Study of Life Cycle Cost Analysis and Value Engineering and their use in UAE

دراسة تكاليف دورة الحياة والهندسة القيمة واستخدامها في دولة الامارات العربية المتحدة

by

ZEIN BASHAR AL SHELEH

Dissertation submitted in fulfilment

of the requirements for the degree of

MSc STRUCTURAL ENGINEERING

at

The British University in Dubai

June 2021

DECLARATION

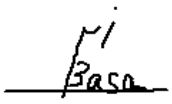
I warrant that the content of this research is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that a copy of my research will be deposited in the University Library for permanent retention.

I hereby agree that the material mentioned above for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make a digital copy available in the institutional repository.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my thesis for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.



Signature of the student

COPYRIGHT AND INFORMATION TO USERS

ABSTRACT

When planning a project, the main stakeholders' concern is always about the potential for failures, defects, delays, overruns, and conflicts that the project might face. According to studies and statistics, most projects take around 20% longer than scheduled to complete and frequently go much over budget. There are several techniques to plan a project effectively, but they all need a thorough strategy, managing, supervision, and collaboration. Life cycle cost analysis and value engineering are some of the most recently used techniques that evaluate and analyse all costs related to the project over its service life and give the essential project functions at the lowest possible cost.

This research calculates the life cycle cost of a residential building in Sharjah city, in UAE over 40 years life span. Including the three main phases: initial cost, operation & maintenance cost and decommissioning cost. And then the same calculation was done for 60 years of life span for the same project. in the end, a comparison between both cases is made to find out which case will be more financially beneficial.

Results show that investing more money in the initial phase, mainly the construction phase, to improve the materials and construction quality would increase the service life by up to 20 years. which will result in more profit to the owners/stakeholders taking into consideration safety requirements.

المـــلخـــــص

عند التخطيط لمشروع ما ، ينصب اهتمام أصحاب المصلحة دائمًا على احتمالية حدوث حالات فشل وعيوب وتأخيرات وتجاوزات وتضارب قد يواجهه المشروع. وفقًا للدراسات والإحصائيات ، تستغرق معظم المشاريع حوالي 20٪ وقتًا أطول مما هو مقرر لإكمالها وغالبا ما يتم تجاوز الميزانية كثيرًا. هناك العديد من الأساليب الفعالة للتخطيط لمشروع ما، لكنها كلها بحاجة إلى استراتيجية شاملة وإدارة وإشراف وتعاون. يعد تحليل تكلفة دورة الحياة وهندسة القيمة من أحدث التقنيات المستخدمة لتقييم وتحليل جميع التكاليف المتعلقة بالمشروع على مدار فترة خدمته وإعطاء المشروع وظائفه الأساسية بأقل تكلفة ممكنة.

استثمرت الإمارات مليارات الدولارات في المباني ومشاريع البنية التحتية خلال العقد الماضي. لذلك طالبت السلطات بزيادة العمر الافتراضي لجميع أنواع المشاريع الهيكلية بسبب التأثير المتوقع على الاقتصاد إذا تطلبت هذه المشاريع الصيانة والإصلاح في المستقبل. وعليه ، فإن الخطط المستقبلية لدولة الإمارات العربية المتحدة هي استخدام مواد فريدة لبناء هياكل خالية من الصيانة لمدة 100 عام. تعتمد معظم الهياكل التي يتم بناؤها حاليًا في منطقة الخليج على الخرسانة المسلحة كمواد البناء الرئيسية.

كان المالكون يعانون من ارتفاع تكاليف دورة الحياة لمنشآتهم ؛ هذا هو السبب في أن هناك حاجة لتطوير تكلفة دورة الحياة، حيث أنه يمكن لهذه التقنية تحسين التكلفة الإجمالية للمشروع من خلال تحديد جميع تكاليف المشروع بدءًا من تكلفة الأرض وانتهاءً بتكلفة إيقاف التشغيل.

يحسب هذا البحث تكلفة دورة حياة مبنى سكني في مدينة الشارقة على مدى 40 عامًا. والتي تتضمن المراحل الرئيسية الثلاث: التكلفة الأولية ، وتكلفة التشغيل والصيانة وتكلفة إيقاف التشغيل. ثم تم إجراء نفس الحساب لمدة 60 عامًا من العمر الافتراضي لنفس المشروع. في النهاية ، تم إجراء مقارنة بين كلتا الحالتين لمعرفة الحالة التي ستكون أكثر فائدة من الناحية المادية.

تظهر النتائج أن استثمار المزيد من الأموال في المرحلة الأولية ، وخاصة مرحلة البناء ، لتحسين المواد وجودة البناء ، يمكن أن يؤدي إلى زيادة عمر الخدمة حتى 20 عامًا. مما سيترتب عليه المزيد من الأرباح للملاك / أصحاب المصلحة وذلك بالطبع مع مراعاة متطلبات السلامة.

