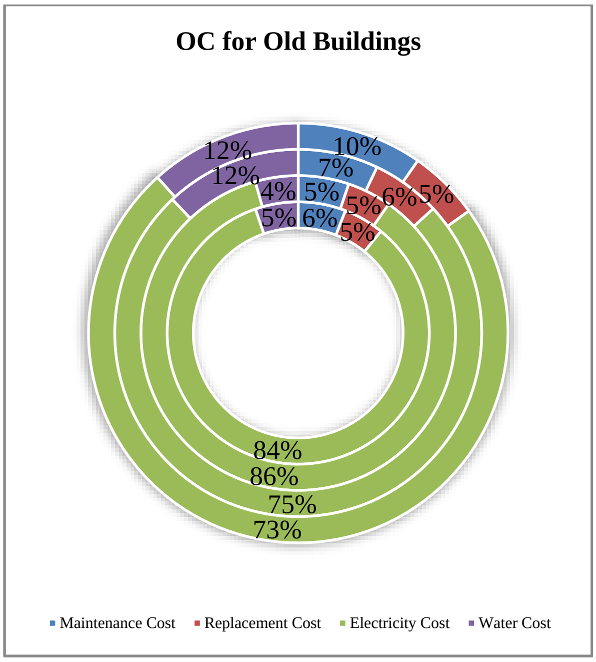


Figure 36: Breakdown of OC for Old Buildings

Based on our assumption that new buildings are installing new and energy efficiency appliances and old buildings are installing old and non-energy efficiency, the annual electricity cost for new buildings is less than old buildings. Indeed, old buildings are burdening the users and the government.

Although the annual electricity cost for old buildings is more than new buildings as shown below in Fig. (37), the total operation cost for new buildings is more than old buildings through a life cycle of 35 years. This difference is referred to the decrease in tariff of electricity charge during the first twenty years from the old buildings' life, leads to decrease the total life cycle cost for old buildings. In another meaning, the tariff of electricity cost for year 1 (say on 1996) for old buildings is less than the tariff of electricity charge for year 1 (say on 2016) for new buildings.

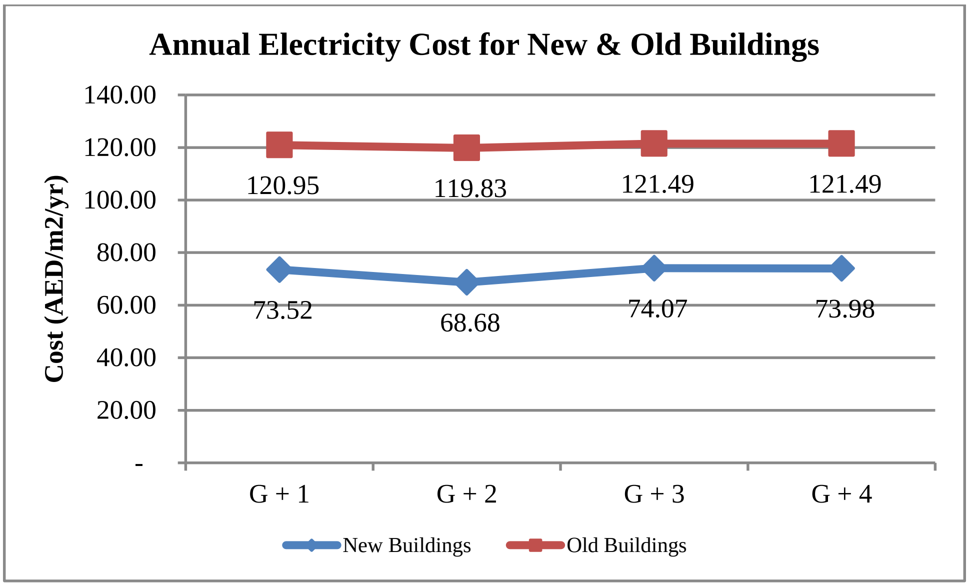


Figure 37: Annual electricity cost for new and old buildings for all types of buildings

On the other hand, water cost for new and old buildings are almost same because water cost was calculated based on the estimated number of bedrooms in each unit. Likewise, replacement costs were almost so close for the same reason.

Although maintenance cost does not have significant weight in operation cost, maintenance cost for new buildings is more than old buildings. Maintenance cost for new and old buildings have very small percentages of 13% and 7% respectively. Maintenance cost for old buildings is very small because most of owner properties does not want to spend more money to maintain their properties because they will be illegible to demolish and rebuild new building by a subsidized loan by the government of Abu Dhabi. Guidelines for granting housing loans for UAE nationals are stated at the Department of Finance website (Department of Finance n.d.).

6.4.3. Net present value (NPV)

Net present value covers all costs happening from cradle to grave. LCC combines initial cost, operation cost and demolition cost. Table (22) and Fig. (38) show the net present value for both new and old buildings for each type of buildings.

It has been found that there is variance in net present value between new and old buildings especially in (G+1) buildings reaches 43%. While the difference of NPV for (G+2) and (G+4) buildings between new and old are almost similar. The lowest difference in NPV was found for (G+3) buildings.

The reason behind the increase or decrease in NPV is initial cost and operation cost. Demolition cost does not weight anything and can be overlooked. As illustrated earlier, initial cost for new buildings are effected by the increase in prices in raw materials, labour cost, new requirements and regulations by new authorities. The variance between new and old buildings in operation cost explains the importance of applying value engineering. Old appliances – non-energy efficient - consume extensive electricity consumption, which proportionally increases the operation cost.

Building Typology	G + 1	G + 2	G + 3	G + 4
New Buildings (AED/m^2)	7,218.10	6,557.95	6,858.82	7,991.39
Old Buildings (AED/m^2)	4,120.68	4,322.61	5,410.55	5,393.31
Difference (Percentage)	43%	34%	21%	33%

Table 22: The average of life cycle cost for all types of buildings

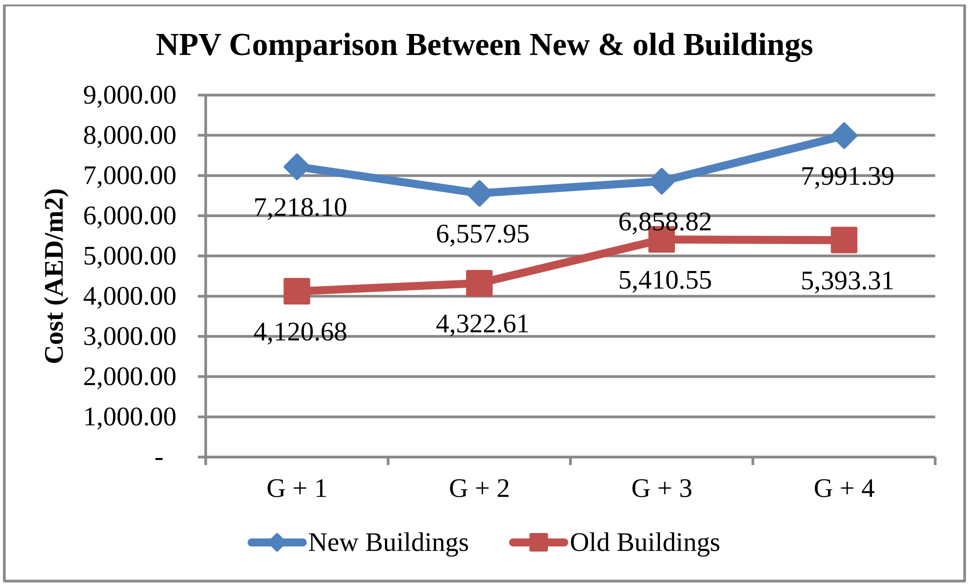


Figure 38: Net present value for new and old buildings for all types of buildings

6.5. Comparison between LCCA in Al Ain and in the UK

Author has relied on the solid sample of new buildings, which has been collected from ADCE and ADCP in order to compare Al Ain buildings to the UK case. Al Ain buildings results were compared to Cuéllar-Franca and Azapagic (2014) results. There is difference between Al Ain and the UK houses. Therefore, we assumed that detached houses are similar to villas (G+1 and G+2 buildings) and terraced houses are similar to apartments (G+3 and G+4 buildings).

Therefore, based on the above results for new buildings in Al Ain, Fig. (39) shows a histogram, which includes initial cost, maintenance cost and demolition cost for (G+1), (G+2), (G+3) and (G+4) buildings. On the other hand, Fig. (40) shows the life cycle cost for the UK houses after changing the currency from GPB to AED and dividing operation cost by 50 years.

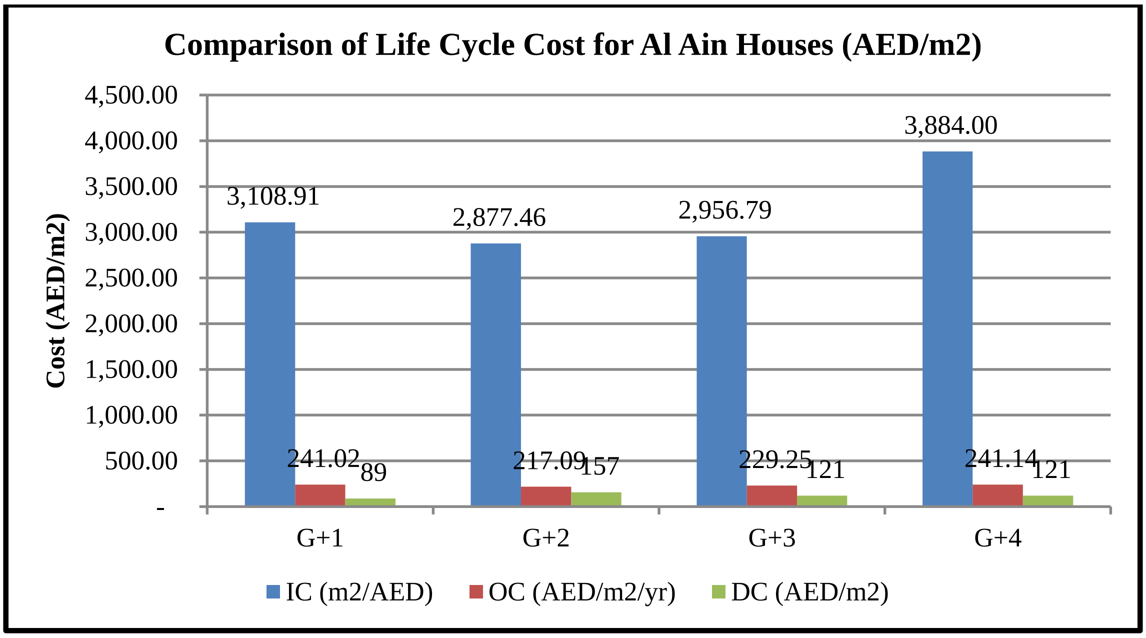


Figure 39: Comparison of life cycle costs for all types of new buildings in Al Ain (AED/m2)

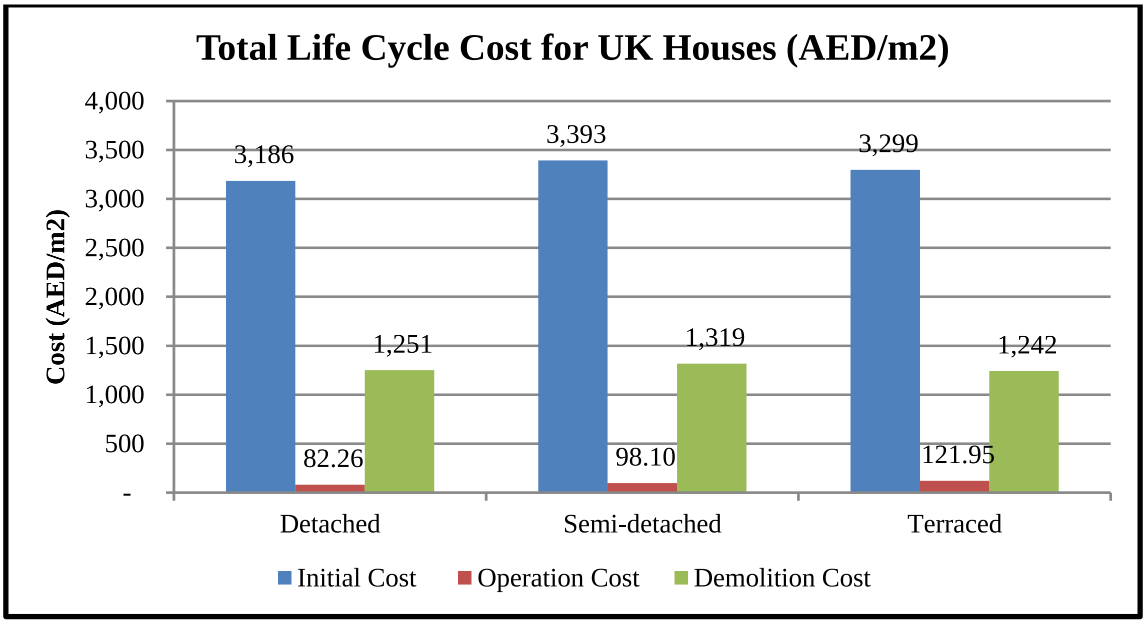


Figure 40: Comparison of life cycle costs for all types of houses in the UK (AED/m2)

Table (23) illustrates all costs for both Al Ain and the UK. It has been found that initial cost for detached houses in the UK is slightly more than villas in Al Ain. On the other hand, initial cost for apartments in Al Ain are slightly more than terraced houses in the UK. Therefore, we can say that initial cost in Al Ain and in the UK are close.

	UK		Al Ain	
	Detached	Terraced	Villa	Apartment
Initial Cost (AED/m2)	3,185.17	3,297.08	2,993.18	3,420.40
Operation Cost (AED/m2/yr)	82.26	121.95	229.06	235.20
Demolition Cost (AED/m2)	1,252.35	1,242.38	123.01	120.57

Table 23: Comparison between Al Ain and the UK

On the other hand, in order to compare operation cost in Al Ain and in the UK a breakdown for operation cost in the UK were illustrated as shown in Fig. (41). Author has computed space heating, water heating, cooking, lighting and appliances under one category of electricity cost. It has been found that breakdown for operation percentages in the UK are 38% for electricity, 33.3% for maintenance and transport, 16.3% for wastewater treatment and 12.3% for water. Generally, it is difficult to compare operation cost in Al Ain and in the UK due the difference in methodologies applied to calculate the operation cost. For demolition cost, detached and terraced houses in the UK are higher the villas and apartments almost by 100%.

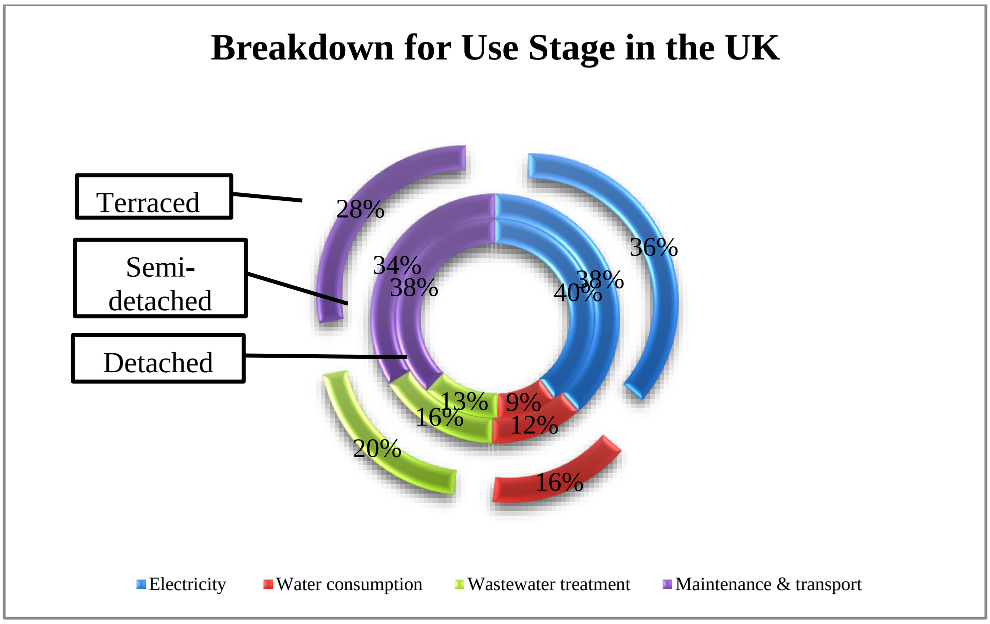


Figure 41: Breakdown of percentages of annual operation cost in the UK

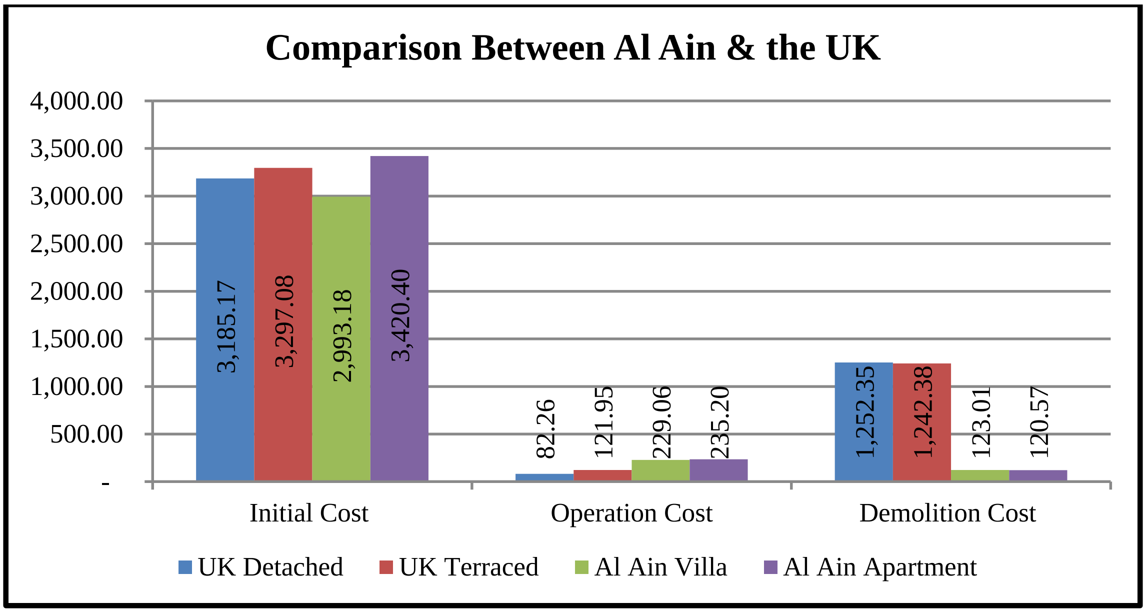


Figure 42: Comparison between Al Ain and the UK

6.6. Sensitivity Analysis

Following to NPV method a sensitivity analysis was applied to predict what the most sensitive variable is, if it changes. Sensitivity analysis was computed for each building category individually for new buildings in Al Ain. In order to examine sensitivity analysis, input values were changed with a step of 10 % from -30 % to 30 %. Input values were changed one by one at a time in order to determine the output result (NPV value).This analysis assists in decision-making that allow analysts to predict the highest sensitivity variable. Sensitivity analysis aimed to examine initial cost, operation cost and interest rate. Same sensitivity analysis were computed for old buildings at Appendix IV.

6.6.1. Sensitivity Analysis for (G+1) for new Buildings

At the beginning, Table (24) shows the change in input values for initial cost, maintenance cost, replacement cost, electricity cost, water cost and interest rate. Table (25) presents the output results of sensitivity analysis.

From the sensitivity analysis outputs reflected at Fig. (43), it has been noticed that the rank of the highest slopes are for initial cost, interest rate, utility cost and maintenance and replacement cost in order. The relative change in initial cost between -30% changes in input and the base equals -15% and equals 11% at 30% change in input values. Also, the relative change in interest rate between -30% change in input and the base equals 11% and equals the same value but in negative with the positive change in input values.