DEDICATION / الاهداء

ليس كُلّ مَا فِي القَلبِ قَابِلٌ للبَوح ..هُنَاكَ مَا يُولَد ويَموُت، وَلا يُفصَح عَنهُ. — جلال الدين الرُّومِي

إلى روحي...إلي أنا...

شكر وتقدير / ACKNOWLEDGMENTS

﴿لَئِن شَكَرْتُمْ لَأَزِيدَنَّكُمْ ﴾

الحمدالله أقصى مبلغ الحمد ، الحمدالله في سري وفي علني والحمدالله في حزني وفي سعدي.

والشكر لله من قبل ومن بعد، الشكر لله على تسهيل امري وتيسيره ، والشكر لله على انارة دربي وترتيبه.

أما بعد، لكل مقام مقال، ولكل نجاح شكر وتقدير..

والدي الغالي ,, بشار الشلح ,, يا صاحب القلب الطيب، والضحكة الجميلة، يا صاحب الخلق الكريم والفضل الكبير، يا أكبر سند،، شكرا لك لوجودك لنعمك لفضلك لدعمك لعطاءك ... شكرا لك أبي.

أمي الغالية ,, سحر الحير ,, يا مدى الروح ويا سكينة القلب، يا خير من نصح وخير من منح، يا من حاربت وساهمت بالكثير من أجلي،، شكرا لك لحنانك لعطفك لدفئك لاهتمامك وتشجيعك ... شكرا لك أمي.

اخوتي .. حسين،غيث،عمر،حور،دانيا... ممتنة لوجودكم يا نكهة حياتي ، لولاكم لما كنت هنا الآن انهي مشروع تخرجي هذا ، لولا دعمكم، ثقتكم، حبكم ... شكرا لكم.

مشرفي الأستاذ الدكتور عابد ابو طير شكرا على الارشاد والتوجيه، على الملاحظات المهمة والداعمة، وعلى المساعدة الدائمة.

وشكر خاص للاستاذ سمير زراق ، رحمة الله عليه الذي لم يبخل باعطائي أي معلومة بل وساعدني بالكثير بلا كلل او ملل.

إلى كل من شجعني ودعمني واعطاني دفعة نحو الأمام ...شكرا.

Table of Contents

LIST OF FIGURE

LIST OF TABLE

LIST OF ABBREVIATIONS

LCCA	Life Cycle Costing Analysis
ASTM	American Society for Testing and Materials
UAE	United Arab Emirates
GDP	Gross Domestic Product
MOHRE	Ministry Of Human Resources & Emiratisation
ODA	Official Development Assistance
LCC	Life Cycle Costing
CDOT	Colorado Department of Transportation
GDOT	Georgia Department of Transportation
FHWA	Federal Highway Administration
MACC	Marginal Abatement Cost Curve
RSL	Remaining Service Life
NPV	Net Present Value
IC	Initial Cost
WBS	Work Breakdown Structure
O&MC	Operation & Maintenance Cost
DC	Decommissioning Cost
AAC	Average Annual Cost
IRR	Internal Rate of Return (IRR)
ROI	Return of Investment
BLCC	Building Life-cycle Cost
NIST	National Institute of Standards and Technology
TVM	Time Value of Money

PV	Present Value
FV	Future Value
NCHRP	National Cooperative Highway Research Program
VE	Value Engineering
VA	Value Analysis
SAVE	Society of American Value Engineers
GEC	General Electric Company
IVM	Institute of Value Management
INVEST	Indian Value Engineering Society
SJVE	Society of Japanese Value Engineering
CSVA	Canadian Society of Value Analysis
HKIVM	Hong Kong Institute of Value Management
SEWA	Sharjah Electricity Water & Gas Authority
IG	Imperial Gallon
AC	Air Condition
S/D	Split Ducted
W/D	Wall Decorative
PA	Packaged System
W	Window Type
INC	Incandescent Light
FL	Fluorescent Lights
LED	Light Emitting Diode
ACI	American Concrete Institute
RERD	Real Estate Registration Directorate

DTPS	Department Of Town Planning and Survey
FM	Facility Management
BHK	Bedroom, Hall, Kitchen
IMF	International Monetary Fund
MEED	Middle East Economic Digest
BIM	Building Information Modeling

LIST OF SYMBOLS

CO_2	Carbon Dioxide
C_I	Initial Cost
$C_{O\&M}$	Operation & maintenance Cost
C_D	Decommissioning Cost

CHAPTER 1:

INTRODUCTION

1.1 Introduction

Life cycle cost analysis (LCCA) is a technique of examining all the costs related to a product, system, or facility through a particular duration. This particular duration is known as the life span of the project. Life span is the period of time where a structure meets or exceeds the minimum requirements specified for it. Different factors might limit the service life; it might be technical, functional or even economic factors.