Change in Input Value for (G+1) buildings								
Variables		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	2,176.23	2,487.12	2,798.02	3,108.91	3,419.80	3,730.69	4,041.58
MC	(AED/m2)	8.73	9.98	11.22	12.47	13.72	14.96	16.21
RC	(AED/m2)	380.09	434.39	488.69	542.99	597.29	651.59	705.89
EC	(AED/m2)	51.46	58.82	66.17	73.52	80.87	88.22	95.58
WC	(AED/m2)	13.37	15.28	17.19	19.10	21.01	22.92	24.83
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

Table 24: Change in input value for (G+1) buildings

LCC Sensitivity Analysis for (G+1) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	6,285.43	6,596.32	6,907.21	7,218.10	7,529.00	7,839.89	8,150.78
OC	(AED/m2)	6,909.91	7,012.64	7,115.37	7,218.10	7,320.83	7,423.56	7,526.29
MC	(AED/m2)	7,073.48	7,121.69	7,169.90	7,218.10	7,266.31	7,314.52	7,362.73
RC	(AED/m2)	7,146.96	7,170.67	7,194.39	7,218.10	7,241.82	7,265.54	7,289.25
EC	(AED/m2)	6,353.80	6,641.90	6,930.00	7,218.10	7,506.21	7,794.31	8,082.41
WC	(AED/m2)	7,065.42	7,116.32	7,167.21	7,218.10	7,269.00	7,319.89	7,370.79
Interest Rate %		8,134.58	7,801.94	7,497.33	7,218.10	6,961.88	6,726.50	6,510.07
M&RC		7,110.22	7,146.18	7,182.14	7,218.10	7,254.07	7,290.03	7,325.99
UC		6,709.61	6,879.11	7,048.61	7,218.10	7,387.60	7,557.10	7,726.60

Table 25: LCC for sensitivity analysis for (G+1) for new buildings

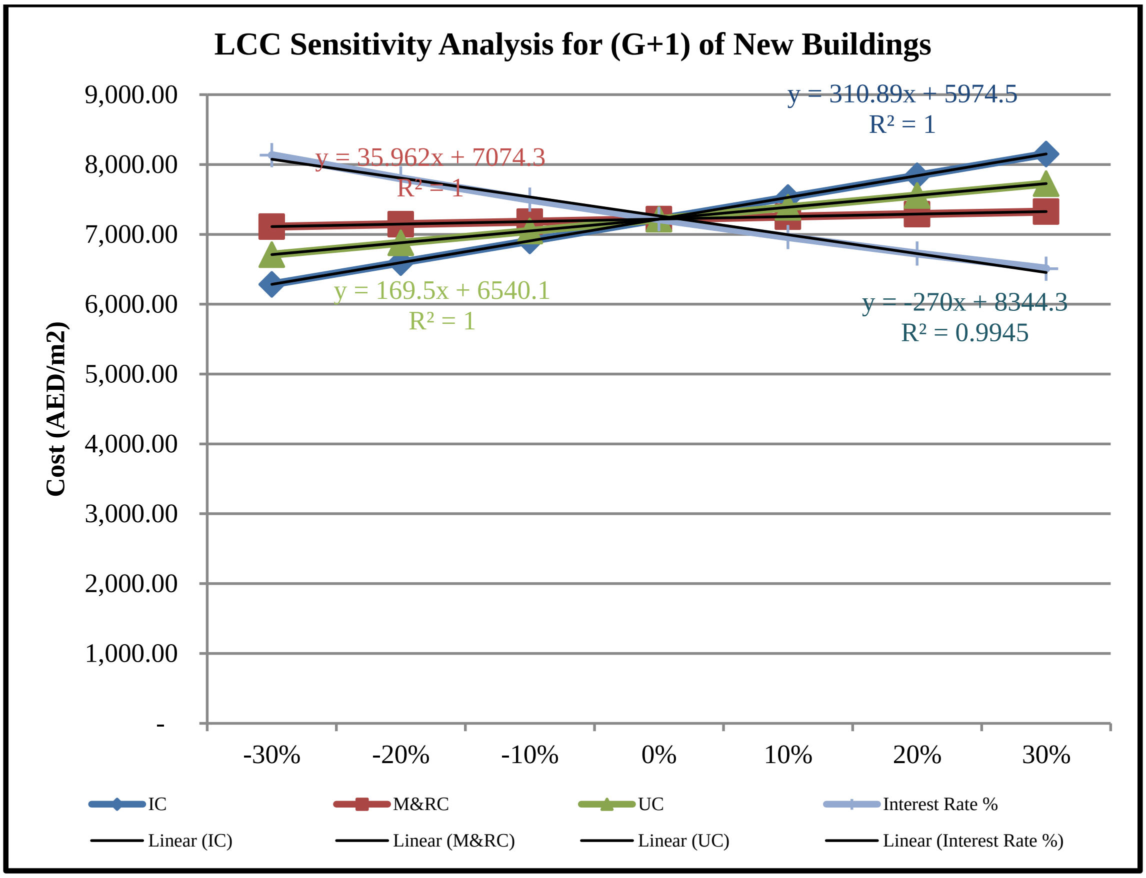


Figure 43: Sensitivity analysis for (G+1) for new buildings

6.6.2. Sensitivity Analysis for (G+2) for new Buildings

Similarly, Table (26) depicts the change in input values for initial cost, maintenance cost, replacement cost, electricity cost, water cost and interest rate. Table (27) illustrates the output results of sensitivity analysis.

From the sensitivity analysis outputs reflected at Fig. (44), it has been found again that the rank of the highest slopes are for initial cost, interest rate, utility cost and maintenance and replacement cost in order. The relative change in initial cost between -30% changes in input and the base equals -15% and equals 12% at 30% change in input values. The relative change in interest rate for G+2 buildings is identical to G+1 buildings.

Change in Input Value for (G+2) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	2,014.22	2,301.97	2,589.72	2,877.46	3,165.21	3,452.96	3,740.70
MC	(AED/m2)	9.10	10.40	11.70	13.00	14.30	15.60	16.90
RC	(AED/m2)	243.78	278.61	313.43	348.26	383.08	417.91	452.74
EC	(AED/m2)	48.30	55.20	62.10	69.00	75.90	82.80	89.70
WC	(AED/m2)	6.19	7.07	7.96	8.84	9.72	10.61	11.49
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

Table 26: Change in input value for (G+2) buildings

LCC Sensitivity Analysis for (G+2) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	5,694.71	5,982.46	6,270.20	6,557.95	6,845.69	7,133.44	7,421.19
OC	(AED/m2)	6,281.91	6,373.92	6,465.94	6,557.95	6,649.96	6,741.97	6,833.98
MC	(AED/m2)	6,407.17	6,457.43	6,507.69	6,557.95	6,608.21	6,658.46	6,708.72
RC	(AED/m2)	6,486.41	6,510.25	6,534.10	6,557.95	6,581.79	6,605.64	6,629.49
EC	(AED/m2)	5,746.78	6,017.17	6,287.56	6,557.95	6,828.34	7,098.72	7,369.11
WC	(AED/m2)	6,487.28	6,510.84	6,534.39	6,557.95	6,581.50	6,605.06	6,628.61
Interest Rate %		7,386.83	7,085.89	6,810.40	6,557.95	6,326.36	6,113.69	5,918.20
M&RC		6,446.79	6,483.84	6,520.90	6,557.95	6,595.00	6,632.05	6,669.11
UC		6,117.03	6,264.00	6,410.98	6,557.95	6,704.92	6,851.89	6,998.86

Table 27: Life cycle cost for initial sensitivity for (G+2) buildings

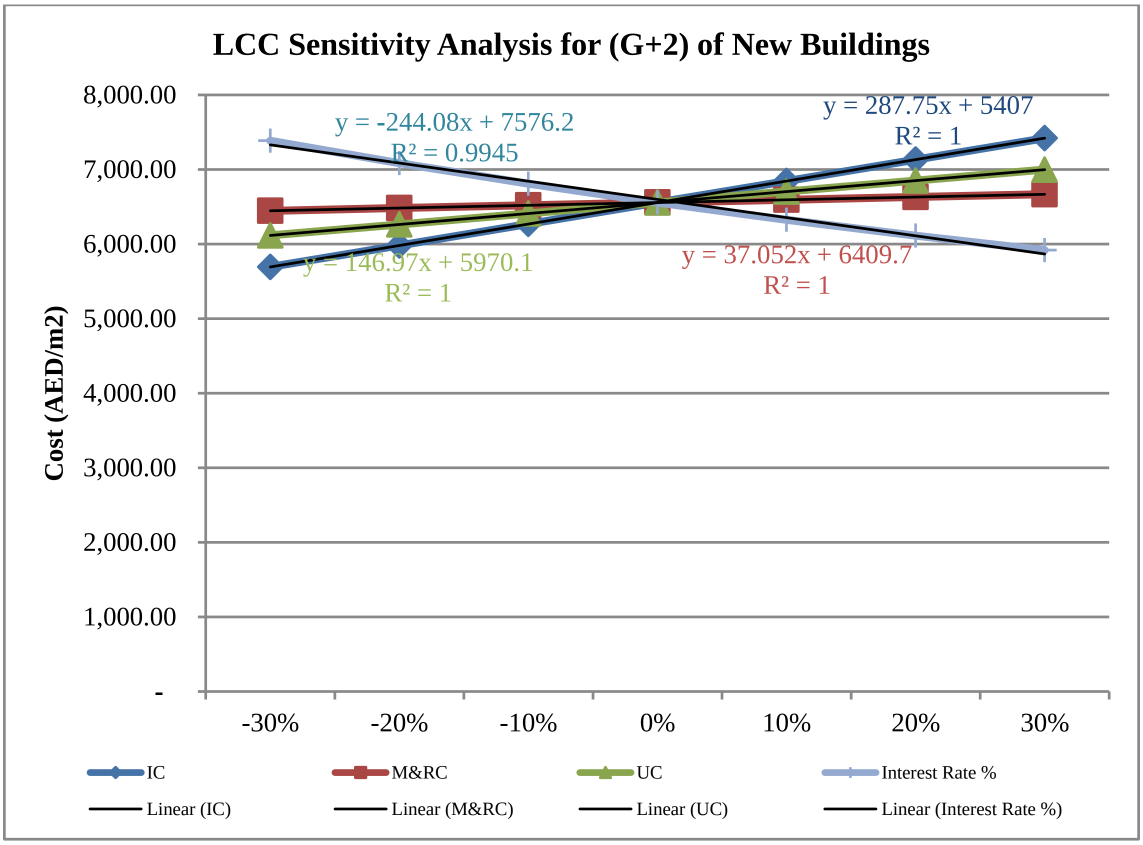


Figure 44: Sensitivity analysis for (G+2) buildings

6.6.3. Sensitivity Analysis for (G+3) for new Buildings

In a like manner, Table (28) outlines the change in input values for initial cost, maintenance cost, replacement cost, electricity cost, water cost and interest rate. Table (29) plots the output results of sensitivity analysis.

Results of the sensitivity analysis outputs were shown in Fig. (45), gives same ranking order with different slope values. The results of relative changes for initial cost and interest rate for G+3 buildings are typically like G+1 buildings.

Change in Input Value for (G+3) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	2,069.76	2,365.44	2,661.12	2,956.79	3,252.47	3,548.15	3,843.83
MC	(AED/m2)	8.44	9.64	10.85	12.05	13.26	14.46	15.67
RC	(AED/m2)	243.34	278.10	312.86	347.62	382.39	417.15	451.91
EC	(AED/m2)	51.85	59.26	66.66	74.07	81.48	88.88	96.29
WC	(AED/m2)	9.82	11.23	12.63	14.03	15.44	16.84	18.24
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

Table 28: Change in input value for (G+3) buildings

LCC Sensitivity Analysis for (G+3) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	5,971.78	6,267.46	6,563.14	6,858.82	7,154.50	7,450.18	7,745.86
OC	(AED/m2)	6,566.17	6,663.72	6,761.27	6,858.82	6,956.37	7,053.92	7,151.47
MC	(AED/m2)	6,719.07	6,765.65	6,812.24	6,858.82	6,905.41	6,951.99	6,998.58
RC	(AED/m2)	6,810.91	6,826.88	6,842.85	6,858.82	6,874.79	6,890.76	6,906.74
EC	(AED/m2)	5,988.06	6,278.31	6,568.57	6,858.82	7,149.07	7,439.33	7,729.58
WC	(AED/m2)	6,746.64	6,784.04	6,821.43	6,858.82	6,896.21	6,933.61	6,971.00
Interest Rate %		7,731.41	7,414.65	7,124.64	6,858.82	6,614.94	6,390.94	6,184.99
M&RC		6,764.99	6,796.26	6,827.54	6,858.82	6,890.10	6,921.38	6,952.66
UC		6,367.35	6,531.18	6,695.00	6,858.82	7,022.64	7,186.47	7,350.29

Table 29: Life cycle cost for initial sensitivity for (G+3) buildings

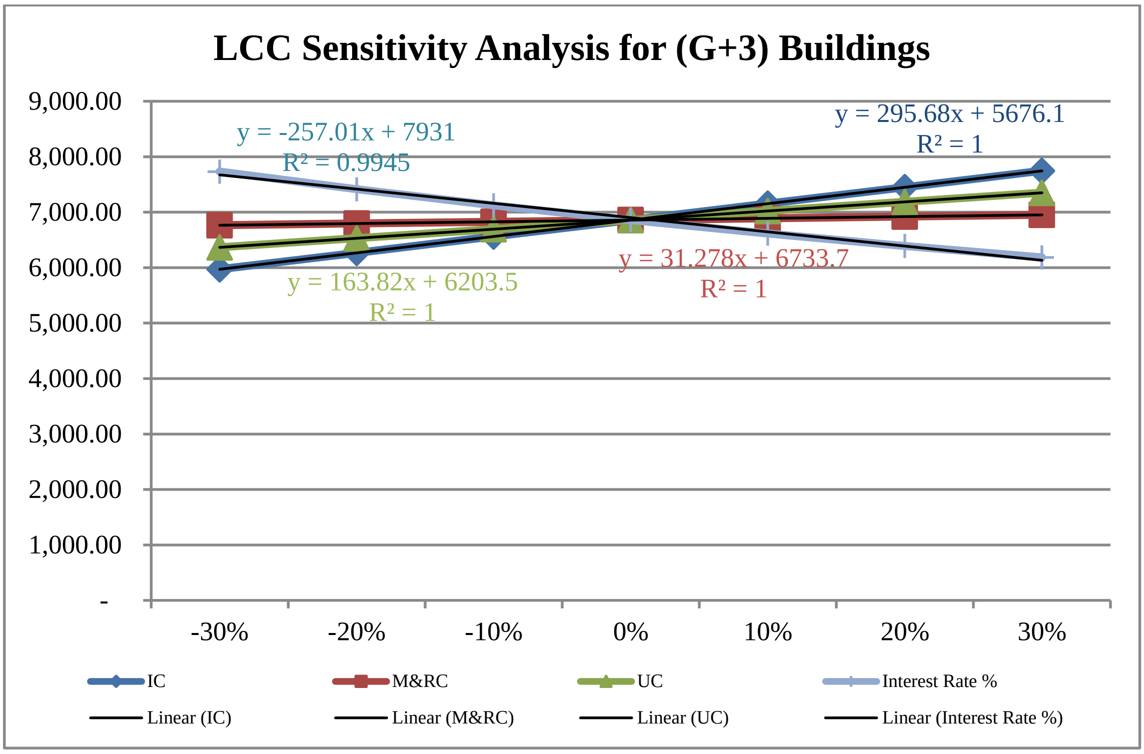


Figure 45: Sensitivity analysis for (G+3) buildings

6.6.4. Sensitivity Analysis for (G+4) for new Buildings

Finally, for (G+4) buildings Table (30) summarizes the change in input values for initial cost, maintenance cost, replacement cost, electricity cost, water cost and interest rate. Table (31) represents the output results of the sensitivity analysis.

Results of the sensitivity analysis outputs for G+4 new buildings were shown in Fig. (46), which shows thirdly the same ranking order with different slope values. The relative change in initial cost between -30% changes in input and the base equals -17% and equals 13% at 30% change in input values. Also, the relative change in interest rate between -30% change in input and the base equals 10% and equals the same value but in negative with the positive change in input values.

Change in Input Value for (G+4) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	2,718.80	3,107.20	3,495.60	3,884.00	4,272.40	4,660.80	5,049.20
MC	(AED/m2)	10.15	11.60	13.05	14.50	15.95	17.40	18.85
RC	(AED/m2)	297.60	340.12	382.63	425.15	467.66	510.18	552.69
EC	(AED/m2)	51.79	59.18	66.58	73.98	81.38	88.78	96.17
WC	(AED/m2)	11.87	13.57	15.26	16.96	18.66	20.35	22.05
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

Table 30: Life cycle cost for initial sensitivity for (G+3) buildings

LCC Sensitivity Analysis for (G+4) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	6,826.19	7,214.59	7,602.99	7,991.39	8,379.79	8,768.19	9,156.59
OC	(AED/m2)	7,683.34	7,786.02	7,888.71	7,991.39	8,094.08	8,196.76	8,299.45
MC	(AED/m2)	7,823.22	7,879.28	7,935.33	7,991.39	8,047.45	8,103.51	8,159.56
RC	(AED/m2)	7,932.63	7,952.22	7,971.81	7,991.39	8,010.98	8,030.56	8,050.15
EC	(AED/m2)	7,121.68	7,411.59	7,701.49	7,991.39	8,281.29	8,571.20	8,861.10
WC	(AED/m2)	7,855.81	7,901.01	7,946.20	7,991.39	8,036.58	8,081.78	8,126.97
Interest Rate %		8,908.85	8,575.83	8,270.90	7,991.39	7,734.93	7,499.35	7,282.75
M&RC		7,877.93	7,915.75	7,953.57	7,991.39	8,029.21	8,067.04	8,104.86
UC		7,488.75	7,656.30	7,823.84	7,991.39	8,158.94	8,326.49	8,494.03

Table 31: Life cycle cost for initial sensitivity for (G+3) buildings

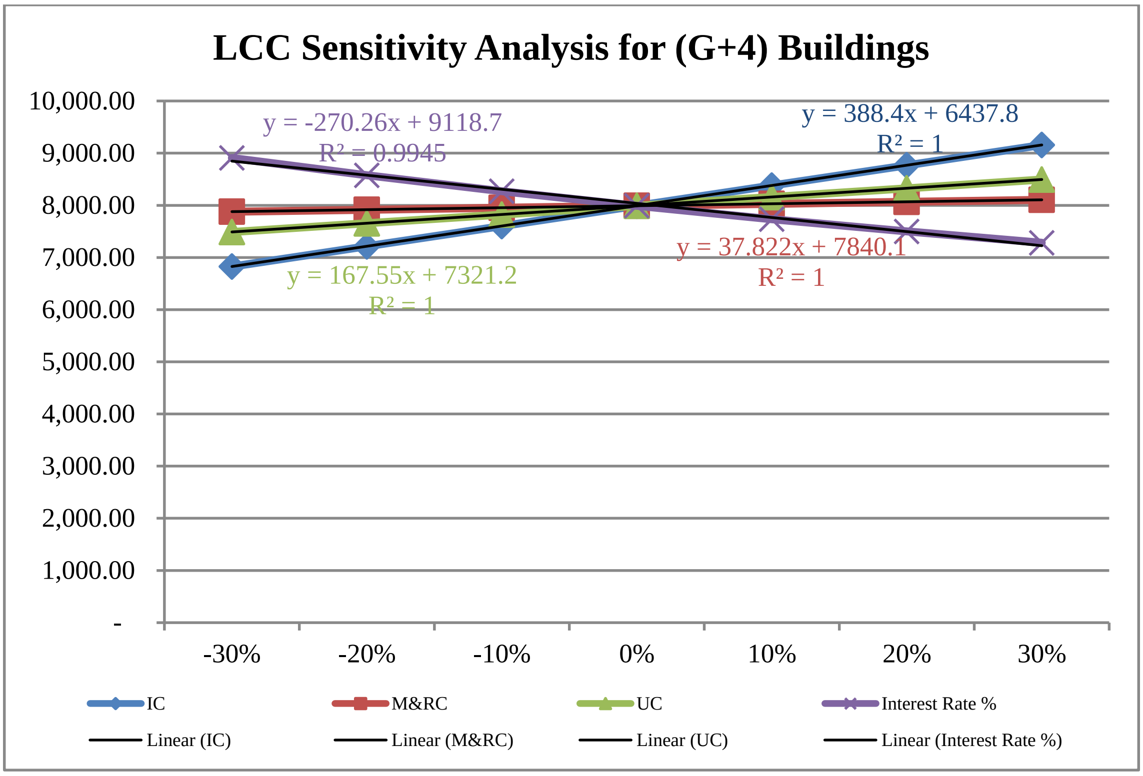


Figure 46: Sensitivity analysis for (G+4) buildings

Finally and from all the above, it has been noticed that the most sensitive cost is initial cost. Following initial cost at the second place is interest rate. Although utility cost impact is not high as much as initial cost and interest rate, utility cost comes at the third place with a huge difference in slope comparing to the final place (maintenance and replacement cost).