Controlling the initial and future costs of a building can be easily using LCCA. This technique can be applied for evaluating existing building systems at any phase of the design. American Society for Testing and Materials (ASTM) sets a series of standards for building economically. Life cycle cost analysis (LCCA) and internal rate of return (IRR) are two examples of such standards used to estimate the total life cost.

This research consists of eight chapters. The first chapter is an introduction to the research. The second, third, fourth and fifth chapter is a literature review, which firstly talks about UAE in brief, how it grew and still growing in a limited time followed by a glance at the construction industry in UAE. Then the life cycle cost will be introduced with the Current LCCA procedures and phases. after that, the financial analysis with different economic evaluation methods for LCCA & models and value engineering will be shown. The sixth chapter will describe the methodology with some details. Chapter seven presents the results of the case study with a discussion based on the data obtained. Finally, a conclusion and recommendations will be shown in chapter eight.

Chapter two introduces a brief history of the United Arab Emirates, how this country started, the obstacles during its rising, also short ideation of its investments and fulfilment. One emirate of the seven emirates will be highlighted because the case study of this research is located in it,

the emirate of Sharjah. in this chapter also a major topic will be covered, which is the construction industry in the United Arab Emirates, challenges faced, recommendations for change from the UAE Construction Industry Think Tank and finally the digital Innovation benefits in the construction industry.

Chapter three introduces one of the most crucial techniques in evaluating buildings called life cycle cost analysis. LCCA starts by developing initial alternatives that give the same structural and performance aims, estimate the costs of each one of them, ends by finding the present value of the other options (if applicable) and analyse the results to choose the best alternative. The value of LCCA with its study categories assessed by Stanford University will be presented. after that, a description of the relation between LCCA and sustainability and how this technique helps in evaluating the environmental costs related to the project. some of the LCCA applications is going to be shown with different examples of countries that used this method in evaluating the projects. Life cycle cost phases were explained, starting with the initial cost, operation & maintenance cost, and decommissioning cost. LCCA limitations will be discussed at the end of this chapter.

Chapter four represent financial analysis principles such as present value, future value, inflation rate, interest rate and discount rate. In addition, the financial analysis three main parts were illustrated. LCCA methods like average annual cost, net present value, payback, and internal rate of return were explored. At the end of this chapter, some LCCA calculations software generally introduced.

Chapter five talks about the value engineering concept, and its three main phases, planning phase, design phase and methodology phase. after that, this chapter aims to show the best time to use value engineering and the future behind using this technique.

Chapter six explains this research methodology using the mixed method way, which is a combination of qualitative & quantitative methods. All data of the study case were prepared and organised to be shown in its most straightforward way. Furthermore, an explanation of the service life of the project was represented. The fundamental costs of the case study were also illustrated in detail, starting with the initial cost and ending up with the demolition cost. In the end, some main terms related to the case study analysis of this research were mentioned.

Chapter seven illustrates the results obtained for the life cycle cost analysis for the 40 and 60 life span cases. A detailed comparison between the first existing case (40 years) and the second proposed case (60 years).

Results have shown that investing some more money at the beginning might worth it in most cases. In case of investing the extra money on the construction phase to use better materials and methods, this will help in extending the life span of the project, which means the income of the project will continue. On the other hand, if the extra money was invested in the design phase this will help in reducing future operation and maintenance costs. Stakeholders can always decide upon setting their goals and targets for the project.

Lastly, chapter eight will be talking about some recommendations found and a conclusion summarising all the main ideas that came in this research.

CHAPTER 2:
UAE HISTORY AND THE CONSTRUCTION INDUSTRY

2.1 Overview

This chapter will concentrate on one of the most critical countries nowadays, the United Arab Emirates, and one of it is main cities, Sharjah. This first section of this chapter will briefly discuss UAE's journey, obstacles, investments, achievements and finally, some details about Sharjah city particularly. The second section will focus on the UAE construction industry and several challenges this country are facing, followed by some recommendations to get rid of these difficulties. and in the end, digital innovation will be discussed and its benefits in the construction sector.

2.2 UAE: A brief history

The United Arab Emirates (UAE) is a union of seven different emirates, announced as an independent country on the unforgettable date, 2nd December 1971. The late H. H. Sheikh Zayed bin Sultan Al Nahyan served as President of the United Arab Emirates since the union's formation until he passed away in 2004.

2.2.1 The Beginning

The late H. H. Sheikh Zayed bin Sultan Al Nahyan formed the foundation for a robust, united federation that welcomed modernisation while preserving the UAE's cultural and social heritage. His main goal was to invest in Emiratis to earn their involvement in building the nation. The late H. H. Sheikh Zayed philosophy as a leader and statesman was represented in utilising the country's resources to the max for the people benefit.