Furthermore, it has been found that initial cost has the highest slope for all types of buildings. Initial cost is proportionally increasing with the increase in change in input values. Whereas, results show that the sensitivity analysis for interest rate increases at the decrease of change in input value and decreases at the increase in change inputs values.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

Although life cycle cost analysis has been applied for a long by different organizations, practicing this analysis is still a challenge for many project managers and developers. This research analyses residential buildings from a financial perspective. Then value engineering methodology were introduces and its need and importance were illustrated.

The aim of this research is to apply the concept of life cycle cost analysis as a financial technique along with applying value engineering upon residential buildings in Al Ain city in the United Arab Emirates. The purpose of this research is to present the life cycle cost analysis data for new and old buildings in Al Ain. After that conduct another detailed comparison between these two categories. Also, researcher has compared Al Ain results to similar sample in the UK. Therefore, sensitivity analysis was examined to discover the most sensitive factor.

Results for the life cycle cost analysis for new buildings in Al Ain has shown that operation cost over 35 years is more than twice initial cost for (G+1), (G+2), (G+3) and (G+4) buildings.

It has been noticed that the most expensive cost is electricity cost. Electricity cost is approximately 6 times over the water cost for (G+1) buildings, 12 times over the water cost for (G+2) buildings, 9 times over the water cost for (G+3) buildings and 7 times over the water cost for (G+4) buildings.

As well, it is clear that maintenance cost does not have a notable weight through the lifetime of the project. Maintenance cost was so close to water cost. Also, replacement cost and demolition cost were almost zero unless some years. It has been noticed that replacement cost at 30 years is 3 times more than the required replacement cost at year 15^{th}.

On the other hand, results for the life cycle cost analysis for old buildings in Al Ain has shown that initial cost to operation cost in old buildings is approximately 1 to 3 for (G+1) and (G+2) buildings and initial cost to operation cost is 1 to 2.5 for (G+3) and (G+4) buildings.

It has been found that electricity cost is more than water cost by 19 times for (G+1) and (G+2) buildings and 6 times only for (G+3) and (G+4) buildings. Maintenance and water costs are so close to each other through the life cycle of 35 years.

A detailed comparison between new and old buildings in Al Ain based on initial cost, operation cost and net present value revealed that there is an extensive difference between new and old buildings in initial cost for (G+1) buildings, (G+1) new buildings cost almost 50% more than old buildings. In general, the average difference between new and old buildings for all types of buildings equals 38%. New buildings initial cost are more than old buildings initial cost due to the change in raw materials' prices, labour costs and new requirements by new authorities.

It has been found that the comparison indicates that operation cost for new buildings is obviously higher than operation cost for old buildings. Electricity cost is the most effective cost in both new and old buildings during the lifetime operation cost. It has been found that the annual electricity cost for new buildings is less than the annual electricity cost for old buildings. Old buildings are burdening the users and the government because of the non-energy efficiency installed appliances.

The annual electricity cost for old buildings is more than new buildings while the total operation cost for new buildings is more than old buildings through a life cycle of 35 years. That is because the decrease in tariff of electricity charge during the first twenty years from the old buildings' life, leads to decrease the total life cycle cost for old buildings.

On the other hand, water cost for new and old buildings are almost same because water cost was calculated based on the estimated number of bedrooms in each unit. Likewise, replacement costs were almost so close for the same reason.

Although maintenance cost does not have significant weight in operation cost, maintenance cost for new buildings is more than old buildings. Maintenance cost for new and old buildings have very small percentages of 13% and 7% respectively. Maintenance cost for old buildings is very small because most of owners do not want to spend more money to maintain their properties because they will be illegible to demolish and rebuild new building by a subsidized loan.

It has been found that there is variance in net present value between new and old buildings especially in (G+1) buildings reaches 43%. While the difference of NPV for (G+2) and (G+4) buildings between new and old are almost similar. The lowest difference in NPV was found for (G+3) buildings.

The second comparison between Al Ain new buildings and the UK residential buildings indicated that initial cost for both are near to each other. Operation cost was difficult to compare due to the difference in methodologies. While it was found that electricity cost in the UK occupies 38% from the total operation cost. The other proportions of 33.3% for maintenance and transport, 16.3% for wastewater treatment and 12.3% for water cost. For demolition cost, houses in the UK are higher than buildings in Al Ain by 100%.

After that a sensitivity analysis was conducted for new buildings in Al Ain. It has been noticed that the rank of the highest slopes are for initial cost, interest rate, utility cost and maintenance and replacement cost in order for all types of buildings. The relative change in initial cost at -30% change in input varies from -15% to -17% and the relative change in initial cost at 30% change in input varies 11% to 13%. Initial Cost increases with the increase in change in input values.

Also, the relative change in interest rate at -30% change was found 11% for (G+1), (G+2) and (G+3) buildings and 10% for (G+4) buildings. the relative change in interest rate at 30% change was found constant at -11% for (G+1), (G+2) and (G+3) buildings and -10% for (G+4) buildings. Interest rate decreases with the increase in input value.

7.2. Recommendations

- New buildings in Al Ain shows that initial cost are almost half of the operation cost through the life cycle of 35 years. This shows that initial cost reflects a significant amount. Indeed, initial cost was built based on the building's specification and the type of materials used in this building. Since, the sample was collected from ADCE databases, we can easily say that the specification for new buildings under ADCE supervision has good quality materials and energy efficient appliances. Initial cost for other buildings in Al Ain also, does not cost as much as it cost under ADCE. That is because ADCE design review team considers safety requirements, quality, environmental specifications and life cycle cost. These requirements increase the initial cost in order to increase the building life cycle more than 35 years. This is the concept of value engineering. Since, electricity cost is the most expensive cost, energy efficiency appliances affects the operation cost directly.
- Old buildings in Al Ain have very poor specification, non-energy efficient appliances and non-environmental materials. All of these factors lead to very high electricity consumption. Therefore, expensive operation cost more than operation cost in new buildings.
- Old buildings are burdening the government by supplying high electricity to cover the heavy consumption. Also, property owners are not able to rent their properties by the normal market rate as like new buildings. Both parties here are losing not earning that much from these old buildings. Therefore, we recommend either doing an extensive retrofitting for some appliances like air conditions, light systems and water heaters or, demolish the building and rebuild new building compatible with energy-efficient and sustainable requirements.
- We recommend to force all properties owners to follow new requirements and regulations to assist in increasing the building life cycle by installing energy efficient appliances and improving the maintenance schedule.

REFFRENCES AND APPENDICES

References

Abdullah, E. (2001). 'Experts discuss life span of buildings'. *General*, [online]. [Accessed 3 September 2016]. Available at: http://gulfnews.com/news/uae/general/experts-discuss-life-span-of-buildings-1.429893

Abu Dhabi Council for Economic Development & Abu Dhabi Urban Planning Council. (2007). *Abu Dhabi economic vision 2030 - Abu Dhabi urban planning vision 2030* [online]. Abu Dhabi:Abu Dhabi Council for Economic Development & Abu Dhabi Urban Planning Council. [Accessed 2016]. Available at: http://www.upc.gov.ae/template/upc/pdf/abu-dhabi-vision-2030-revised-en.pdf

Abu Dhabi Urban Planning Council. (2010). *Al Ain architectural guidelines* [online]. Abu Dhabi:Abu Dhabi Urban Planning Council. [Accessed 5 September 2016]. Available at: http://www.upc.gov.ae/template/upc/pdf/Al-Ain-Architectual-Guidelines-English.pdf

Abu Dhabi Water & Electricity Company. (2015a). *Statistical leaflet 2014* [online]. Abu Dhabi:Abu Dhabi Water & Electricity Company. [Accessed 27 September 2016]. Available at: http://www.adwec.ae/Documents/Leaflet/Statistical%20Leaflet%202014.pdf

Abu Dhabi Water & Electricity Company. (2015b). *Statistical report 1998 - 2014* [online]. Abu Dhabi:Abu Dhabi Water & Electricity Company. [Accessed 25 September 2016]. Available at: http://www.adwec.ae/Documents/Report/2015/2015StatisticalReport.pdf

Afshari, A., Nikolopoulou, C. & Martin, M. (2014). Life-cycle analysis of building retrofits at the urban scale: A case study in United Arab Emirates. *Sustainability*, vol. 6 (1), pp. 453–473.

Aktas, C.B. & Bilec, M.M. (2012). Impact of lifetime on US residential building LCA results. *The International Journal of Life Cycle Assessment*, vol. 17 (3), pp. 337–349.

Al Ain Distribution Company. (2015). *New electricity and water tariff* [online]. [Accessed 6 September 2016]. Available at: http://www.aadc.ae/en/pages/ElectricityWaterTariff.aspx

Al Awadi, W.Y. (2014). *Reducing of the energy consumption in the federal buildings in UAE using lighting and control technologies*. MSc. Thesis. British University in Dubai.

Ammar, M., Zayed, T. & Moselhi, O. (2013). Fuzzy-based life-cycle cost model for decision making under subjectivity. *Journal of Construction Engineering and Management*, vol. 139 (5), pp. 556–563.

Assaf, S., Jannadi, O.A. & Al-Tamimi, A. (2000). Computerized system for application of value engineering methodology. *Journal of Computing in Civil Engineering*, vol. 14 (3), pp. 206–214.

ASTM International. (2013). *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*.

Ates, S.A. (2015). Life cycle cost analysis: An evaluation of renewable heating systems in turkey. *Energy, Exploration & Exploitation*, vol. 33 (4), pp. 621–638.

Azeez, K., Zayed, T. & Ammar, M. (2013). Fuzzy- versus simulation-based life-cycle cost for sewer rehabilitation alternatives. *Journal of Performance of Constructed Facilities*, vol. 27 (5), pp. 656–665.

Borrego, M., Douglas, E.P. & Amelink, C.T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education*, vol. 98 (1), pp. 53–66.

Boubekri, M. (2012). Life cycle cost analysis of building re-lamping alternatives. *Journal of Renewable and Sustainable Energy*, vol. 4 (2), p. 023119.

Boussabaine, H.A. & Kirkham, R.J. (2004). *Whole life-cycle costing: Risk and risk responses*. Oxford, UK:Wiley, John & Sons.

Buys, A., Bendewald, M. & Tupper, K. (2011). Life cycle cost analysis: Is it worth the effort? *ASHRAE Transactions*, vol. 117 (1), pp. 541–548.

Cabeza, L.F., Rincón, L., Vilariño, V., Pérez, G. & Castell, A. (2014). Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renewable and Sustainable Energy Reviews*, vol. 29, pp. 394–416.

Cetiner, I. & Edis, E. (2014). An environmental and economic sustainability assessment method for the retrofitting of residential buildings. *Energy and Buildings*, vol. 74, pp. 132–140.

Chang, H.-J., Huang, K.-C. & Wu, C.-H. (2006). Determination of sample size in using central limit theorem for Weibull distribution. *Information and Management Sciences*, vol. 17 (3), pp. 31–46.

Choi, S.-M., Oh, S.-K. & Seo, C.-H. (2012). Construction of an evaluation system for selecting an appropriate waterproofing method for the roof of a building. *Canadian Journal of Civil Engineering*, vol. 39 (12), pp. 1264–1273.

Cuéllar-Franca, R.M. & Azapagic, A. (2014). Life cycle cost analysis of the UK housing stock. *The International Journal of Life Cycle Assessment*, vol. 19 (1), pp. 174–193.

Davis, K. (2016). A method to measure success dimensions relating to individual stakeholder groups. *International Journal of Project Management*, vol. 34 (3), pp. 480–493.

Department for Business, Innovation and Skills. (2013). *UK construction: an economic analysis for the sector*. London:Department for Business, Innovation and Skills (BIS).

Department of Finance. (n.d.). 'Commercial & Residential Buildings Loans Directorate'. *Department of Finance* [online]. [Accessed 13 December 2016]. Available at: http://dof.abudhabi.ae/en/portal/resd.loan.directorate.aspx

Dhillon, B.S. (2009). *Life cycle costing for engineers*. Boca Raton, FL:Taylor & Francis.

Dunston, P.S. & Williamson, C.E. (1999). Incorporating Maintainability in Constructability review process. *Journal of Management in Engineering*, vol. 15 (5), pp. 56–60.

Eisenberger, I. & Lorden, G. (1977). *Life-cycle costing : practical consideration* [online]. California:National Aeronautics and Space Administration. [Accessed 25 June 2016]. Available at: http://ipnpr.jpl.nasa.gov/progress_report2/42-40/40M.PDF

Elmakis, D. & Lisnianski, A. (2006). Life cycle cost analysis: Actual problem in industrial management. *Journal of Business Economics and Management*, vol. 7 (1), pp. 5–8.

Eno Center for Transportation & American Society of Civil Engineers. (2014). *Maximizing the Value of Investments Using Life Cycle Cost Analysis* [online]. Washington. [Accessed 2016]. Available at: https://www.enotrans.org/wp-content/uploads/2015/09/LCCA1.pdf

The Executive Council. (2007). *Policy Agenda 2007-2008: The Emirate of Abu Dhbai*. The Executive Council. [Accessed 2016].

Fuller, S. (2010). 'Life-cycle cost analysis (LCCA)'. *National Institute of Building Sciences* [online]. [Accessed 28 May 2016]. Available at: https://www.wbdg.org/resources/lcca.php?r=use_analysis

Gardiner, P.D. & Stewart, K. (2000). Revisiting the golden triangle of cost, time and quality: The role of NPV in project control, success and failure. *International Journal of Project Management*, vol. 18 (4), pp. 251–256.

General Secretariat of the Executive Council, Department of Planning Economy in Abu Dhabi & Abu Dhabi Council for Economic Development. (2008). *The Abu Dhabi Economic Vision 2030* [online]. Abu Dhabi: The Government of Abu Dhabi. [Accessed 2016]. Available at: https://www.ecouncil.ae/PublicationsEn/economic-vision-2030-full-versionEn.pdf

Goh, K.C. & Yang, J. (2014). Managing cost implications for highway infrastructure sustainability. *International Journal of Environmental Science and Technology*, vol. 11 (8), pp. 2271–2280.

Hamelin, M.-C. & Zmeureanu, R. (2014). Optimum envelope of a single-family house based on life cycle analysis. *Buildings*, vol. 4 (2), pp. 95–112.

Hastak, M. (2015). *Skills and Knowledge of Cost Engineering*. 6th edn. Morgantown:AACE International.

Heijungs, R., Settanni, E. & Guinée, J. (2013). Toward a computational structure for life cycle sustainability analysis: Unifying LCA and LCC. *The International Journal of Life Cycle Assessment*, vol. 18 (9), pp. 1722–1733.

Higham, A., Fortune, C. & James, H. (2015). Life cycle costing: Evaluating its use in UK practice. *Structural Survey*, vol. 33 (1), pp. 73–87.

Houdeshel, C.D., Pomeroy, C.A., Hair, L. & Moeller, J. (2011). Cost-estimating tools for low-impact development best management practices: Challenges, limitations, and implications. *Journal of Irrigation and Drainage Engineering*, vol. 137 (3), pp. 183–189.

Hwang, B.-G., Zhao, X. & Ong, S.Y. (2015). Value management in Singaporean building projects: Implementation status, critical success factors, and risk factors. *Journal of Management in Engineering*, vol. 31 (6), pp. 04014094–0 – 04014094–10.

International Standard Organization (ISO). (2016). *ISO/DIS 15686-5.2(en) Buildings and constructed assets — Service-life planning — Part 5: Life-cycle costing* [online]. [Accessed 13 September 2016]. Available at: https://www.iso.org/obp/ui/#iso:std:iso:15686:-5:dis:ed-2:v2:en

Karim, H., Magnusson, R. & Natanaelsson, K. (2012). Life-cycle cost analyses for road barriers. *Journal of Transportation Engineering*, vol. 138 (7), pp. 830–851.

Kim, H. & Kang, H. (2016). A study on development of a cost optimal and energy saving building model: Focused on industrial building. *Energies*, vol. 9 (3), p. 181.

Kim, T.-H., Lee, H.W. & Hong, S.-W. (2016). Value engineering for roadway expansion project over deep thick soft soils. *Journal of Construction Engineering and Management*, vol. 142 (2), p. 05015014.

Kshirsagar, A.S., El-GafyMohamedA. & Abdelhamid, T.S. (2010). Suitability of life cycle cost analysis (LCCA) as asset management tools for institutional buildings. *Journal of Facilities Management*, vol. 8 (3), pp. 162–178.

Kulczycka, J. & Smol, M. (2016). Environmentally friendly pathways for the evaluation of investment projects using life cycle assessment (LCA) and life cycle cost analysis (LCCA). *Clean Technologies and Environmental Policy*, vol. 18 (3), pp. 829–842.

Minne, E. & Crittenden, J.C. (2014). Impact of maintenance on life cycle impact and cost assessment for residential flooring options. *The International Journal of Life Cycle Assessment*, vol. 20 (1), pp. 36–45.

Naderpajouh, N. & Afshar, A. (2008). A case-based reasoning approach to application of value engineering methodology in the construction industry. *Construction Management and Economics*, vol. 26 (4), pp. 363–372.

National Bank of Abu Dhabi. (2016). 'Foreign exchange | NBAD UAE'. *NBAD UAE* [online]. [Accessed 1 October 2016]. Available at: https://www.nbad.com/en-ae/personal-banking/save-and-invest/foreign-exchange.html

National Center of Meteorology & Seismology. (n.d.). *BackClimate yearly report 2003-2015* [online]. [Accessed 26 September 2016]. Available at: http://www.ncms.ae/en/climate-reports-yearly.html?id=128

National Institute of Standards and Technology. (1996). *NIST handbook 135: Life-cycle costing manual for the Federal Energy Management Program*. 1995th edn. Washington, D.C:U.S. Government Printing Office.

Office National of Statistics. (2016). *Construction output in Great Britain: July 2016 and new orders quarter 2 (Apr to June) 2016*. UK:Office National of Statistics.

Park, H.S., Lee, D.C., Oh, B.K., Choi, S.W. & Kim, Y. (2014). Performance-based Multiobjective optimal seismic retrofit method for a steel moment-resisting frame considering the life-cycle cost. *Mathematical Problems in Engineering*, vol. 2014, pp. 1–14.

Ramesh, T., Prakash, R. & Kumar Shukla, K. (2013). Life cycle energy analysis of a multifamily residential house: A case study in Indian context. *Open Journal of Energy Efficiency*, vol. 02 (01), pp. 34–41.

Regulation & Supervision Bureau. (2009). *Guide to water supply regulations*. 1st edn. Abu Dhabi:Regulation & Supervision Bureau for the Water, Wastewater and Electricity Sector.

Regulation & Supervision Bureau. (2016). *How can I save electricity? residential: air conditioning* [online]. [Accessed 27 September 2016]. Available at: http://www.powerwise.gov.ae/en/section/how-can-i-save-electricity/residential/air-conditioning

Ren, Y. & Shan, J. (2014). Decision of national and provincial highway asphalt pavement structure based on value engineering. *Mathematical Problems in Engineering*, vol. 2014, pp. 1–8.

SAVE International. (2016). *SAVE: what is value engineering* [online]. [Accessed 10 June 2016]. Available at: http://www.value-eng.org/value_engineering.php

Seçer, M. & Bozdağ, Ö. (2011). Effect of x-bracing configuration on earthquake damage cost of steel building. *Journal of Civil Engineering and Management*, vol. 17 (3), pp. 348–356.

Shin, Y. & Cho, K. (2015). BIM application to select appropriate design alternative with consideration of LCA and LCCA. *Mathematical Problems in Engineering*, vol. 2015, pp. 1–14.

Shtub, A., Bard, J.F. & Globerson, S. (2005). *Project management: Engineering, technology and implementation*. 2nd edn. United States:Pearson Prentice Hall.

Singh, A., Berghorn, G., Joshi, S. & Syal, M. (2011). Review of life-cycle assessment applications in building construction. *Journal of Architectural Engineering*, vol. 17 (1), pp. 15–23.

Sloan, B., Tokede, O., Wamuziri, S. & Brown, A. (2014). Cost analysis error? Exploring issues relating to whole-life cost estimation in sustainable housing. *Journal of Financial Management of Property and Construction*, vol. 19 (1), pp. 4–23.

Statistic Centre - Abu Dhabi. (2016). *Statistical yearbook of Abu Dhabi* [online]. Abu Dhabi:Statistic Centre - Abu Dhabi. [Accessed 2016]. Available at: https://www.scad.ae/en/Pages/ThemePublication.aspx?PID=7&ThemeID=1

Stephan, A., Crawford, R.H. & de Myttenaere, K. (2012). Towards a comprehensive life cycle energy analysis framework for residential buildings. *Energy and Buildings*, vol. 55, pp. 592–600.

Swarr, T.E., Hunkeler, D., Klöpffer, W., Pesonen, H.-L., Ciroth, A., Brent, A.C. & Pagan, R. (2011). Environmental life-cycle costing: A code of practice. *The International Journal of Life Cycle Assessment*, vol. 16 (5), pp. 389–391.

Sweidan, O.D. (2012). Energy consumption and real output: New evidence from the UAE. *OPEC Energy Review*, vol. 36 (3), pp. 287–300.

Tang, P. & Bittner, R.B. (2014). Use of value engineering to develop creative design solutions for marine construction projects. *Practice Periodical on Structural Design and Construction*, vol. 19 (1), pp. 129–136.

Tesfamariam, S. & Sanchez-Silva, M. (2011). A model for earthquake risk management based on the life-cycle performance of structures. *Civil Engineering and Environmental Systems*, vol. 28 (3), pp. 261–278.

U.S. Energy Information Administration. (2015). *United Arab Emirates - international - U.S. Energy information administration (EIA)* [online]. [Accessed 26 September 2016]. Available at: http://www.eia.gov/beta/international/country.cfm?iso=ARE

United Arab Emirates - Ministry of Energy. (2014). *Statistical data for electricity and water 2013 - 2014*. Abu Dhabi:United Arab Emirates - Ministry of Energy. [Accessed 2016].

Vahdat-Aboueshagh, H., Nazif, S. & Shahghasemi, E. (2014). Development of an algorithm for sustainability based assessment of reservoir life cycle cost using fuzzy theory. *Water Resources Management*, vol. 28 (15), pp. 5389–5409.

Venkataraman, R.R. & Pinto, J.K. (2008). *Cost and Value Management in Projects*. New Jersey:John Wiley & Sons.

Yildiz, Y., Ozbalta, T. & Eltez, A. (2014). Energy-saving retrofitting of houses in cold climates. *Journal of Thermal Science and Technology*, vol. 34 (1), pp. 53–61.

Zeynalian, M., Trigunarsyah, B. & Ronagh, H.R. (2013). Modification of advanced programmatic risk analysis and management model for the whole project life cycle's risks. *Journal of Construction Engineering and Management*, vol. 139 (1), pp. 51–59.

APPENDICES

APPENDIX I

Questionnaire	استـــــــــــبيان
1. What is the typology of Building?	**1.ما هي مكونات المبنى ؟**
☐ G+1	☐ أرضي + أول
☐ G+2	☐ أرضي + أول + ثاني
☐ G+3	☐أرضي + أول + ثاني + ثالث
☐ G+4	☐أرضي + أول + ثاني + ثالث + رابع
2. How many units are in the building?	**2.كم عدد الوحدات في المبنى؟**
☐ 1 unit (Villa)	☐ وحدة واحدة (فيلا)
☐ From 2 – 5 Units	☐ من وحدتين إلى 5 وحدات
☐ From 6 – 10 Units	☐ من 6 وحدات إلى 10 وحدات
☐ More than 10 Units	☐ أكثرمن 10 وحدات
3. How old is the Building?	**3. كم يبلغ عمر المبنى ؟**
☐ Less than 10 years old	☐ أقل من 10 سنوات
☐ 10 – 20 years	☐ من 10 إلى 20 سنة
☐ 21 – 30 years	☐ من 21 إلى 30 سنة
☐ More than 31 years	☐من 31 سنة فأكثر
4. What is the Plot Area? (m2)	**4.ما هي مساحة قطعة الأرض ؟ (متر مربع)**
☐ Less than 500	☐ أقل من 500
☐ From 500 - 1000	☐ من 500 إلى 1000
☐ From 1001 - 2000	☐من 1001 إلى 2000
☐ More than 2001	☐ أكثر من 2001
5. What was the approximate cost of construction? (AED)	**5.كم كانت تكلفة البناء التقديرية ؟ (درهم)**
☐ Less than 1,000,000	☐ أقل من 1,000,000
☐ From 1,000,000 - 1,500,000	☐من 1,000,000 إلى 1,500,000
☐ From 1,500,001 – 2,000,000	☐من 1,500,001 إلى 2,000,000
☐ More than 2,000,001	☐أكثر من 2,000,001
6. What is the approximate cost of maintenance? (AED/year)	**6. ما هي تكلفة الصيانة التقديرية ؟ (درهم/السنة)**
☐ Less than 20,000	☐ أقل من 20,000

□ From 20,000 – 40,000	□ من 20,000 إلى 40,000
□ From 40,000 – 60,000	□ من 40,000 إلى 60,000
□ More than 60,000	□ أكثر من 60,000
7. What is the A/C Type?	**7.ما نوع تكييف الهواء المستخدم في المبنى؟**
□ AC Split Window	□ مكيف شباك منفصل
□ AC Split Ducted	□ مكيف أنبوبي منفصل
□ AC VRF System	□ مكيف صديق للبيئة
□ AC Chiller	□ مكيف مركزي
8. What is the lighting Type?	**8.ما نوع الإضاءة المستخدمة في المبنى؟**
□ Incandescent Lamps	□ إضاءة ساطعة / متوهجة
□ Compact or Florescent Lamp (CFL)	□ إضاءة فلوريسنت
□ Light Emitting Diodes (LEDs)	□ إضاءة موفرة للطاقة (LED)
□ Another lighting type	□ إضاءة من نوع آخر
9. What is the approximate income? (AED/year)	**9. كم يبلغ معدل الدخل التقريبي ؟ (درهم / السنة)**
□ Less than 500,000	□ أقل من 500,000
□ From 500,000 – 1,000,000	□ من 500,000 إلى 1,000,000
□ From 1,000,000 – 2,000,000	□ من 1,000,000 إلى 1,500,000
□ More than 2,000,000	□ أكثر من 2,000,000

S/N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
1	A	B	C	B		A	A	B	A
2	A	B	C	B		A	B	B	A
3	A	A	B	D		B	B	B	A
4	A	C	B	B		B	A	B	A
5	D	D	B	A		D	D	B	C
6	A	A	B	B		D	B	B	B
7	C	D	B	A		D	A	B	B
8	A	D	B	C		B	A	B	A
9	A	B	B	B		A	B	B	A
10	A	B	B	B		B	B	B	A
11	D	D	B	A		D	D	B	C
12	A	B	B	B		B	B	B	B
13	C	D	D	A	C	A	A	B	B
14	C	D	D	A	C	A	A	B	B
15	C	D	D	A	C	B	A	B	C
16	B	A	C	A	C	A	A	B	A
17	A	A	C	A	B	A	A	B	A
18	B	A	C	C	D	B	C	C	D
19	B	A	C	C	D	B	C	C	D
20	C	D	D	B		B	A	B	B
21	D	D	D	B		C	D	B	C
22	D	D	D	A		B	A	B	A
23	A	B	C	B	C	A	A	B	A
24	A	B	C	A	B	A	A	B	A
25	C	D	C	A	D	B	A	B	B
26	A	D	B	B	D	B	B	C	B
27	C	D	B	A	D	B	C	C	D
28	D	D	B	A	D	B	D	D	D
29	B	C	C	A	C	A	A	B	A
30	A	D	B	C	D	A	A	B	A
31	B	B	B	A	A	A	D	B	A
32	D	D	B	A	D	B	C	C	B

Total Life Cycle Cost for New Buildings in AL Ain

Legend	
PV=	Present Value
IC=	Initial Cost
MC =	Maintenance Cost
EC =	Electricty Cost
WC =	Water Cost
DC =	Demolition Cost

	Electricty			Water		
	Flat	Villa	Unit	Flat	Villa	Unit
Limit of	20	200	Kwh/d	700	5,000	lit/d
Consumption	7,300	73,000	Kwh/Yr	255,500	1,825,000	lit/Yr
Up to Limit	0.2100	0.2100	AED	5.95	5.95	AED
Over Limit	0.3180	0.3180	AED	10.550	10.550	AED

Estimation of Appliances Consumption			
	Unit	Avg. of Consumption	No. of Working hrs
AC	Watt/m2	65	8
Lightings	Watt/m2	12	10

Rounded Estimated of daily rate of consumption (liter)	
Residential Flat	
1 Bedroom	550
2 Bedroom	820
3 Bedroom	1000
4 Bedroom	1250

Input Value

Financial Factors	
Interest Rate of National Banks =	0.035

Economic Service Life = 35 Years

1 2 3 4

S/N	Building Typology	No. of 1BR	No.of 2BR	No. of 3BR	No. of 4BR	No. of units	Type of Units	Income (AED/Yr)	Plot Area (m^2)	Residential Area (m^2)	Built Up Area (m^2)	Date of Evaluating Initial Cost	Date of Handing Over	IC(AED)	IC (m2/AED)	Compound IC (m2/AED)	Lift MC (AED/Yr)	Civil MC (AED/Yr)	MEP MC (AED/Yr)
1	G+2	0	0	4	0	4	Villa	345,000	520	681	1,077	2012	2014	2,750,042	2,553	2,930	-	5,000	10,000
2	G+4	4	12	0	0	16	Apartment	267,512	432	1,403	2,761	2007	2011	8,747,680	3,168	4,318	-	15,000	11,000
3	G+1	0	0	8	0	8	Apartment	662,971	1,068	1,672	1,803	2007	2009	3,558,630	1,974	2,690	-	7,000	10,000
4	G+1	0	0	0	3	3	Villa	330,250	900	1,335	1,456	2008	2012	4,959,675	3,406	4,486	-	8,000	15,000
5	G+1	2	8	2	0	12	Apartment	576,050	900	1,256	1,642	2010	2012	4,290,000	2,613	3,212	6,500	6,000	10,000
6	G+1	2	8	0	0	10	Apartment	448,600	595	1,145	1,186	2010	2012	2,749,175	2,318	2,849	-	6,500	10,000
7	G+1	0	12	0	0	12	Apartment	652,400	900	1,362	1,410	2008	2009	4,377,417	3,105	4,088	-	10,000	8,000
8	G+4	4	16	4	0	24	Apartment	582,677	432	1,405	2,740	2009	2010	10,589,740	3,865	4,917	6,500	10,000	12,000
9	G+1	0	8	0	0	8	Villa	566,500	930	1,780	2,615	2009	2010	6,656,000	2,545	3,238	-	8,000	8,000
10	G+1	0	16	0	0	16	Apartment	410,025	325	1,285	2,154	2008	2010	8,960,640	4,160	5,478	6,000	12,000	11,000

S/N	MC (AED/Yr)	MC (AED/m2/yr)	AC (KW/Yr)	Lighting (KWh/yr)	EC in (KWh/Yr)	EC Up to Limit (AED)	EC Over Limit (AED)	EC (AED/Yr)	EC (AED/m2/Yr)	WC (Liter/Yr)	WC Up to Limit (AED)	WC Over Limit (AED)	WC (AED/Yr)	WC (AED/m2/Yr)	DC (AED)	DC (AED/m2)
1	15,000	13.9	204,415	47,173	251,587	15,330.00	56,791	72,121	67	1,460,000	10,859	-	10,859	10.08	40,000	37.1
2	26,000	9.4	524,038	120,932	644,970	1,533.00	202,779	204,312	74	4,394,600	1,520	43,667.51	45,188	16.37	100,000	36.2
3	17,000	9.4	342,209	78,971	421,181	1,533.00	131,614	133,147	73.85	2,920,000	1,520	28,110	29,631	16.43	25,000	13.9
4	23,000	15.8	276,349	63,773	340,122	15,330.00	84,945	100,275	68.87	1,368,750	10,859	-	10,859	7.46	25,000	17.2
5	22,500	13.7	311,652	71,920	383,571	1,533.00	119,654	121,187	73.80	3,525,900	1,520	34,503	36,023	21.94	25,000	15.2
6	16,500	13.9	225,103	51,947	277,050	1,533.00	85,780	87,313	73.62	2,795,900	1,520	26,801	28,321	23.88	25,000	21.1
7	18,000	12.8	267,618	61,758	329,376	1,533.00	102,420	103,953	73.73	3,591,600	1,520	35,196	36,716	26.04	25,000	17.7
8	28,500	10.4	520,052	120,012	640,064	1,533.00	201,219	202,752	74	7,051,800	1,520	71,701	73,221	26.72	100,000	36.5
9	16,000	6.1	496,327	114,537	610,864	15,330.00	171,041	186,371	71.27	2,394,400	10,859	6,007	16,866	6.45	25,000	9.6
10	29,000	13.5	408,829	94,345	503,174	1,533.00	157,688	159,221	73.92	4,788,800	1,520	47,826	49,347	22.91	25,000	11.6

APPENDIX II

LCC & NPV Results for New Buildings

1. (G+1) Buildings

LCC calculation for New Buildings in Al Ain for G+1

Input Values		No. of 1 BR	1.60	Inflation Rate	5.0%
G+1		No. of 2 BR	8.43	Interest Rate	3.50%
BUA	1,822.05	No. of 3 BR	1.17	Electricity Escalation rate	4.935%
		No. of 4 BR	0.10	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

(MC @ yr 5) (1+i)^(5yr)

	Rep. Yr	No. of Quant.	0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			3,108.91	-	-	-		-	-	-	-	-	-	-
Operation Cost					84.11	100.73	105.09	109.16	122.62	121.32	125.98	130.87	135.98	200.88
Maintenance Cost			-	-	0	12.47	12.47	12.47	12.47	15.92	15.92	15.92	15.92	15.92
Replacement Cost			-	-	-		-	-	9.21	-	-	-	-	59.55
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	22.37	-	-	-	-	-	-	9.21	-	-	-	-	11.75
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	5.49
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	5.49
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	22.37	-	-	-	-	-	-	-	-	-	-	-	36.83
Utilities Cost					84.11	88.26	92.62	96.69	100.95	105.40	110.07	114.95	120.06	125.41
Electricity Cost					66.77	70.06	73.52	77.15	80.96	84.95	89.14	93.54	98.16	103.00
Water Cost					17.35	18.20	19.10	19.54	19.99	20.45	20.93	21.41	21.90	22.41
Demolition Cost														
Total LCC			-	-	84.11	100.73	105.09	109.16	122.62	121.32	125.98	130.87	135.98	200.88
Total PV			3,108.91	-	81.27	94.04	94.79	95.13	103.25	98.69	99.02	99.38	99.77	142.41
Cumulative PV			3,108.91	3,108.91	3,190.17	3,284.21	3,379.00	3,474.12	3,577.37	3,676.06	3,775.08	3,874.46	3,974.23	4,116.64

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
151.32	157.19	163.32	169.75	248.92	189.14	196.52	204.25	212.34	300.97	236.86	246.16	255.90	266.11	301.22
20.31	20.31	20.31	20.31	20.31	25.92	25.92	25.92	25.92	25.92	33.09	33.09	33.09	33.09	33.09
-	-	-	-	72.44	-	-	-	-	80.15	-	-	-	-	24.43
-	-	-	-	27.44	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30.00	-	-	-	-	-	-	-	-	-	-
-	-	-	-	15.00	-	-	-	-	19.14	-	-	-	-	24.43
-	-	-	-	-	-	-	-	-	7.00	-	-	-	-	-
-	-	-	-	-	-	-	-	-	7.00	-	-	-	-	-
-	-	-	-	-	-	-	-	-	47.00	-	-	-	-	-
131.01	136.87	143.01	149.44	156.17	163.22	170.60	178.33	186.42	194.90	203.77	213.07	222.82	233.02	243.71
108.09	113.42	119.02	124.89	131.05	137.52	144.31	151.43	158.90	166.74	174.97	183.61	192.67	202.18	212.16
22.93	23.45	24.00	24.55	25.12	25.70	26.29	26.90	27.52	28.15	28.80	29.47	30.15	30.84	31.55
151.32	157.19	163.32	169.75	248.92	189.14	196.52	204.25	212.34	300.97	236.86	246.16	255.90	266.11	301.22
103.65	104.02	104.43	104.87	148.58	109.08	109.50	109.96	110.45	151.26	115.01	115.49	116.00	116.54	127.46
4,220.29	4,324.31	4,428.74	4,533.61	4,682.19	4,791.27	4,900.77	5,010.73	5,121.18	5,272.44	5,387.45	5,502.94	5,618.94	5,735.48	5,862.94

26	27	28	29	30	31	32	33	34	35	Total	Ratio to IC
-	-	-	-	-	-	-	-	-	-	3,108.91	
297.13	308.87	321.16	334.03	575.99	373.33	388.14	403.67	419.93	476.77	8,435.76	2.71
42.23	42.23	42.23	42.23	42.23	53.89	53.89	53.89	53.89	53.89	1,006.68	0.32
-	-	-	-	228.46	-	-	-	-	39.79	514.03	0.17
-	-	-	-	57.05	-	-	-	-	-	84.49	
-	-	-	-	62.37	-	-	-	-	-	92.37	
-	-	-	-	31.18	-	-	-	-	39.79	150.49	
-	-	-	-	8.94	-	-	-	-	-	21.43	
-	-	-	-	8.94	-	-	-	-	-	21.43	
-	-	-	-	59.99	-	-	-	-	-	143.81	
254.91	266.64	278.93	291.81	305.30	319.44	334.25	349.77	366.04	383.09	6,915.04	2.22
222.63	233.61	245.14	257.24	269.93	283.25	297.23	311.90	327.29	343.45	5,949.88	1.91
32.28	33.03	33.79	34.57	35.37	36.18	37.02	37.87	38.75	39.64	965.16	0.31
					-	-	-	-	89.12	89.12	0.03
297.13	308.87	321.16	334.03	575.99	373.33	388.14	403.67	419.93	476.77	8,435.76	
121.48	122.01	122.57	123.17	205.21	128.51	129.09	129.72	130.38	143.02	7,218.10	2.32
5,984.42	6,106.43	6,229.00	6,352.17	6,557.38	6,685.90	6,814.99	6,944.71	7,075.08	7,218.10		

2. (G+2) Buildings

LCC calculation for New Buildings in Al Ain for G+2

Input Values					
G+2		No. of 1 BR	-	Inflation Rate	5.0%
BUA	1,460.46	No. of 2 BR	-	Interest Rate	3.50%
		No. of 3 BR	2.75	Electricity Escalation rate	4.935%
		No. of 4 BR	2.00	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.	0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			2,877.46	-	-	-		-	-	-	-	-	-	-
Operation Cost					70.69	87.18	90.84	94.45	106.58	105.79	109.94	114.29	118.85	181.36
Maintenance Cost			-	-	0	13.00	13.00	13.00	13.00	16.59	16.59	16.59	16.59	16.59
Replacement Cost			-	-	-		-	-	8.34	-	-	-	-	57.72
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	16.25	-	-	-	-	-	-	8.34	-	-	-	-	10.65
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	6.85
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	6.85
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	16.25	-	-	-	-	-	-	-	-	-	-	-	33.38
Utilities Cost					70.69	74.18	77.84	81.45	85.23	89.19	93.35	97.70	102.26	107.04
Electricity Cost					62.66	65.75	69.00	72.41	75.98	79.73	83.66	87.79	92.12	96.67
Water Cost					8.03	8.42	8.84	9.04	9.25	9.47	9.68	9.91	10.14	10.37
Demolition Cost														
Total LCC			-	-	70.69	87.18	90.84	94.45	106.58	105.79	109.94	114.29	118.85	181.36
Total PV			2,877.46	-	68.30	81.38	81.93	82.31	89.73	86.06	86.41	86.79	87.21	128.57
Cumulative PV			2,877.46	2,877.46	2,945.76	3,027.15	3,109.08	3,191.39	3,281.12	3,367.18	3,453.59	3,540.38	3,627.59	3,756.15