In 1950, the UAE's economy depended on fishing and the pearl industry. Oil was discovered later, in 1958. After three years, exporting began, the country's society and economy were revolutionised, and the UAE became one of the Middle East's most important economic

countries. The current President of the UAE is H. H. Sheikh Khalifa bin Zayed Al Nahyan. He was appointed to this job in 2004 and has remained in it ever since.

2.2.2 Obstacles

Most smart oil nations know that oil wealth is not forever, and even if the nation's oil wells never actually run dry, oil is just a commodity; it fluctuates in price. Every country has a different strategy for dealing with this problem.

According to economic activity, the distribution of GDP in 2018, the various non-oil sectors accounted for 70% of GDP, while the oil sector accounted for 30% of real GDP. Among the non-oil sectors, "the construction and building" sector accounted for the second largest share with two other sectors, 8.5% of total GDP each; this is how UAE started to solve this problem by investing in the construction section.

2.2.3 Investments

The improvement of oil revenues level in 2018 than in 2017 related to the rise in oil prices by 33.0% and the increase in tax revenues, financial surpluses, and the private sector's involvement. As well as the government, in implementing projects, has provided the financial resources needed to inject growth-enhancing investments, achieve sustainable development and activate a policy of diversification of income sources and shift toward a competitive, high-productivity knowledge economy based on research, creativity, and innovation. These investments focused on completing the implementation of strategic projects and investments five infrastructure projects, mainly the construction of the World Expo 2020 projects, the Metro and light rail lines, the expansion of Abu Dhabi Airport, the Al Maktoum International Airport

expansion project and other stages of the Federation Railway Project of the union railway company.

Moreover, implementing investment projects in all economic sectors, exceptionally high value-added sectors, will stimulate growth, achieve sustainable development, increase levels of economic diversification and support human development.

The United Arab Emirates has put its bet on diversification because infrastructure spending was building these beautiful metropolises, the former of which is the most popular tourist destination in all middle east and the fifth most globally. Tourism is a huge growth industry that was ignored in previous years. Many major attractions are the Burj Khalifa, the Burj al Arab, the palm, SHEIKH ZAYED grand mosque, emirates palace, Louvre Abu Dhabi.

2.2.4 Achievements

The UAE is a politically and economically stable country that ranks 25th in the World Economic Forum's Global Competitiveness Report 2019. According to data from the Organisation for Economic Cooperation and Development's Development Assistance Committee, the UAE donated 1.26 percent of its gross national GDP to development aid.

It is also one of the top 10 official development aid donor countries (ODA). In the last ten years, the United Arab Emirates has emerged as the Arab region's epicentre of innovation and development.

2.2.5 Sharjah City

The Sharjah emirate is the third biggest of the United Arab Emirates' seven emirates. Since 1972, it has been ruled by His Highness Sheikh Dr Sultan bin Muhammad Al-Qasimi. The Emirate of Sharjah is located on the Arabian Gulf coast, with a coast length of 16 km and

stretches more than 80 kilometres deep inside the land, and it is the only city with land on the Arabian Gulf Coast as well as the Gulf of Oman. Sharjah's Emirate covers around 2590 square kilometres. (Figure 1)