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133.23	138.48	143.98	149.75	233.63	167.99	174.63	181.59	188.89	273.98	212.04	220.45	229.27	238.51	270.35
21.18	21.18	21.18	21.18	21.18	27.03	27.03	27.03	27.03	27.03	34.49	34.49	34.49	34.49	34.49
-	-	-	-	77.83	-	-	-	-	77.43	-	-	-	-	22.14
-	-	-	-	34.24	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30.00	-	-	-	-	-	-	-	-	-	-
-	-	-	-	13.59	-	-	-	-	17.35	-	-	-	-	22.14
-	-	-	-	-	-	-	-	-	8.74	-	-	-	-	-
-	-	-	-	-	-	-	-	-	8.74	-	-	-	-	-
-	-	-	-	-	-	-	-	-	42.60	-	-	-	-	-
112.05	117.30	122.81	128.57	134.62	140.96	147.60	154.57	161.87	169.52	177.55	185.96	194.78	204.02	213.72
101.44	106.45	111.70	117.21	123.00	129.07	135.44	142.12	149.13	156.49	164.22	172.32	180.82	189.75	199.11
10.61	10.86	11.11	11.36	11.62	11.89	12.17	12.45	12.74	13.03	13.33	13.64	13.95	14.27	14.60
133.23	138.48	143.98	149.75	233.63	167.99	174.63	181.59	188.89	273.98	212.04	220.45	229.27	238.51	270.35
91.25	91.64	92.06	92.51	139.45	96.88	97.30	97.76	98.25	137.69	102.96	103.42	103.92	104.46	114.40
3,847.41	3,939.05	4,031.11	4,123.62	4,263.07	4,359.95	4,457.26	4,555.02	4,653.27	4,790.96	4,893.92	4,997.35	5,101.27	5,205.73	5,320.13

26	27	28	29	30	31	32	33	34	35	Total	Ratio to IC
-	-	-	-	-	-	-	-	-	-	2,877.46	
267.90	278.56	289.73	301.44	552.21	338.77	352.28	366.44	381.29	432.93	7,598.27	2.64
44.02	44.02	44.02	44.02	44.02	56.19	56.19	56.19	56.19	56.19	1,049.47	0.36
-	-	-	-	238.48	-	-	-	-	36.07	518.02	0.18
-	-	-	-	71.17	-	-	-	-	-	105.41	
-	-	-	-	62.37	-	-	-	-	-	92.37	
-	-	-	-	28.26	-	-	-	-	36.07	136.40	
-	-	-	-	11.15	-	-	-	-	-	26.74	
-	-	-	-	11.15	-	-	-	-	-	26.74	
-	-	-	-	54.37	-	-	-	-	-	130.35	
223.88	234.53	245.71	257.42	269.71	282.59	296.09	310.25	325.10	340.68	6,030.79	2.10
208.94	219.25	230.07	241.42	253.34	265.84	278.96	292.73	307.17	322.33	5,584.08	1.94
14.94	15.29	15.64	16.00	16.37	16.75	17.13	17.53	17.93	18.35	446.70	0.16
					-	-	-	-	156.89	156.89	0.05
267.90	278.56	289.73	301.44	552.21	338.77	352.28	366.44	381.29	432.93	7,598.27	2.64
109.53	110.03	110.58	111.16	196.74	116.62	117.16	117.75	118.38	129.87	6,557.95	2.28
5,429.66	5,539.69	5,650.27	5,761.43	5,958.17	6,074.78	6,191.95	6,309.70	6,428.08	6,557.95		

3. (G+3) Buildings

LCC calculation for New Buildings in Al Ain for G+3

Input Values					
G+3		No. of 1 BR	10.00	Inflation Rate	5.0%
BUA	3,877.10	No. of 2 BR	6.40	Interest Rate	3.50%
		No. of 3 BR	2.40	Electricity Escalation rate	4.935%
		No. of 4 BR	0.40	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.	0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			2,956.79	-	-	-		-	-	-	-	-	-	-
Operation Cost					80.01	96.01	100.15	104.13	114.41	115.99	120.56	125.35	130.36	173.03
Maintenance Cost			-	-	0	12.05	12.05	12.05	12.05	15.38	15.38	15.38	15.38	15.38
Replacement Cost			-	-	-		-	-	6.11	-	-	-	-	37.41
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	31.60	-	-	-	-	-	-	6.11	-	-	-	-	7.80
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.58
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.58
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	31.60	-	-	-	-	-	-	-	-	-	-	-	24.45
Utilities Cost					80.01	83.96	88.10	92.08	96.25	100.61	105.18	109.97	114.98	120.24
Electricity Cost					67.27	70.59	74.07	77.72	81.56	85.59	89.81	94.24	98.89	103.77
Water Cost					12.74	13.37	14.03	14.36	14.69	15.03	15.37	15.73	16.09	16.46
Demolition Cost														
Total LCC			-	-	80.01	96.01	100.15	104.13	114.41	115.99	120.56	125.35	130.36	173.03
Total PV			2,956.79	-	77.30	89.63	90.33	90.74	96.33	94.36	94.76	95.19	95.65	122.66
Cumulative PV			2,956.79	2,956.79	3,034.10	3,123.72	3,214.06	3,304.80	3,401.13	3,495.49	3,590.25	3,685.44	3,781.10	3,903.76

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
145.36	151.13	157.16	163.49	222.97	182.48	189.75	197.37	205.36	264.22	229.41	238.60	248.23	258.32	285.11
19.63	19.63	19.63	19.63	19.63	25.05	25.05	25.05	25.05	25.05	31.97	31.97	31.97	31.97	31.97
-	-	-	-	52.85	-	-	-	-	50.50	-	-	-	-	16.22
-	-	-	-	12.90	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30.00	-	-	-	-	-	-	-	-	-	-
-	-	-	-	9.96	-	-	-	-	12.71	-	-	-	-	16.22
-	-	-	-	-	-	-	-	-	3.29	-	-	-	-	-
-	-	-	-	-	-	-	-	-	3.29	-	-	-	-	-
-	-	-	-	-	-	-	-	-	31.21	-	-	-	-	-
125.74	131.50	137.54	143.86	150.49	157.43	164.70	172.32	180.31	188.67	197.44	206.63	216.26	226.35	236.92
108.89	114.27	119.91	125.82	132.03	138.55	145.39	152.56	160.09	167.99	176.28	184.98	194.11	203.69	213.74
16.84	17.23	17.63	18.04	18.45	18.88	19.31	19.76	20.22	20.68	21.16	21.65	22.15	22.66	23.18
145.36	151.13	157.16	163.49	222.97	182.48	189.75	197.37	205.36	264.22	229.41	238.60	248.23	258.32	285.11
99.57	100.01	100.49	101.00	133.09	105.24	105.73	106.26	106.82	132.79	111.40	111.94	112.52	113.13	120.65
4,003.32	4,103.34	4,203.83	4,304.83	4,437.92	4,543.15	4,648.88	4,755.14	4,861.96	4,994.75	5,106.14	5,218.08	5,330.60	5,443.74	5,564.38

26	27	28	29	30	31	32	33	34	35	Total	Ratio to IC
-	-	-	-	-	-	-	-	-	-	2,956.79	
288.81	300.43	312.60	325.36	496.85	364.03	378.73	394.14	410.29	453.63	8,023.86	2.71
40.81	40.81	40.81	40.81	40.81	52.08	52.08	52.08	52.08	52.08	972.78	0.33
-	-	-	-	158.11	-	-	-	-	26.42	347.62	0.12
-	-	-	-	26.81	-	-	-	-	-	39.71	
-	-	-	-	62.37	-	-	-	-	-	92.37	
-	-	-	-	20.70	-	-	-	-	26.42	99.92	
-	-	-	-	4.20	-	-	-	-	-	10.07	
-	-	-	-	4.20	-	-	-	-	-	10.07	
-	-	-	-	39.83	-	-	-	-	-	95.49	
248.01	259.62	271.80	284.56	297.93	311.95	326.65	342.06	358.21	375.14	6,703.45	2.27
224.29	235.36	246.97	259.16	271.95	285.37	299.45	314.23	329.74	346.01	5,994.34	2.03
23.72	24.26	24.82	25.40	25.98	26.58	27.20	27.82	28.47	29.12	709.11	0.24
					-	-	-	-	120.57	120.57	0.04
288.81	300.43	312.60	325.36	496.85	364.03	378.73	394.14	410.29	453.63	8,023.86	2.71
118.08	118.67	119.31	119.98	177.02	125.31	125.96	126.65	127.38	136.08	6,858.82	2.32
5,682.46	5,801.13	5,920.44	6,040.42	6,217.43	6,342.74	6,468.70	6,595.36	6,722.74	6,858.82		

4. (G+4) Buildings

Input Values		No. of 1 BR	6.50	Inflation Rate	5.0%
G+4		No. of 2 BR	9.13	Interest Rate	4.55%
BUA	2,656.17	No. of 3 BR	0.81	Electricity Escalation rate	4.935%
		No. of 4 BR	-	Water Escalaion Rate	2.308%

LCC calculation for New Buildings in Al Ain for G+4

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.	0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			3,884.00	-	-	-		-	-	-	-	-	-	-
Operation Cost					82.59	105.51	109.79	113.83	125.74	127.70	132.34	137.19	142.28	195.64
Maintenance Cost			-	-	0	18.85	18.85	18.85	18.85	24.06	24.06	24.06	24.06	24.06
Replacement Cost			-	-	-		-	-	7.68	-	-	-	-	48.04
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	27.19	-	-	-	-	-	-	7.68	-	-	-	-	9.80
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	3.76
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	3.76
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	27.19	-	-	-	-	-	-	-	-	-	-	-	30.71
Utilities Cost					82.59	86.66	90.94	94.98	99.21	103.64	108.28	113.14	118.22	123.54
Electricity Cost					67.19	70.50	73.98	77.63	81.46	85.48	89.70	94.13	98.77	103.65
Water Cost					15.40	16.16	16.96	17.35	17.75	18.16	18.58	19.01	19.45	19.90
Demolition Cost														
Total LCC			-	-	82.59	105.51	109.79	113.83	125.74	127.70	132.34	137.19	142.28	195.64
Total PV			3,884.00	-	78.99	96.53	96.07	95.27	100.66	97.78	96.92	96.10	95.33	125.38
Cumulative PV			3,884.00	3,884.00	3,963.00	4,059.53	4,155.60	4,250.87	4,351.53	4,449.31	4,546.23	4,642.34	4,737.67	4,863.04

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
159.82	165.66	171.77	178.18	246.21	200.39	207.74	215.45	223.52	296.74	251.66	260.94	270.66	280.84	311.89
30.70	30.70	30.70	30.70	30.70	39.19	39.19	39.19	39.19	39.19	50.01	50.01	50.01	50.01	50.01
-	-	-	-	61.33	-	-	-	-	64.76	-	-	-	-	20.37
-	-	-	-	18.82	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30.00	-	-	-	-	-	-	-	-	-	-
-	-	-	-	12.51	-	-	-	-	15.96	-	-	-	-	20.37
-	-	-	-	-	-	-	-	-	4.80	-	-	-	-	-
-	-	-	-	-	-	-	-	-	4.80	-	-	-	-	-
-	-	-	-	-	-	-	-	-	39.19	-	-	-	-	-
129.12	134.96	141.07	147.47	154.18	161.20	168.55	176.26	184.33	192.78	201.64	210.92	220.64	230.83	241.50
108.76	114.13	119.76	125.67	131.87	138.38	145.21	152.38	159.90	167.79	176.07	184.76	193.87	203.44	213.48
20.36	20.83	21.31	21.80	22.30	22.82	23.34	23.88	24.43	25.00	25.57	26.16	26.77	27.39	28.02
159.82	165.66	171.77	178.18	246.21	200.39	207.74	215.45	223.52	296.74	251.66	260.94	270.66	280.84	311.89
97.97	97.12	96.33	95.57	126.31	98.33	97.50	96.72	95.97	121.87	98.86	98.04	97.27	96.54	102.54
4,961.01	5,058.13	5,154.46	5,250.03	5,376.34	5,474.67	5,572.17	5,668.89	5,764.86	5,886.73	5,985.59	6,083.63	6,180.90	6,277.43	6,379.97

26	27	28	29	30	31	32	33	34	35	Total	Ratio to IC
-	-	-	-	-	-	-	-	-	-	3,884.00	
316.52	328.23	340.51	353.38	556.65	398.62	413.43	428.95	445.21	495.44	8,791.01	2.26
63.83	63.83	63.83	63.83	63.83	81.47	81.47	81.47	81.47	81.47	1,521.73	0.39
-	-	-	-	189.79	-	-	-	-	33.18	425.15	0.11
-	-	-	-	39.13	-	-	-	-	-	57.96	
-	-	-	-	62.37	-	-	-	-	-	92.37	
-	-	-	-	26.00	-	-	-	-	33.18	125.49	
-	-	-	-	6.13	-	-	-	-	-	14.70	
-	-	-	-	6.13	-	-	-	-	-	14.70	
-	-	-	-	50.02	-	-	-	-	-	119.93	
252.68	264.40	276.68	289.54	303.03	317.15	331.96	347.48	363.75	380.79	6,844.13	1.76
224.02	235.07	246.67	258.85	271.62	285.03	299.09	313.85	329.34	345.59	5,987.11	1.54
28.66	29.33	30.00	30.70	31.40	32.13	32.87	33.63	34.41	35.20	857.02	0.22
					-	-	-	-	212.20	212.20	0.05
316.52	328.23	340.51	353.38	556.65	398.62	413.43	428.95	445.21	495.44	8,791.01	
99.53	98.73	97.96	97.24	146.51	100.35	99.55	98.79	98.07	104.39	7,421.09	1.91
6,479.51	6,578.23	6,676.19	6,773.43	6,919.94	7,020.29	7,119.84	7,218.63	7,316.70	7,421.09		

APPENDIX III

LCC & NPV Results for Old Buildings

1. (G+1) Buildings

LCC calculation for old Buildings in Al Ain for G+1

Input Values					
G+1		No. of 1 BR	1.60	Inflation Rate	5.0%
BUA	2,483.93	No. of 2 BR	8.43	Interest Rate	3.50%
		No. of 3 BR	1.17	Electricity Escalation rate	4.935%
		No. of 4 BR	0.10	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.			19	18	17	16	15	14	13	12	11	10
			0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			1,453.60	-	-	-		-	-	-	-	-	-	-
Operation Cost					110.65	120.62	133.75	64.27	70.69	70.77	74.27	77.93	81.78	111.49
Maintenance Cost			-	-	3.70	3.88	4.07	4.28	4.49	4.71	4.94	5.18	5.44	5.71
Replacement Cost			-	-	-		-	-	3.25	-	-	-	-	25.67
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	22.37	-	-	-	-	-	-	3.25	-	-	-	-	4.15
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.47
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.47
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	22.37	-	-	-	-	-	-	-	-	-	-	-	16.58
Utilities Cost					106.95	112.23	129.68	60.00	62.96	66.07	69.33	72.75	76.34	80.11
Electricity Cost					48.43	50.82	53.33	55.96	58.72	61.62	64.66	67.85	71.20	74.71
Water Cost					3.50	3.67	3.85	4.04	4.24	4.45	4.67	4.90	5.14	5.39
Demolition Cost														
Total LCC			-	-	110.65	116.11	133.75	64.27	70.69	70.77	74.27	77.93	81.78	111.49
Total PV			1,453.60	-	106.91	108.39	120.64	56.01	59.52	57.58	58.37	59.18	60.00	79.04
Cumulative PV			1,453.60	1,453.60	1,560.51	1,668.90	1,789.54	1,845.55	1,905.08	1,962.65	2,021.03	2,080.21	2,140.21	2,219.25

	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Initial Cost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operation Cost	90.05	94.49	99.16	104.05	153.75	114.57	120.23	126.16	132.39	173.15	145.09	151.56	158.34	168.01	184.09
Maintenance Cost	5.99	6.29	6.60	6.92	7.26	7.62	8.00	8.39	8.81	9.24	9.24	9.24	9.24	9.24	9.24
Replacement Cost	-	-	-	-	44.57	-	-	-	-	34.23	-	-	-	-	8.62
Civil Works															
GRP lining for Water Tank	-	-	-	-	15.77	-	-	-	-	-	-	-	-	-	-
External Paints	-	-	-	-	23.51	-	-	-	-	-	-	-	-	-	-
MEP Works															
Water heater	-	-	-	-	5.29	-	-	-	-	6.75	-	-	-	-	8.62
Booster pump	-	-	-	-	-	-	-	-	-	3.15	-	-	-	-	-
Transfer pump	-	-	-	-	-	-	-	-	-	3.15	-	-	-	-	-
DX units & DX units-compressor	-	-	-	-	-	-	-	-	-	21.17	-	-	-	-	-
Utilities Cost	84.06	88.21	92.56	97.13	101.92	106.95	112.23	117.77	123.58	129.68	135.85	142.32	149.10	156.22	163.67
Electricity Cost	78.40	82.27	86.33	90.59	95.06	99.75	104.68	109.84	115.26	120.95	126.92	133.18	139.75	146.65	153.89
Water Cost	5.66	5.94	6.23	6.54	6.86	7.20	7.56	7.93	8.32	8.73	8.93	9.14	9.35	9.56	9.79
Demolition Cost															
Total LCC	90.05	94.49	99.16	104.05	153.75	114.57	120.23	126.16	132.39	173.15	145.09	151.56	158.34	165.46	181.53
Total PV	61.68	62.53	63.40	64.28	91.77	66.08	66.99	67.92	68.86	87.02	70.45	71.10	71.77	72.46	76.82
Cumulative PV	2,280.93	2,343.46	2,406.86	2,471.14	2,562.92	2,628.99	2,695.98	2,763.90	2,832.77	2,919.78	2,990.24	3,061.34	3,133.11	3,205.58	3,282.39

6	7	8	9	10	11	12	13	14	15	Total	Ratio to IC
26	27	28	29	30	31	32	33	34	35		
-	-	-	-	-	-	-	-	-	-	1,453.60	
183.29	191.49	200.09	209.10	346.28	228.47	242.13	253.04	264.47	290.51	5,340.19	3.67
11.79	11.79	11.79	11.79	11.79	15.05	15.05	15.05	15.05	15.05	301.92	0.21
-	-	-	-	127.72	-	-	-	-	14.04	258.10	0.18
-	-	-	-	32.79	-	-	-	-	-	48.56	
-	-	-	-	48.87	-	-	-	-	-	72.37	
-	-	-	-	11.00	-	-	-	-	14.04	53.10	
-	-	-	-	4.03	-	-	-	-	-	9.65	
-	-	-	-	4.03	-	-	-	-	-	9.65	
-	-	-	-	27.01	-	-	-	-	-	64.76	
171.49	179.69	188.29	197.31	206.77	216.68	227.08	237.99	249.42	261.41	4,773.82	3.28
161.48	169.45	177.82	186.59	195.80	205.46	215.60	226.24	237.41	249.12	4,315.81	2.97
10.01	10.24	10.48	10.72	10.97	11.22	11.48	11.74	12.02	12.29	272.74	0.19
					-	-	-	-	34.93	34.93	0.02
183.29	191.49	200.09	209.10	346.28	231.73	242.13	253.04	264.47	290.51	5,333.84	3.67
74.93	75.64	76.36	77.11	123.37	79.77	80.53	81.31	82.11	87.14	4,120.68	2.83
3,357.33	3,432.97	3,509.33	3,586.44	3,709.81	3,789.58	3,870.11	3,951.42	4,033.53	4,120.68		

2. (G+2) Buildings

LCC calculation for Old Buildings in Al Ain for G+2

Input Values					
G+2		No. of 1 BR	-	Inflation Rate	5.0%
		No. of 2 BR	-	Interest Rate	3.50%
BUA	2,473.43	No. of 3 BR	2.75	Electricity Escalation rate	4.935%
		No. of 4 BR	2.00	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.			19	18	17	16	15	14	13	12	11	10
			0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			1,736.60	-	-	-		-	-	-	-	-	-	-
Operation Cost					108.33	118.18	130.93	62.97	68.45	69.34	72.76	76.35	80.12	104.16
Maintenance Cost			-	-	3.70	3.88	4.07	4.28	4.49	4.71	4.94	5.18	5.44	5.71
Replacement Cost			-	-	-		-	-	2.37	-	-	-	-	20.09
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	16.25	-	-	-	-	-	-	2.37	-	-	-	-	3.02
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.48
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.48
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	16.25	-	-	-	-	-	-	-	-	-	-	-	12.10
Utilities Cost					104.63	109.79	126.86	58.69	61.59	64.63	67.82	71.17	74.68	78.36
Electricity Cost					47.98	50.35	52.83	55.44	58.18	61.05	64.06	67.22	70.54	74.02
Water Cost					2.81	2.95	3.10	3.25	3.41	3.58	3.76	3.94	4.14	4.34
Demolition Cost														
Total LCC			-	-	108.33	113.67	130.93	62.97	68.45	69.34	72.76	76.35	80.12	104.16
Total PV			1,736.60	-	104.66	106.11	118.10	54.87	57.63	56.41	57.19	57.98	58.79	73.84
Cumulative PV			1,736.60	1,736.60	1,841.26	1,947.38	2,065.47	2,120.35	2,177.98	2,234.39	2,291.57	2,349.56	2,408.34	2,482.18

9	8	7	6	5	4	3	2	1	0	1	2	3	4	5
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88.22	92.58	97.14	101.94	150.17	112.25	117.79	123.60	129.70	160.74	140.11	146.48	153.16	162.15	175.78
5.99	6.29	6.60	6.92	7.26	7.62	8.00	8.39	8.81	7.17	7.17	7.17	7.17	7.17	7.17
-	-	-	-	43.21	-	-	-	-	26.71	-	-	-	-	6.29
-	-	-	-	15.84	-	-	-	-	-	-	-	-	-	-
-	-	-	-	23.51	-	-	-	-	-	-	-	-	-	-
-	-	-	-	3.86	-	-	-	-	4.93	-	-	-	-	6.29
-	-	-	-	-	-	-	-	-	3.17	-	-	-	-	-
-	-	-	-	-	-	-	-	-	3.17	-	-	-	-	-
-	-	-	-	-	-	-	-	-	15.44	-	-	-	-	-
82.23	86.29	90.55	95.02	99.71	104.63	109.79	115.21	120.89	126.86	132.94	139.31	145.99	153.00	160.34
77.68	81.51	85.53	89.75	94.18	98.83	103.71	108.82	114.19	119.83	125.74	131.95	138.46	145.29	152.46
4.56	4.78	5.02	5.27	5.53	5.80	6.08	6.38	6.70	7.03	7.19	7.36	7.53	7.70	7.88
88.22	92.58	97.14	101.94	150.17	112.25	117.79	123.60	129.70	160.74	140.11	146.48	153.16	160.17	173.80
60.43	61.26	62.11	62.98	89.64	64.73	65.63	66.54	67.46	80.78	68.03	68.72	69.42	70.15	73.54
2,542.61	2,603.88	2,665.99	2,728.96	2,818.60	2,883.34	2,948.97	3,015.51	3,082.97	3,163.75	3,231.78	3,300.50	3,369.93	3,440.07	3,513.62

6	7	8	9	10	11	12	13	14	15	Total	Ratio to IC
26	27	28	29	30	31	32	33	34	35		
-	-	-	-	-	-	-	-	-	-	1,736.60	
177.20	185.28	193.76	202.65	329.58	221.75	234.53	245.28	256.56	278.64	5,168.61	2.98
9.15	9.15	9.15	9.15	9.15	11.68	11.68	11.68	11.68	11.68	259.43	0.15
-	-	-	-	117.62	-	-	-	-	10.24	226.52	0.13
-	-	-	-	32.93	-	-	-	-	-	48.77	
-	-	-	-	48.87	-	-	-	-	-	72.37	
-	-	-	-	8.03	-	-	-	-	10.24	38.74	
-	-	-	-	4.04	-	-	-	-	-	9.69	
-	-	-	-	4.04	-	-	-	-	-	9.69	
-	-	-	-	19.71	-	-	-	-	-	47.25	
168.05	176.13	184.61	193.50	202.82	212.59	222.85	233.60	244.88	256.71	4,676.71	2.69
159.99	167.88	176.17	184.86	193.99	203.56	213.60	224.15	235.21	246.81	4,275.85	2.46
8.06	8.25	8.44	8.63	8.83	9.04	9.24	9.46	9.68	9.90	219.63	0.13
					-	-	-	-	22.66	22.66	0.01
177.20	185.28	193.76	202.65	329.58	224.27	234.53	245.28	256.56	278.64	5,162.67	
72.45	73.19	73.95	74.73	117.42	77.20	78.00	78.82	79.66	83.58	4,322.61	2.49
3,586.06	3,659.25	3,733.20	3,807.93	3,925.35	4,002.55	4,080.55	4,159.37	4,239.03	4,322.61		

3. (G+3) Buildings

Input Values		No. of 1 BR	10.00	Inflation Rate	5.0%
G+3		No. of 2 BR	6.40	Interest Rate	3.50%
BUA	2,077.05	No. of 3 BR	2.40	Electricity Escalation rate	4.935%
		No. of 4 BR	0.40	Water Escalaion Rate	2.308%

LCC calculation for Old Buildings in Al Ain for G+3

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.			19	18	17	16	15	14	13	12	11	10
			0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			2,416.30	-	-	-		-	-	-	-	-	-	-
Operation Cost					122.29	132.83	147.86	70.80	79.79	77.96	81.81	85.85	90.09	135.47
Maintenance Cost			-	-	3.70	3.88	4.07	4.28	4.49	4.71	4.94	5.18	5.44	5.71
Replacement Cost			-	-	-		-	-	5.49	-	-	-	-	40.94
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	31.60	-	-	-	-	-	-	5.49	-	-	-	-	7.01
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.96
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.96
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	31.60	-	-	-	-	-	-	-	-	-	-	-	28.02
Utilities Cost					118.59	124.44	143.79	66.53	69.81	73.26	76.87	80.66	84.65	88.82
Electricity Cost					48.65	51.05	53.57	56.21	58.98	61.89	64.95	68.15	71.52	75.05
Water Cost					8.93	9.37	9.83	10.32	10.83	11.36	11.92	12.51	13.13	13.78
Demolition Cost														
Total LCC			-	-	122.29	128.32	147.86	70.80	79.79	77.96	81.81	85.85	90.09	135.47
Total PV			2,416.30	-	118.15	119.79	133.36	61.70	67.18	63.42	64.30	65.19	66.10	96.04
Cumulative PV			2,416.30	2,416.30	2,534.45	2,654.25	2,787.61	2,849.31	2,916.49	2,979.91	3,044.22	3,109.41	3,175.51	3,271.54

	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Initial Cost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operation Cost	99.20	104.09	109.23	114.62	171.58	126.21	132.44	138.97	145.83	212.99	164.78	171.60	178.74	190.22	212.61
Maintenance Cost	5.99	6.29	6.60	6.92	7.26	7.62	8.00	8.39	8.81	14.48	14.48	14.48	14.48	14.48	14.48
Replacement Cost	-	-	-	-	51.31	-	-	-	-	54.72	-	-	-	-	14.56
Civil Works															
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	-	-	-	-	18.86	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	-	-	-	-	23.51	-	-	-	-	-	-	-	-	-	-
MEP Works															
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	-	-	-	-	8.94	-	-	-	-	11.41	-	-	-	-	14.56
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	-	-	-	-	-	-	-	-	-	3.77	-	-	-	-	-
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	-	-	-	-	-	-	-	-	-	3.77	-	-	-	-	-
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	-	-	-	-	-	-	-	-	-	35.76	-	-	-	-	-
Utilities Cost	93.21	97.81	102.63	107.70	113.01	118.59	124.44	130.58	137.03	143.79	150.30	157.12	164.26	171.74	179.57
Electricity Cost	78.75	82.64	86.72	91.00	95.49	100.20	105.14	110.33	115.78	121.49	127.49	133.78	140.38	147.31	154.58
Water Cost	14.46	15.17	15.92	16.70	17.53	18.39	19.30	20.25	21.25	22.30	22.81	23.34	23.88	24.43	24.99
Demolition Cost															
Total LCC	99.20	104.09	109.23	114.62	171.58	126.21	132.44	138.97	145.83	212.99	164.78	171.60	178.74	186.22	208.61
Total PV	67.94	68.89	69.84	70.81	102.42	72.79	73.80	74.82	75.86	107.04	80.01	80.51	81.02	81.56	88.27
Cumulative PV	3,339.49	3,408.37	3,478.21	3,549.02	3,651.44	3,724.22	3,798.02	3,872.84	3,948.69	4,055.73	4,135.75	4,216.25	4,297.27	4,378.83	4,467.10

6	7	8	9	10	11	12	13	14	15	Total	Ratio to IC
26	27	28	29	30	31	32	33	34	35		
-	-	-	-	-	-	-	-	-	-	2,416.30	
206.26	214.85	223.86	233.29	405.10	253.52	269.47	280.84	292.74	328.94	6,006.74	2.49
18.48	18.48	18.48	18.48	18.48	23.59	23.59	23.59	23.59	23.59	409.48	0.17
-	-	-	-	161.94	-	-	-	-	23.72	352.67	0.15
-	-	-	-	39.21	-	-	-	-	-	58.07	
-	-	-	-	48.87	-	-	-	-	-	72.37	
-	-	-	-	18.59	-	-	-	-	23.72	89.72	
-	-	-	-	4.81	-	-	-	-	-	11.54	
-	-	-	-	4.81	-	-	-	-	-	11.54	
-	-	-	-	45.64	-	-	-	-	-	109.42	
187.78	196.37	205.37	214.81	224.69	235.04	245.89	257.25	269.16	281.64	5,237.19	2.17
162.20	170.21	178.61	187.42	196.67	206.38	216.56	227.25	238.47	250.23	4,335.08	1.79
25.57	26.16	26.77	27.38	28.02	28.66	29.32	30.00	30.69	31.40	696.68	0.29
					-	-	-	-	58.00	58.00	0.02
206.26	214.85	223.86	233.29	405.10	258.63	269.47	280.84	292.74	328.94	5,999.33	2.48
84.33	84.87	85.44	86.02	144.33	89.03	89.62	90.25	90.89	98.68	5,410.55	2.24
4,551.43	4,636.30	4,721.73	4,807.76	4,952.09	5,041.11	5,130.74	5,220.98	5,311.87	5,410.55		

4. (G+4) Buildings

LCC calculation for Old Buildings in Al Ain for G+4

Input Values					
G+4		No. of 1 BR	6.50	Inflation Rate	5.0%
BUA	2,084.80	No. of 2 BR	9.13	Interest Rate	4.55%
		No. of 3 BR	0.81	Electricity Escalation rate	4.935%
		No. of 4 BR	-	Water Escalaion Rate	2.308%

SCA =	P*(1+i)^N
SPV =	F*(1/(1+i)^N)

	Rep. Yr	No. of Quant.			19	18	17	16	15	14	13	12	11	10
			0	0	1	2	3	4	5	6	7	8	9	10
Initial Cost			2,351.90	-	-	-		-	-	-	-	-	-	-
Operation Cost					122.22	132.76	147.78	70.77	78.96	77.92	81.77	85.80	90.04	130.40
Maintenance Cost			-	-	3.70	3.88	4.07	4.28	4.49	4.71	4.94	5.18	5.44	5.71
Replacement Cost			-	-	-		-	-	4.71	-	-	-	-	35.91
Civil Works			-											
GRP lining for Water Tank, Replacement cost in 15th year of AED 25,000	15	2	-	-	-	-	-	-	-	-	-	-	-	-
External Paints, Replacement cost in 15th year of AED/m' 30	15	1	-	-	-	-	-	-	-	-	-	-	-	-
MEP Works	-													
Water heater, Replacement cost in 5th, 10th, 15th, 20th, 25th, 30th & 35th year of AED 750	5	27.19	-	-	-	-	-	-	4.71	-	-	-	-	6.01
Booster pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.94
Transfer pump, Replacement cost in 10th & 20th year of AED 10,000	10	1	-	-	-	-	-	-	-	-	-	-	-	2.94
DX units & DX units-compressor, Replacement cost in 10th, 20th &30th year of AED 3000	15	27.19	-	-	-	-	-	-	-	-	-	-	-	24.02
Utilities Cost					118.52	124.37	143.71	66.49	69.77	73.22	76.83	80.62	84.60	88.77
Electricity Cost					48.65	51.05	53.57	56.21	58.98	61.89	64.95	68.15	71.52	75.05
Water Cost					8.90	9.34	9.80	10.28	10.79	11.32	11.88	12.47	13.08	13.73
Demolition Cost														
Total LCC			-	-	122.22	128.26	147.78	70.77	78.96	77.92	81.77	85.80	90.04	130.40
Total PV			2,351.90	-	118.09	119.73	133.29	61.67	66.48	63.39	64.27	65.16	66.06	92.44
Cumulative PV			2,351.90	2,351.90	2,469.99	2,589.72	2,723.01	2,784.68	2,851.16	2,914.55	2,978.82	3,043.98	3,110.05	3,202.49

9	8	7	6	5	4	3	2	1	0	1	2	3	4	5
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.14	104.04	109.17	114.56	170.17	126.14	132.37	138.90	145.76	214.08	172.64	179.45	186.59	200.26	220.58
5.99	6.29	6.60	6.92	7.26	7.62	8.00	8.39	8.81	22.42	22.42	22.42	22.42	22.42	22.42
-	-	-	-	49.96	-	-	-	-	47.95	-	-	-	-	12.48
-	-	-	-	18.79	-	-	-	-	-	-	-	-	-	-
-	-	-	-	23.51	-	-	-	-	-	-	-	-	-	-
-	-	-	-	7.66	-	-	-	-	9.78	-	-	-	-	12.48
-	-	-	-	-	-	-	-	-	3.76	-	-	-	-	-
-	-	-	-	-	-	-	-	-	3.76	-	-	-	-	-
-	-	-	-	-	-	-	-	-	30.66	-	-	-	-	-
93.15	97.75	102.58	107.64	112.95	118.52	124.37	130.51	136.95	143.71	150.22	157.03	164.17	171.65	179.48
78.75	82.64	86.72	91.00	95.49	100.20	105.14	110.33	115.78	121.49	127.49	133.78	140.38	147.31	154.58
14.40	15.11	15.86	16.64	17.46	18.33	19.23	20.18	21.18	22.22	22.73	23.26	23.79	24.34	24.91
99.14	104.04	109.17	114.56	170.17	126.14	132.37	138.90	145.76	214.08	172.64	179.45	186.59	194.07	214.39
67.91	68.85	69.80	70.77	101.57	72.75	73.76	74.78	75.82	107.59	83.83	84.19	84.58	84.99	90.72
3,270.40	3,339.25	3,409.05	3,479.82	3,581.40	3,654.14	3,727.90	3,802.68	3,878.50	3,986.09	4,069.92	4,154.11	4,238.69	4,323.68	4,414.40

6	7	8	9	10	11	12	13	14	15	Total	Ratio to IC
26	27	28	29	30	31	32	33	34	35		
-	-	-	-	-	-	-	-	-	-	2,351.90	
216.30	224.89	233.89	243.32	405.79	263.55	282.30	293.66	305.57	338.38	6,139.96	2.61
28.61	28.61	28.61	28.61	28.61	36.52	36.52	36.52	36.52	36.52	572.45	0.24
-	-	-	-	152.59	-	-	-	-	20.34	323.94	0.14
-	-	-	-	39.07	-	-	-	-	-	57.86	
-	-	-	-	48.87	-	-	-	-	-	72.37	
-	-	-	-	15.93	-	-	-	-	20.34	76.91	
-	-	-	-	4.80	-	-	-	-	-	11.50	
-	-	-	-	4.80	-	-	-	-	-	11.50	
-	-	-	-	39.13	-	-	-	-	-	93.80	
187.68	196.28	205.28	214.71	224.59	234.94	245.78	257.14	269.05	281.52	5,234.57	2.23
162.20	170.21	178.61	187.42	196.67	206.38	216.56	227.25	238.47	250.23	4,335.08	1.84
25.48	26.07	26.67	27.29	27.92	28.56	29.22	29.89	30.58	31.29	694.18	0.30
					-	-	-	-	37.79	37.79	0.02
216.30	224.89	233.89	243.32	405.79	271.46	282.30	293.66	305.57	338.38	6,130.96	2.61
88.43	88.83	89.27	89.72	144.57	93.44	93.89	94.37	94.87	101.51	5,393.31	2.29
4,502.83	4,591.67	4,680.93	4,770.66	4,915.23	5,008.67	5,102.56	5,196.93	5,291.80	5,393.31		

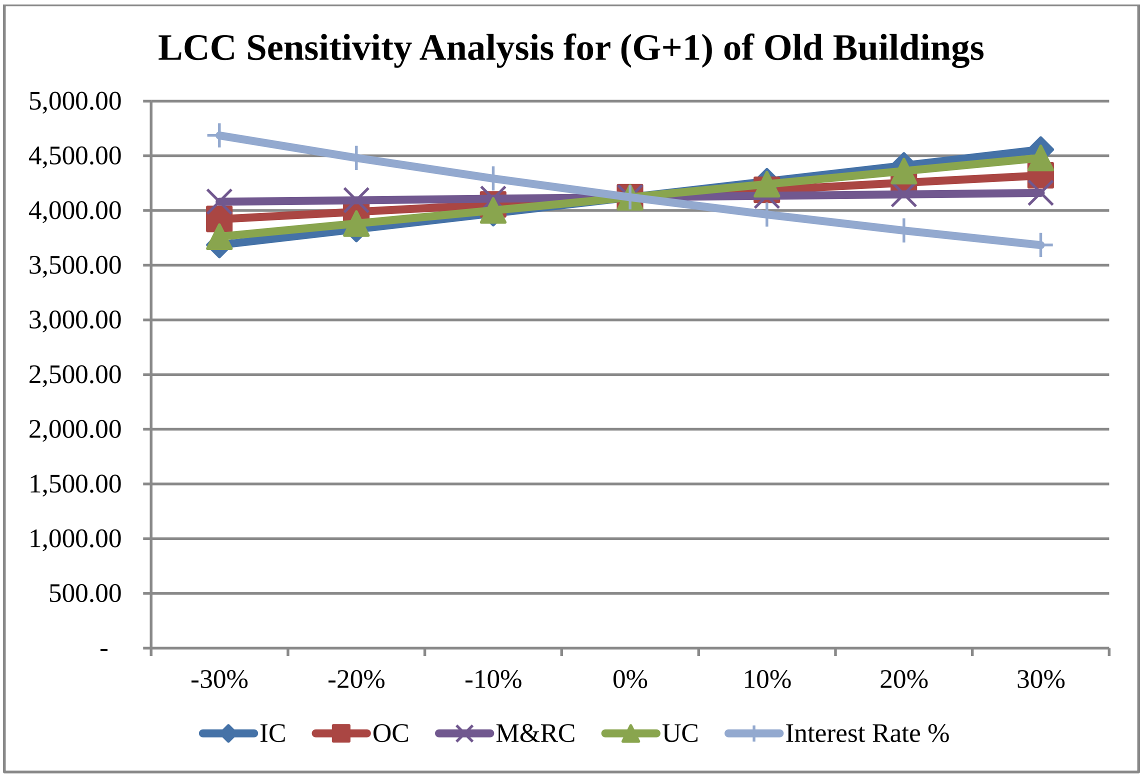
APPENDIX IV

Sensitivity Analysis for Old Buildings in Al Ain

1. (G+1) Buildings

Change in Input Value for (G+1) buildings								
Variables		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	1,017.52	1,162.88	1,308.24	1,453.60	1,598.96	1,744.32	1,889.68
MC	(AED/m2)	6.47	7.39	8.32	9.24	10.16	11.09	12.01
RC	(AED/m2)	180.67	206.48	232.29	258.10	283.91	309.72	335.53
EC	(AED/m2)	84.67	96.76	108.86	120.95	133.05	145.14	157.24
WC	(AED/m2)	6.11	6.98	7.86	8.73	9.60	10.48	11.35
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