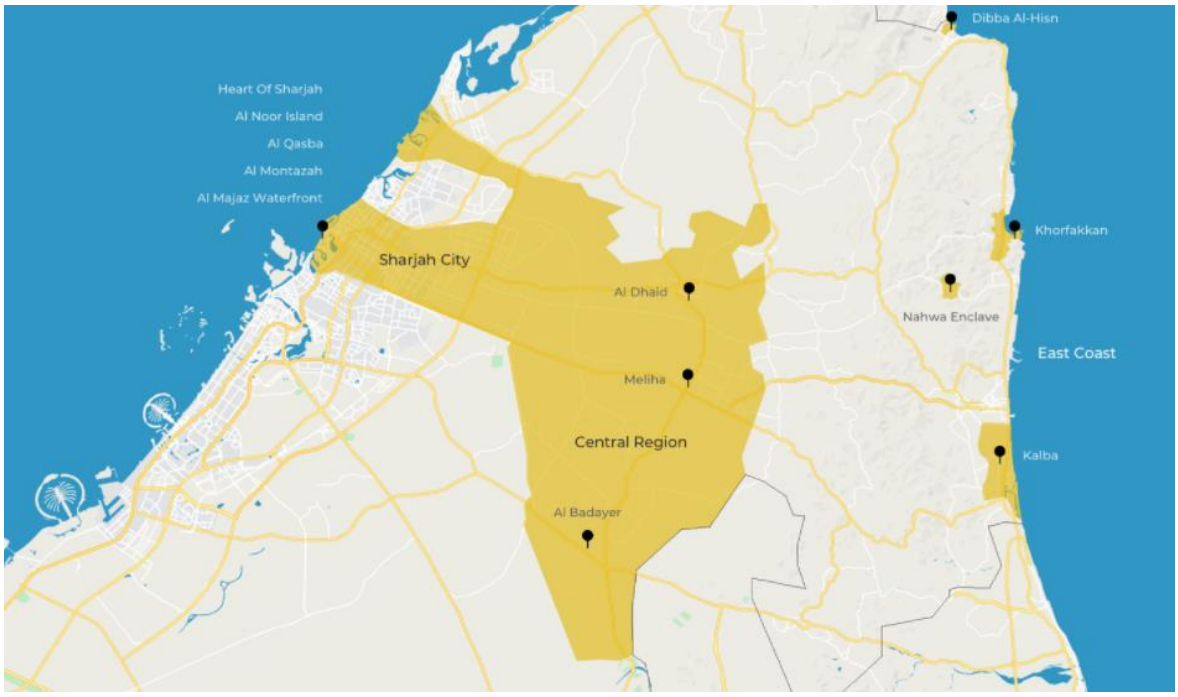


Figure 1 Emirates of Sharjah Map

2.3 Construction Industry in UAE

The main economic barometre of the Arabian Gulf region is the construction sector and it is one of the main investments domain in the country. Where the UAE construction industry has recently provided us with a lot of world-class projects that have marked the industry.

The long term vision of UAE Centennial 2071's framework is critical for achieving the national strategy's goals of strengthening the country's reputation and establishing itself as the world's most competitive nation. where the vision also asks for the construction sector to be the most contemporary, productive, and technology-driven worldwide.

According to the latest data for the third quarter of 2018, the building and construction sector accounted for the biggest percentage of total private sector employees (33.9%). (Figure 2)

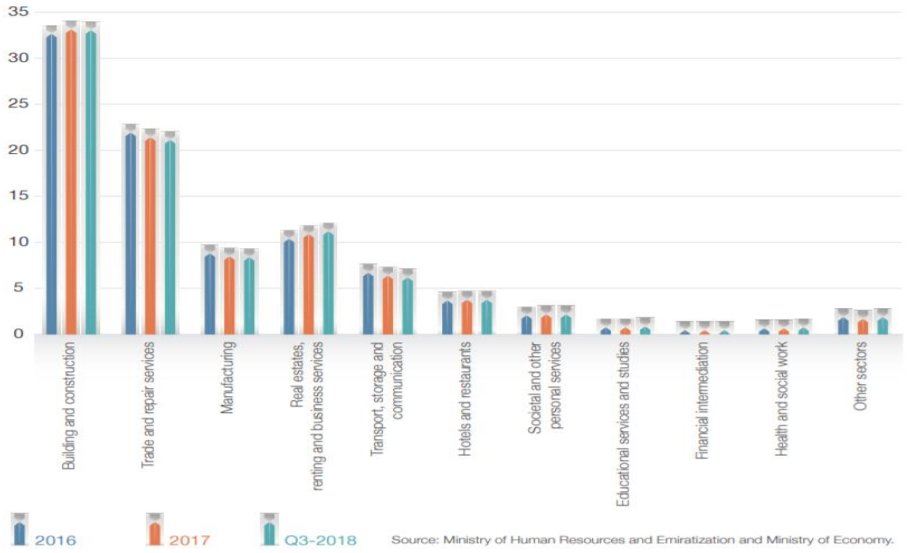


Figure 2 Distribution Of Employees Registered In The Private Sector At The MOHRE By Economic Sector (%)

2.3.1 Challenges for UAE Construction Industry

According to a construction industry survey done by Middle East Economic Digest (MEED), some challenges were found and as consequence recommendations were stated for what the government should do to speed the innovation. Low contracting margins and people's behaviours are the main challenges and the biggest barriers to innovation. (Figure 3)

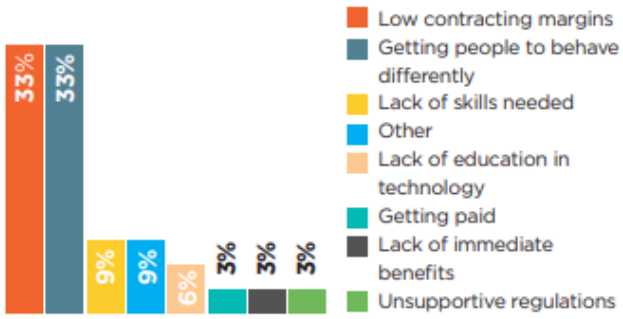


Figure 3 The Main Challenges To Innovation In Construction

Image Source: UAE Construction Think Tank White Paper

2.3.2 Recommendations for UAE Construction Industry

Keep doing things, in the same method, will not deliver the transformation that the construction industry requires. To disrupt some of the negative actions that have gotten rooted in this sector, firm steps are necessary. In this section, some essential proposals will be highlighted to support the success of construction in the UAE in a digital-led future by tackling the industry's development obstacles. Adopting these initiatives will give significantly improve risk allocation, cash flow, and efficiencies in the UAE construction sector.

- Creating standard contracts to share risk and pain/gain possibilities equally between customers, consultants, and contractors in order to increase industry collaboration.
- Imposing limits on contractors who are inexperienced or have a bad track record to promote bids based on whole-life cost and best industry practices.
- Improve the system for contractor accreditation to assess and measure their technical, practical capabilities as well as their financial stability.
- Providing professionals permanent and semi-permanent visas based on their professional achievements and experience.
- Bringing the talent early to the construction is very important, and this can be done through graduate recruitment programs in collaboration with industry stakeholders.
- Construction Industry Development Board should be established to give construction the voice and then the action. Their job would be a resolution of disputes and legal issues, as well as to assist in putting the rules and standards. Overall, the presence of association that works with government and clients will support to regulate the industry and maintain standards.
- Developing incentive systems to reward firms who use new technologies on their projects to encourage and motivate innovation in the building industry.

- creating accreditation bodies to provide training for disciplines and trades that are in demand.

2.3.3 Digital Innovation benefits in the construction industry

UAE construction sector is much aware of the benefits of digital transformation this is why a long-term strategy for innovation has been developed. many technologies such as Offsite prefabrication of modular units, Building Information Modeling (BIM) and Robotics play a significant part in this new era of building and we can be sure that many outstanding projects will exist in the country's near and far future. (Figure 4)

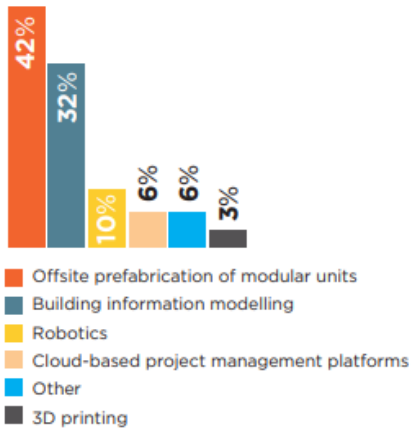


Figure 4 Technologies That Gives The Biggest Gains

Image Source: UAE Construction Think Tank White Paper

There are four main advantages of using digital innovation in construction and project delivery. The first and major benefit is having efficiencies and qualifications which will speed up project completion and delivery on its time. Second, construction costs can be reduced to the maximum. Third, the collaboration between the client, contractor and consultant and suppliers will be enhanced and improved, where this team will work together in the best way to finish the project. Finally, using digital innovation will provide accurate as-built asset data to support lifecycle operations.

CHAPTER 3:

LIFE CYCLE COST

3.1 Overview

Years ago, and till today, experts are working with a great effort to improve managing and controlling projects in the best possibilities. Authorities, stakeholders, and project developers are the ones who are interested and care about these aspects to get a successful project.

Ruegg, Petersen, and Marshall (1980) describe how to measure an investment's total life cycle costs. Practical advice was offered with extra information about understanding and preparation in the civil engineering field, Nigel J. Smith (1995).

Bent and Humphreys (1996) sets valuable updates for engineers and construction managers who want to control their projects in the best approach through applied cost and schedule control.

Also, Albert Hamilton worked on many diverse projects in many development sectors and wrote a book called "managing projects for success", which was first published in 2001. This book was a trilogy containing the three stages that any project will pass: the framework, planning for control, and the tool kit.

Many other engineers and experts worked in this field to give their experience and knowledge to the people seeking this information.

This chapter is broken down into three sections. The first section will define life cycle costing analysis (LCCA), its value, its study categories, how the decision can be more sustainable, applications, procedure, and in the end, some instances of applied LCCA in various countries. The LCC phases, startup cost, operation & maintenance cost, and decommissioning cost are discussed in the second section. The final section will go through some of the limits of this form of analysis.

3.2 Life Cycle Costing Analysis (LCCA)

Value of money is a concept considered when an individual or an organisation is looking to make a purchase or investment. For example, when purchasing a new car, many things to be considered, such as how much it is economical in fuel, the availability of replacement parts, repairing, and other criteria. Based on that, we can decide between the options. Buildings construction are our leading example in this thesis, considering the short-term costs and the long-term costs.

3.2.1 LCCA Definition

Life cycle costing analysis (LCCA) is an economic evaluation approach used to determine the best cost-effective choice between different options to obtain, build, maintain, and dispose of an investment when all these options are suitable to perform on technical grounds. The LCCA can help in deciding between alternatives that might have a higher initial cost but perform in much lower operating and maintenance costs in future.