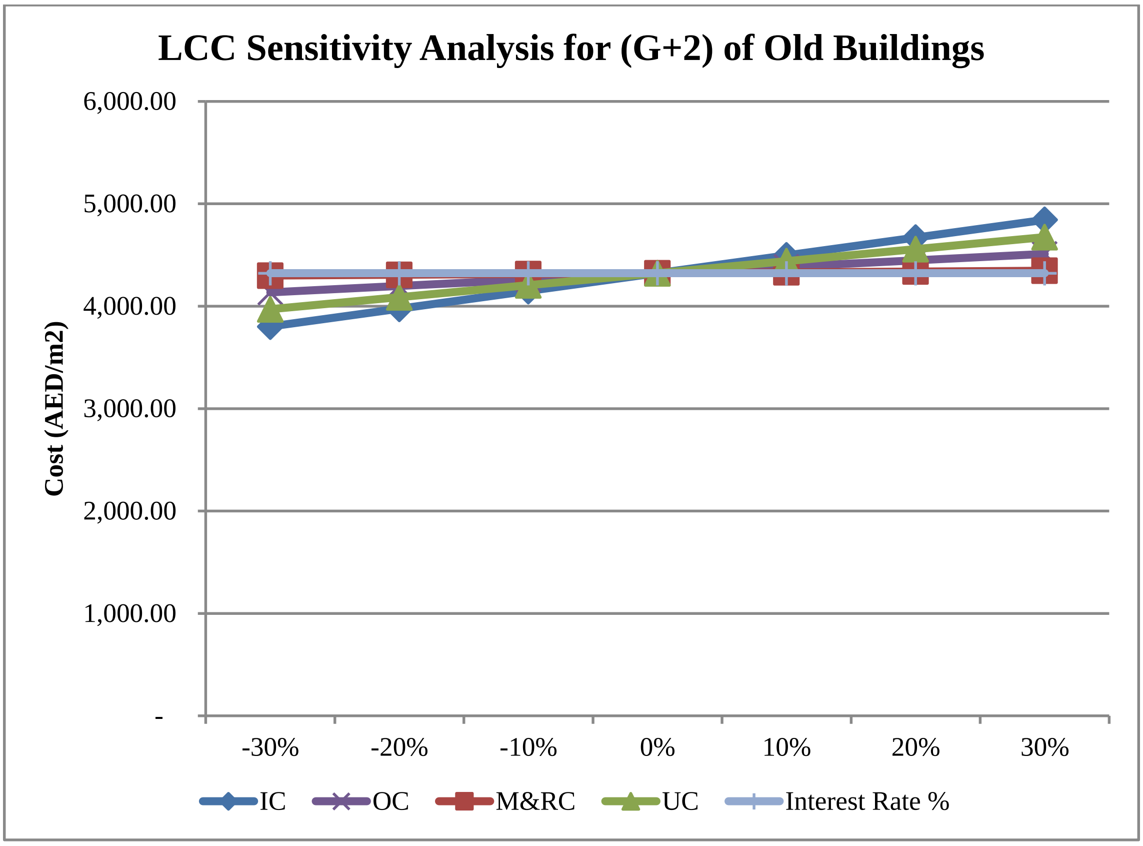
LCC Sensitivity Analysis for (G+1) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	3,684.60	3,829.96	3,975.32	4,120.68	4,266.04	4,411.40	4,556.76
OC	(AED/m2)	3,920.65	3,987.32	4,054.00	4,120.68	4,187.36	4,254.03	4,320.71
MC	(AED/m2)	4,075.84	4,090.79	4,105.73	4,120.68	4,135.62	4,150.57	4,165.51
RC	(AED/m2)	4,085.25	4,097.06	4,108.87	4,120.68	4,132.49	4,144.30	4,156.11
EC	(AED/m2)	3,445.49	3,670.55	3,895.62	4,120.68	4,345.74	4,570.80	4,795.86
WC	(AED/m2)	4,076.01	4,090.90	4,105.79	4,120.68	4,135.57	4,150.46	4,165.35
Interest Rate %		4,685.75	4,480.68	4,292.87	4,120.68	3,962.64	3,817.45	3,683.90
M&RC		4,080.55	4,093.92	4,107.30	4,120.68	4,134.06	4,147.43	4,160.81
UC		3,760.75	3,880.73	4,000.70	4,120.68	4,240.65	4,360.63	4,480.61



2. (G+2) Buildings

Change in Input Value for (G+2) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	1,215.62	1,389.28	1,562.94	1,736.60	1,910.26	2,083.92	2,257.58
MC	(AED/m2)	5.02	5.74	6.45	7.17	7.89	8.60	9.32
RC	(AED/m2)	158.56	181.22	203.87	226.52	249.17	271.82	294.47
EC	(AED/m2)	83.88	95.86	107.85	119.83	131.81	143.80	155.78
WC	(AED/m2)	4.92	5.62	6.33	7.03	7.73	8.44	9.14
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

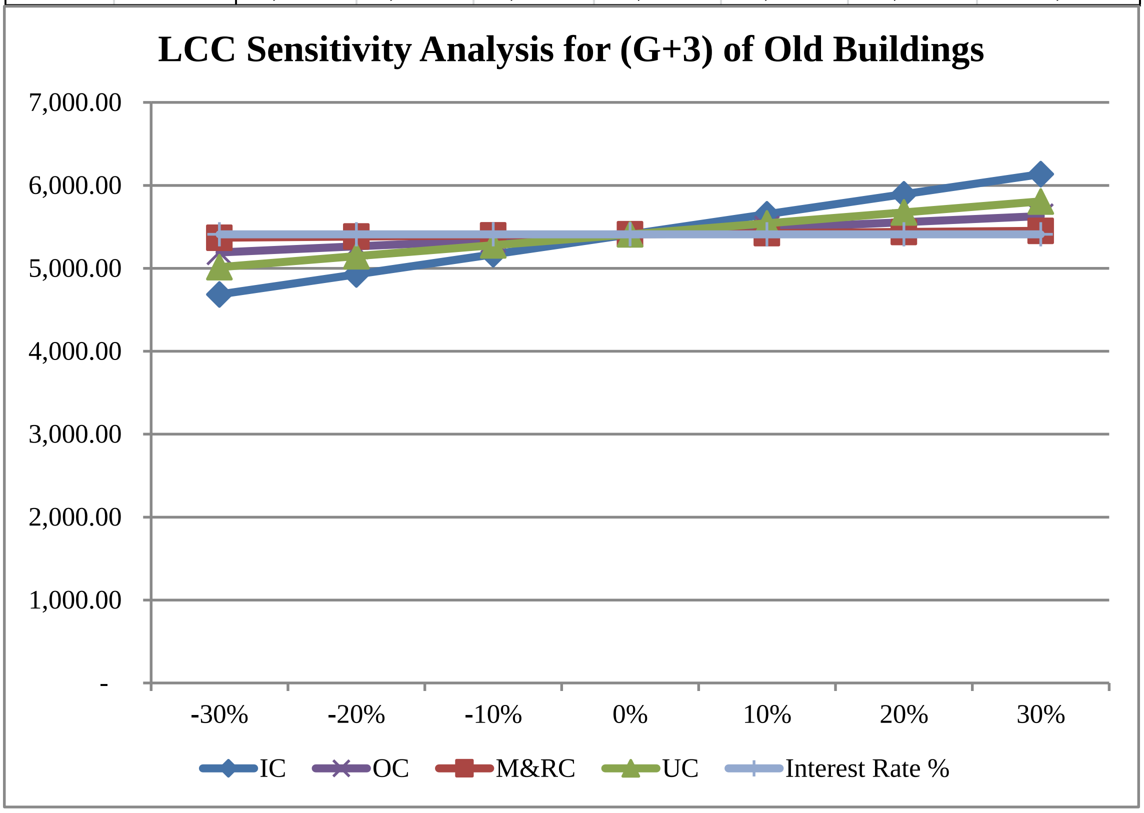
LCC Sensitivity Analysis for (G+2) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	3,801.63	3,975.29	4,148.95	4,322.61	4,496.27	4,669.93	4,843.59
OC	(AED/m2)	4,134.45	4,197.17	4,259.89	4,322.61	4,385.34	4,448.06	4,510.78
MC	(AED/m2)	4,305.77	4,311.39	4,317.00	4,322.61	4,328.23	4,333.84	4,339.46
RC	(AED/m2)	4,291.69	4,302.00	4,312.31	4,322.61	4,332.92	4,343.23	4,353.54
EC	(AED/m2)	3,653.68	3,876.66	4,099.64	4,322.61	4,545.59	4,768.57	4,991.55
WC	(AED/m2)	4,286.64	4,298.63	4,310.62	4,322.61	4,334.61	4,346.60	4,358.59
Interest Rate %		4,322.61	4,322.61	4,322.61	4,322.61	4,322.61	4,322.61	4,322.61
M&RC		4,298.73	4,306.69	4,314.65	4,322.61	4,330.58	4,338.54	4,346.50
UC		3,970.16	4,087.65	4,205.13	4,322.61	4,440.10	4,557.58	4,675.07



3. (G+3) Buildings

Change in Input Value for (G+3) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	1,691.41	1,933.04	2,174.67	2,416.30	2,657.93	2,899.56	3,141.19
MC	(AED/m2)	10.14	11.58	13.03	14.48	15.93	17.38	18.82
RC	(AED/m2)	246.87	282.14	317.40	352.67	387.94	423.20	458.47
EC	(AED/m2)	85.04	97.19	109.34	121.49	133.64	145.79	157.94
WC	(AED/m2)	15.61	17.84	20.07	22.30	24.53	26.76	28.99
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

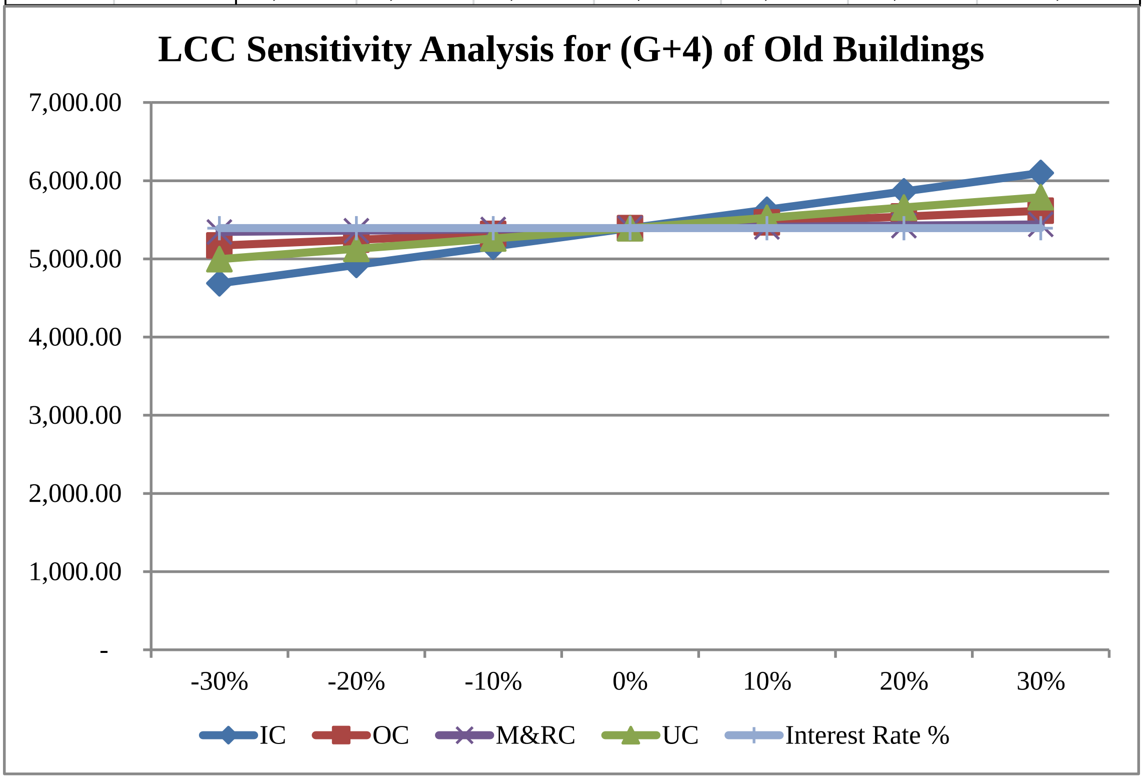
LCC Sensitivity Analysis for (G+3) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	4,685.66	4,927.29	5,168.92	5,410.55	5,652.18	5,893.81	6,135.44
OC	(AED/m2)	5,191.76	5,264.69	5,337.62	5,410.55	5,483.48	5,556.41	5,629.33
MC	(AED/m2)	5,376.53	5,387.87	5,399.21	5,410.55	5,421.89	5,433.23	5,444.56
RC	(AED/m2)	5,361.73	5,378.00	5,394.27	5,410.55	5,426.82	5,443.10	5,459.37
EC	(AED/m2)	4,732.35	4,958.41	5,184.48	5,410.55	5,636.62	5,862.68	6,088.75
WC	(AED/m2)	5,296.44	5,334.48	5,372.51	5,410.55	5,448.58	5,486.62	5,524.66
Interest Rate %		5,410.55	5,410.55	5,410.55	5,410.55	5,410.55	5,410.55	5,410.55
M&RC		5,369.13	5,382.94	5,396.74	5,410.55	5,424.35	5,438.16	5,451.97
UC		5,014.39	5,146.45	5,278.50	5,410.55	5,542.60	5,674.65	5,806.70



4. G+4 Buildings

Change in Input Value for (G+4) buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	1,646.33	1,881.52	2,116.71	2,351.90	2,587.09	2,822.28	3,057.47
MC	(AED/m2)	15.69	17.94	20.18	22.42	24.66	26.90	29.15
RC	(AED/m2)	226.76	259.15	291.55	323.94	356.33	388.73	421.12
EC	(AED/m2)	85.04	97.19	109.34	121.49	133.64	145.79	157.94
WC	(AED/m2)	15.55	17.78	20.00	22.22	24.44	26.66	28.89
Interest Rate %		2.45	2.80	3.15	3.50	3.85	4.20	4.55

LCC Sensitivity Analysis for (G+4) Buildings								
		-30%	-20%	-10%	0%	10%	20%	30%
IC	(AED/m2)	4,687.74	4,922.93	5,158.12	5,393.31	5,628.50	5,863.69	6,098.88
OC	(AED/m2)	5,170.98	5,245.09	5,319.20	5,393.31	5,467.42	5,541.52	5,615.63
MC	(AED/m2)	5,340.64	5,358.20	5,375.75	5,393.31	5,410.86	5,428.42	5,445.97
RC	(AED/m2)	5,348.58	5,363.49	5,378.40	5,393.31	5,408.22	5,423.13	5,438.03
EC	(AED/m2)	4,715.11	4,941.17	5,167.24	5,393.31	5,619.37	5,845.44	6,071.51
WC	(AED/m2)	5,279.61	5,317.51	5,355.41	5,393.31	5,431.21	5,469.11	5,507.01
Interest Rate %		5,393.31	5,393.31	5,393.31	5,393.31	5,393.31	5,393.31	5,393.31
M&RC		5,344.61	5,360.84	5,377.08	5,393.31	5,409.54	5,425.77	5,442.00
UC		4,997.36	5,129.34	5,261.32	5,393.31	5,525.29	5,657.27	5,789.26



APPENDIX V

SPSS Results

1. Built-Up Area

Descriptives

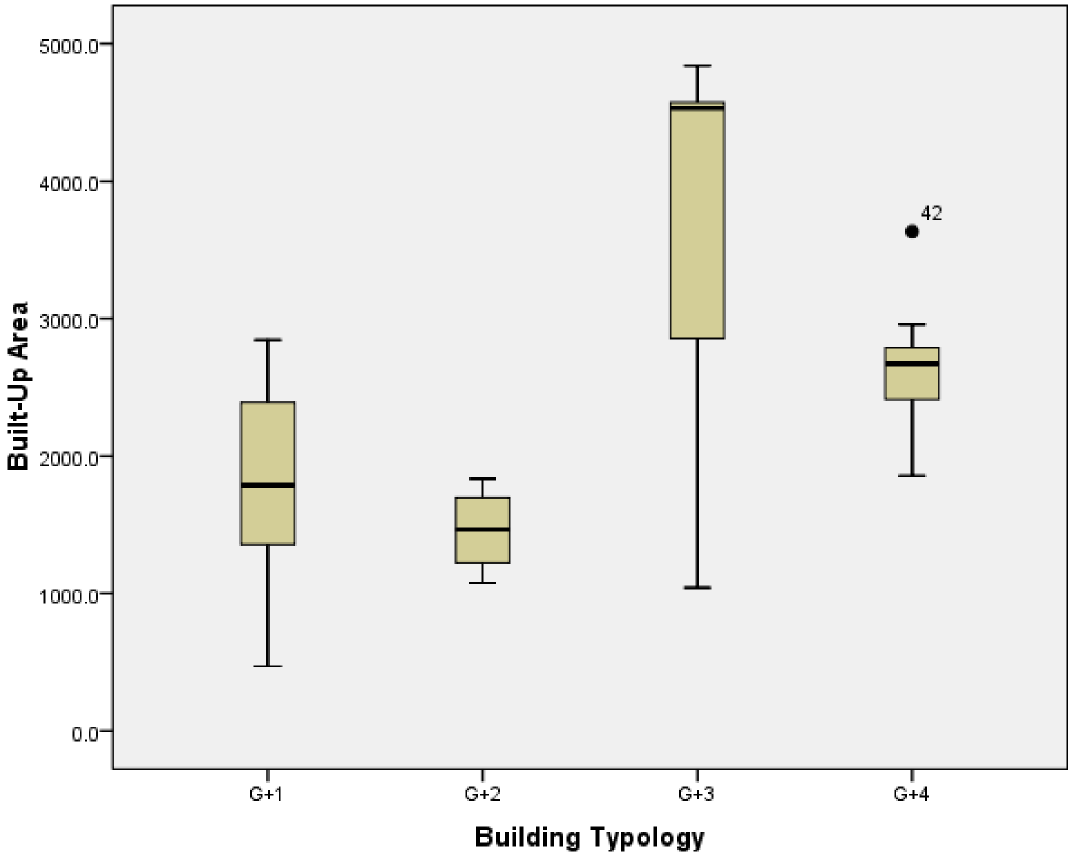
	Building Typology			Statistic	Std. Error
Built-Up Area	G+1	Mean		1822.046	116.8679
		95% Confidence Interval for Mean	Lower Bound	1583.024	
			Upper Bound	2061.067	
		5% Trimmed Mean		1833.542	
		Median		1788.000	
		Variance		409742.951	
		Std. Deviation		640.1117	
		Minimum		470.4	
		Maximum		2845.0	
		Range		2374.6	
		Interquartile Range		1115.3	
		Skewness		.035	.427
		Kurtosis		-.779	.833
	G+2	Mean		1460.458	159.3589
		95% Confidence Interval for Mean	Lower Bound	953.306	
			Upper Bound	1967.609	
		5% Trimmed Mean		1461.008	
		Median		1465.415	
		Variance		101581.059	
		Std. Deviation		318.7178	
		Minimum		1077.0	

	Maximum		1834.0	
	Range		757.0	
	Interquartile Range		615.3	
	Skewness		-.082	1.014
	Kurtosis		-.172	2.619
G+3	Mean		3609.786	537.1894
	95% Confidence Interval for Mean	Lower Bound	2295.331	
		Upper Bound	4924.241	
	5% Trimmed Mean		3684.040	
	Median		4530.000	
	Variance		2020007.321	
	Std. Deviation		1421.2696	
	Minimum		1043.0	
	Maximum		4840.0	
	Range		3797.0	
	Interquartile Range		2053.0	
	Skewness		-1.115	.794
	Kurtosis		.250	1.587
G+4	Mean		2614.198	89.2056
	95% Confidence Interval for Mean	Lower Bound	2426.784	
		Upper Bound	2801.612	
	5% Trimmed Mean		2599.609	
	Median		2670.000	
	Variance		151195.105	
	Std. Deviation		388.8381	
	Minimum		1857.0	
	Maximum		3634.0	
	Range		1777.0	
	Interquartile Range		416.3	
	Skewness		.411	.524

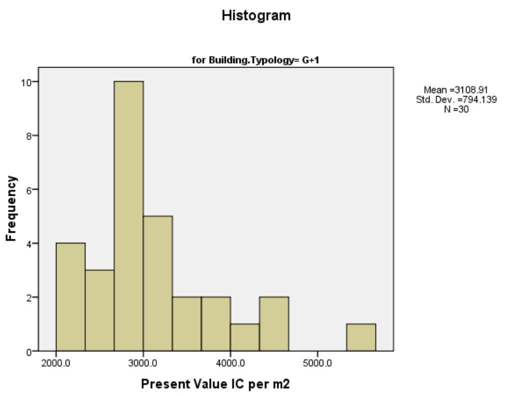
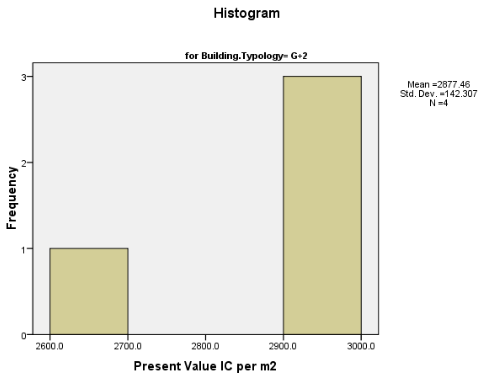
Kurtosis	1.835	1.014