Life cycle cost (LCC) is defined by the National Institute of Standards and Technology Handbook 135 (1996) as "the total discounted dollar cost of owning, operating, maintaining and disposing of a building or a building system over some time".

The options are compared using life cycle cost analysis, allowing an owner/manager to decide which option will maximise savings and profits.

LCC may be described as "a systematic analytical process of evaluating various alternative courses of action to choose the best way to employ scarce resources" according to Fabrycky and Blanchard (1991).

3.2.2 LCCA Value

Building design options and renovated structures are evaluated using a life cycle cost analysis with maintenance and operating costs in mind, resulting in satisfying the desired level of building quality and significant savings. LCCA used for any investment decision, where the fees at the beginning are high, but at the end of the project, costs reduced.

3.2.3 LCCA Study Categories

Stanford University (2005) assessed the project's value using six general categories: Electrical Systems, Mechanical Systems, Energy Systems, Siting/Massing, Structural Systems and Building Envelope. by studying the project carefully, the highest potential LCC benefit from the six categories can be determined. An LCCA Decision Matrix can assist in this determination; each project will have a different customised matrix.

Figure 5 shows one sample matrix. The vertical axis represents the project's potential cost impact, and the horizontal axis reflects the complexity of the analysis required.

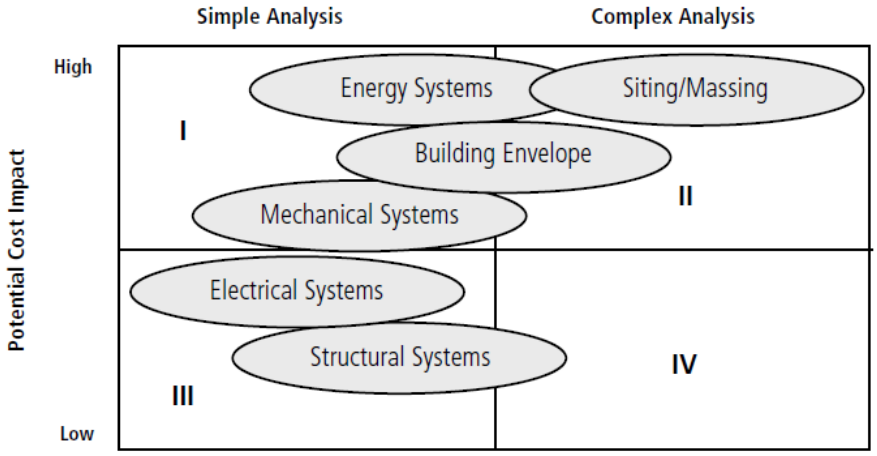


Figure 5 Sample LCCA Decision Matrix

The categories located in (Quadrant I) with high potential cost impact with a simple analysis have the highest priority. Categories with a high potential impact but with complex analysis (Quadrant II) should be next, followed by simple analyses with low potential impact (Quadrant III). In the end, complex analyses with low potential impact (Quadrant IV) will come.

3.2.4 LCCA & Sustainability

Life cycle cost analysis also helps evaluate the environmental costs related to the structure by analysing the energy and materials utilised and wastes discharged into the environment. The term "life cycle" refers to considering everything that goes into or produced as a result of the product or service.

The production of raw materials includes manufacture, distribution, use, disposal, transportation, and the energy consumed by the process, structure, or activity. This cycle is known as a "cradle-to-Grave". (Figure 6)