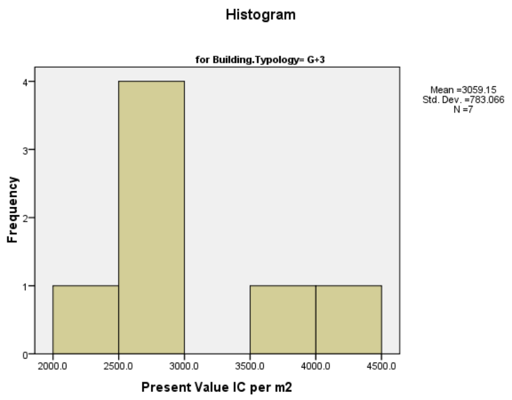
Percentiles

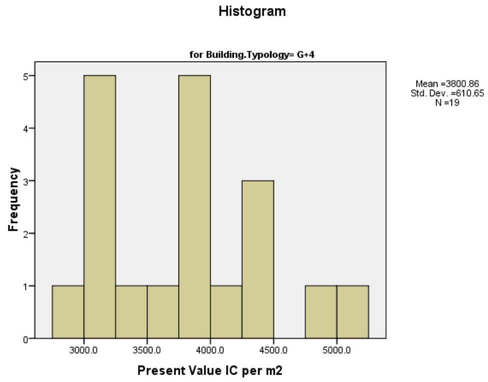
		Building Typology	Percentiles 5	10	25	50	75	90	95
Weighted Average(Definition 1)	Built-Up Area	G+1	687.448	1059.000	1331.000	1788.000	2446.250	2738.100	2828.825
		G+2	1077.000	1077.000	1150.308	1465.415	1765.650	.	.
		G+3	1043.000	1043.000	2564.000	4530.000	4617.000	.	.
		G+4	1857.000	2073.000	2395.400	2670.000	2811.660	2957.000	.
Tukey's Hinges	Built-Up Area	G+1			1356.000	1788.000	2390.000		
		G+2			1223.615	1465.415	1697.300		
		G+3			2854.250	4530.000	4573.500		
		G+4			2411.700	2670.000	2788.330		

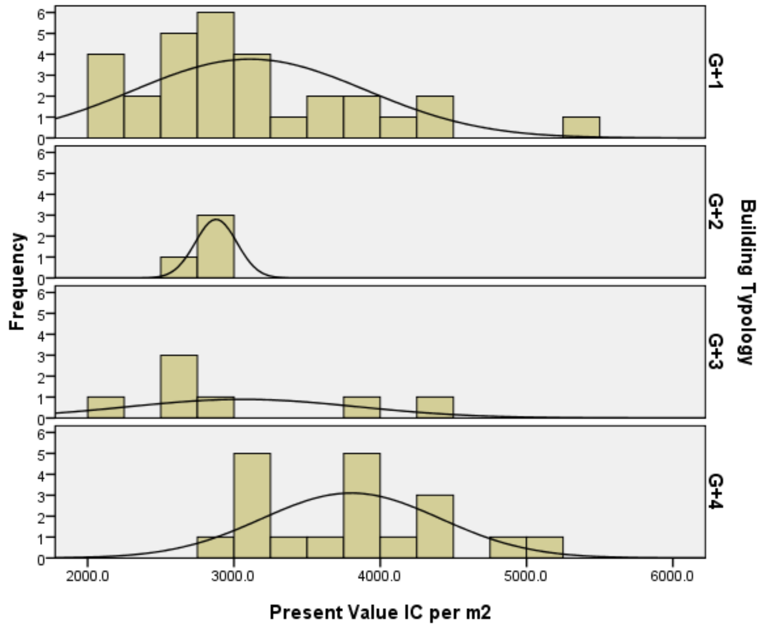


2. Initial Cost (IC)

Initial Cost Histograms for New Buildings
 

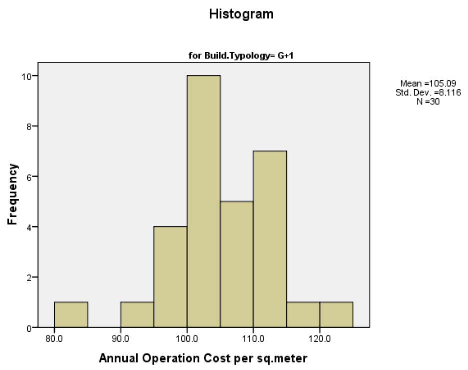


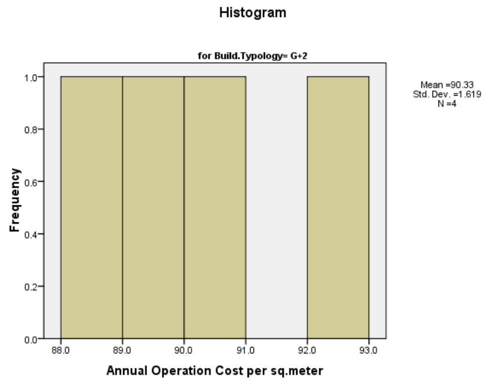


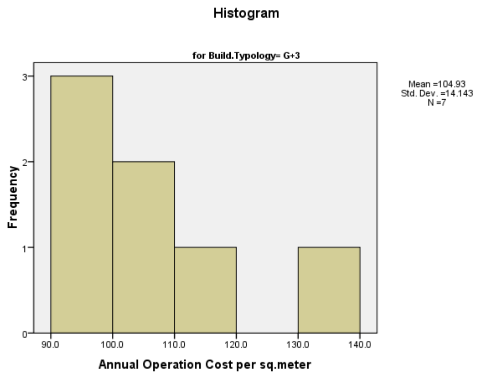


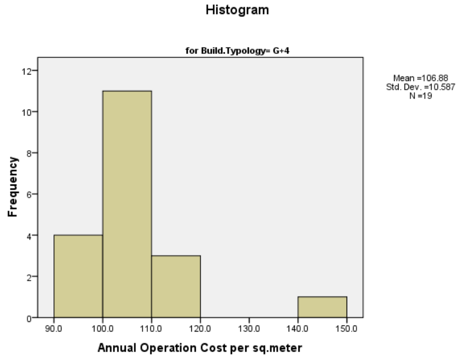
3. Annual Operation Cost (OC)

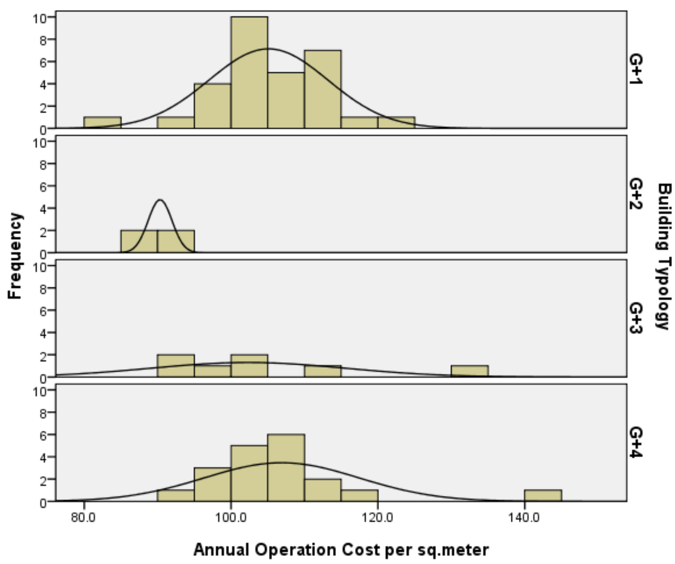
Annual Operation Cost Histograms for New Buildings





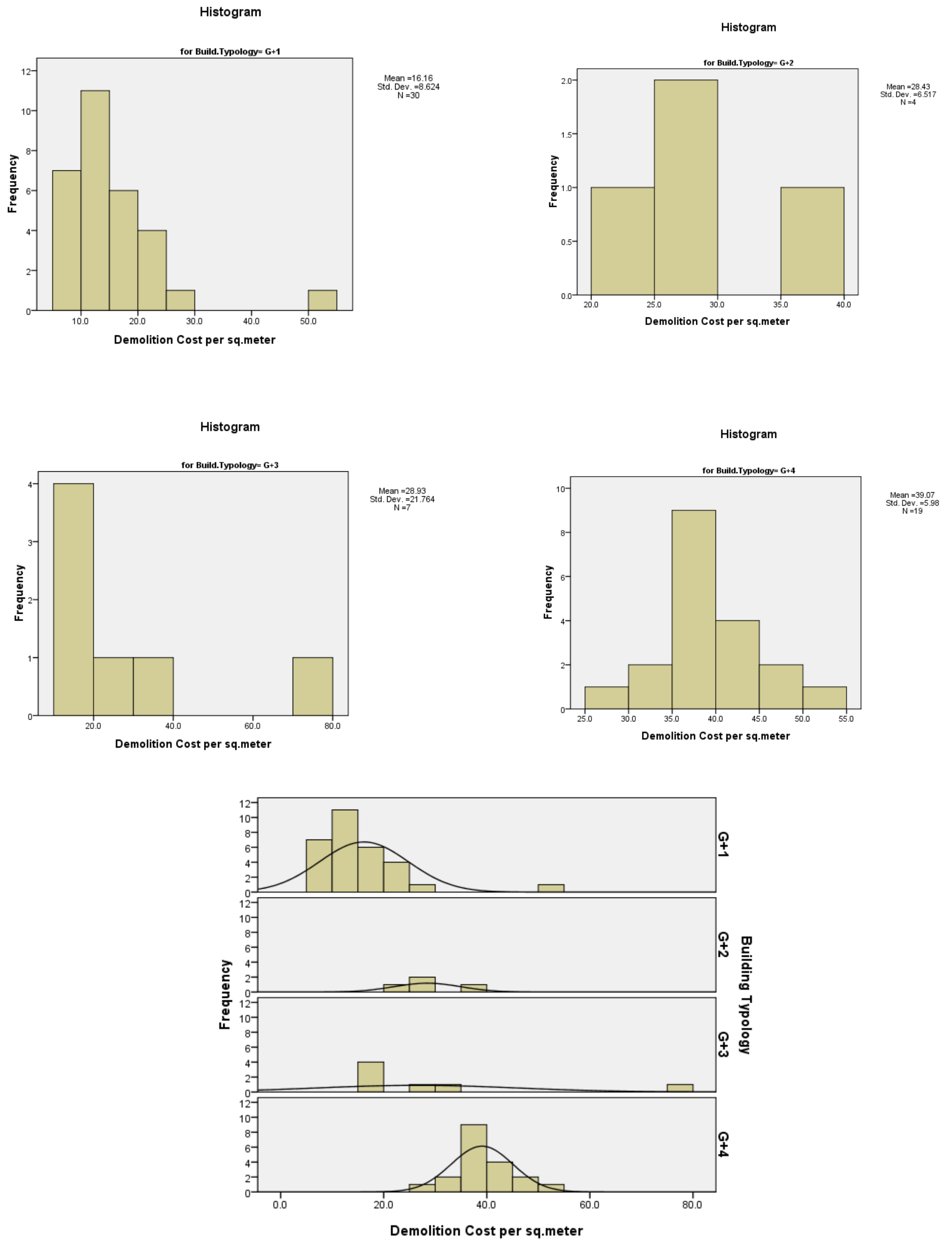






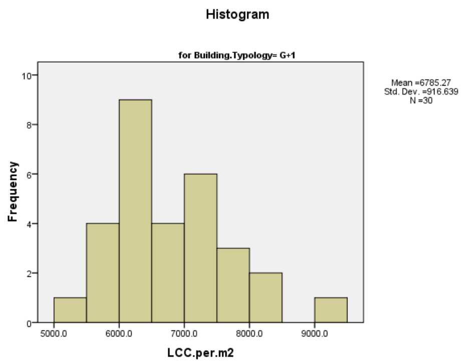
4. Demolition Cost

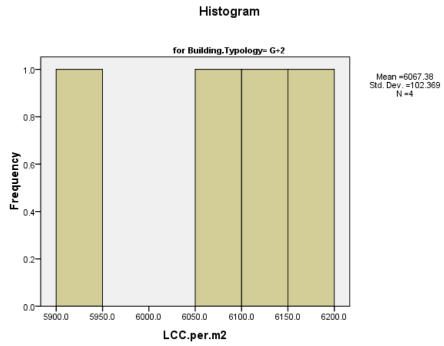
Demolition Cost Histograms for New Buildings

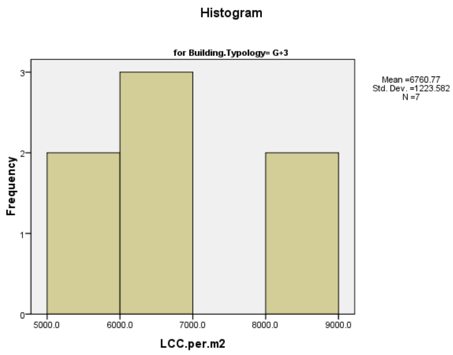


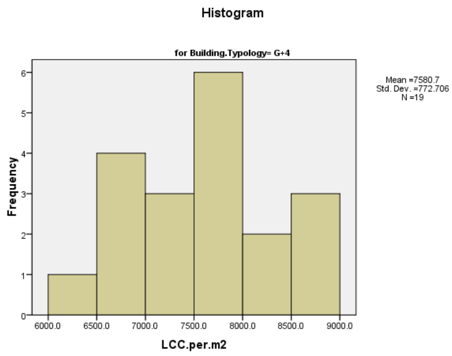
5. Life cycle cost

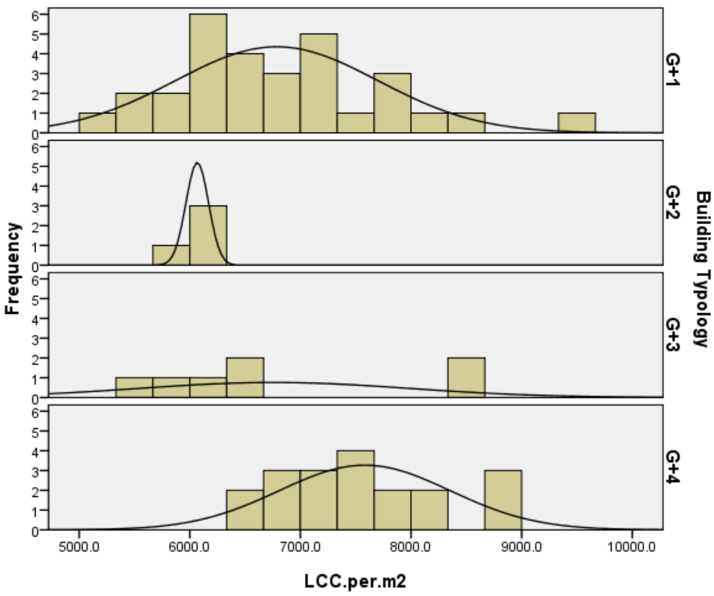
Life cycle cost Histograms for New Buildings











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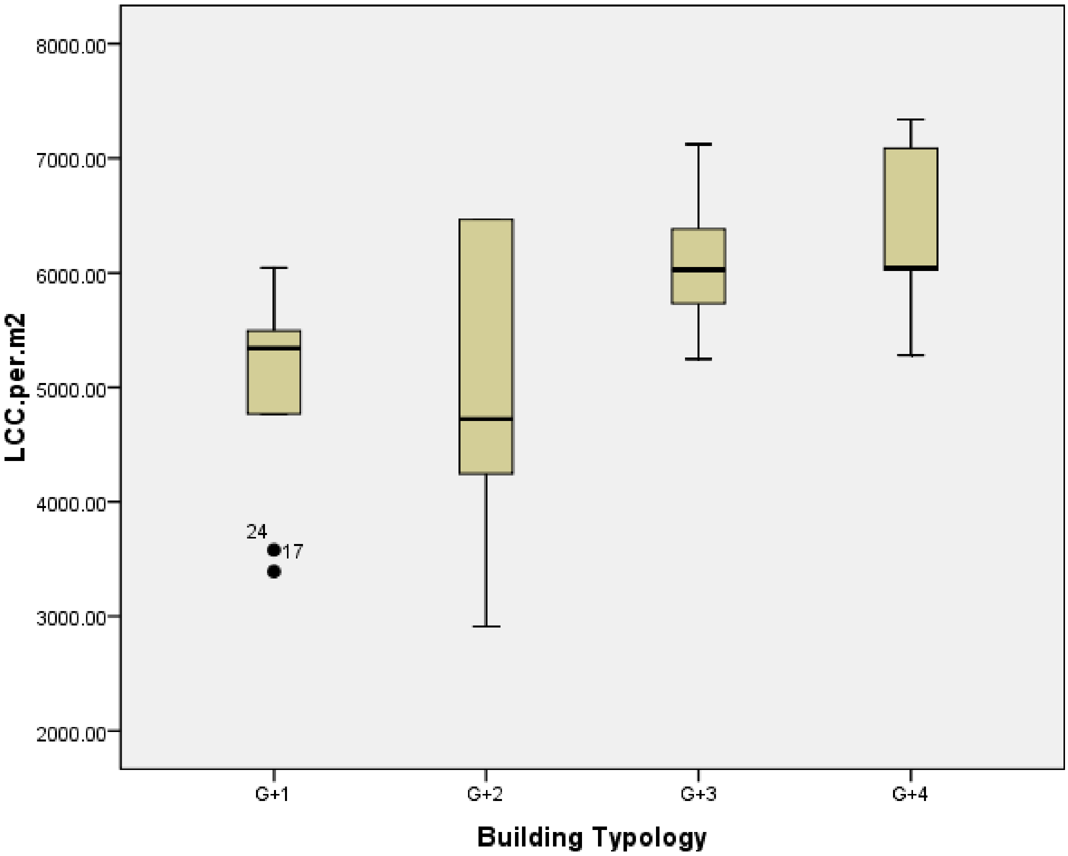

Box Plots for New Buildings

Descriptives

	Building Typology			Statistic	Std. Error
LCC.per.m2	G+1	Mean		5078.1800	203.55968
		95% Confidence Interval for Mean	Lower Bound	4638.4160	
			Upper Bound	5517.9440	
		5% Trimmed Mean		5118.2172	
		Median		5342.5300	
		Variance		580111.620	
		Std. Deviation		761.65059	
		Minimum		3392.04	
		Maximum		6043.65	

	Range		2651.61	
	Interquartile Range		755.75	
	Skewness		-1.350	.597
	Kurtosis		1.395	1.154
G+2	Mean		4963.4400	681.83390
	95% Confidence Interval for Mean	Lower Bound	3070.3656	
		Upper Bound	6856.5144	
	5% Trimmed Mean		4993.8600	
	Median		4724.0700	
	Variance		2324487.311	
	Std. Deviation		1524.62694	
	Minimum		2912.44	
	Maximum		6466.88	
	Range		3554.44	
	Interquartile Range		2887.19	
	Skewness		-.260	.913
	Kurtosis		-1.481	2.000
G+3	Mean		6089.5071	238.25495
	95% Confidence Interval for Mean	Lower Bound	5506.5183	
		Upper Bound	6672.4960	
	5% Trimmed Mean		6078.9540	
	Median		6026.4600	
	Variance		397357.958	
	Std. Deviation		630.36335	
	Minimum		5245.32	
	Maximum		7123.65	
	Range		1878.33	
	Interquartile Range		960.44	
	Skewness		.569	.794
	Kurtosis		-.076	1.587

	G+4	Mean		6305.0983	312.76125
		95% Confidence Interval for Mean	Lower Bound	5501.1200	
			Upper Bound	7109.0767	
		5% Trimmed Mean		6304.5731	
		Median		6048.4250	
		Variance		586917.579	
		Std. Deviation		766.10546	
		Minimum		5282.25	
		Maximum		7337.40	
		Range		2055.15	
		Interquartile Range		1309.67	
		Skewness		.302	.845
		Kurtosis		-.925	1.741

Statistics Descriptives for New Buildings

2