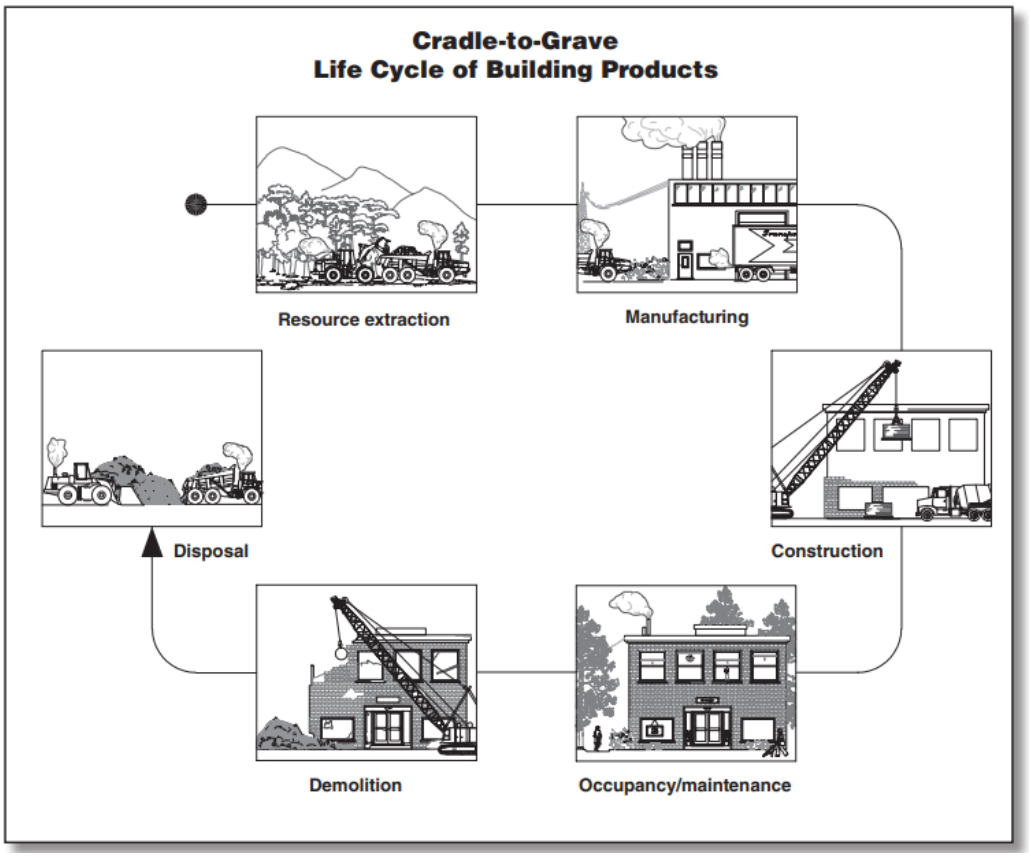


Figure 6 Cradle-to-Grave Life Cycle

However, some products can be wholly or partly reused or remanufactured into new products after they have served their intended purpose. In these circumstances, the cycle is commonly referred to as "cradle-to-cradle". (Figure 7)

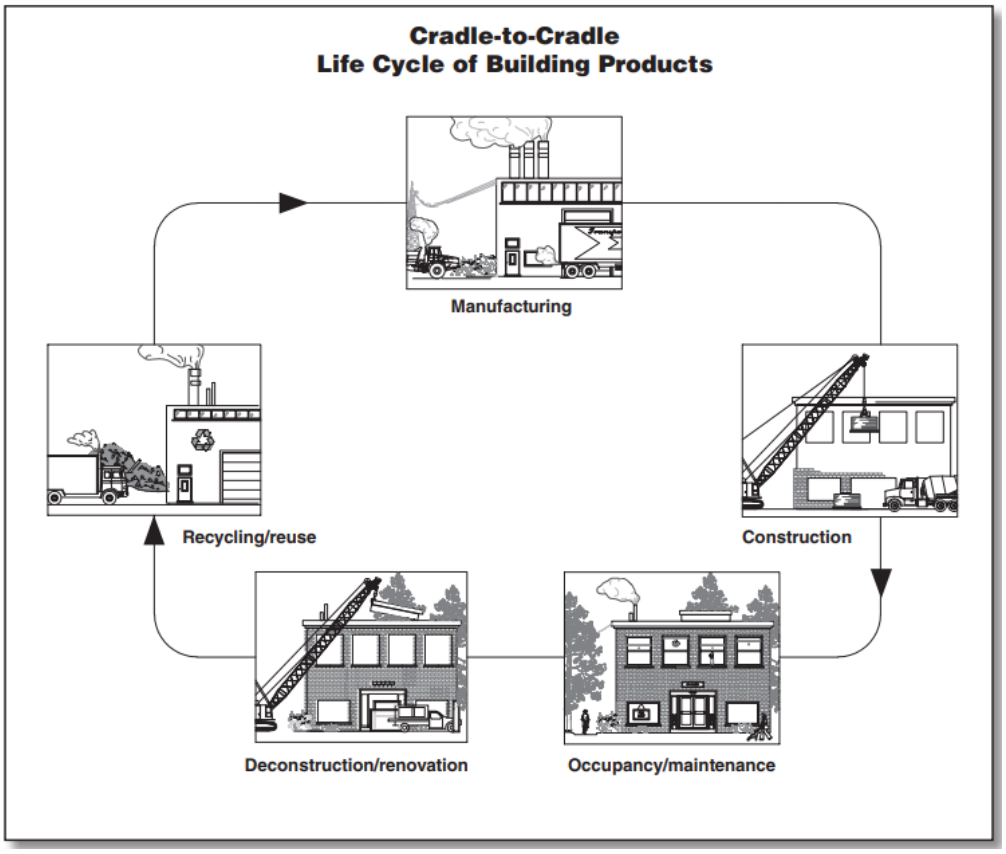


Figure 7 Cradle-to-Cradle Life Cycle

To demonstrate the life cycle assessment methodology, consider comparing the environmental costs of materials used in the project. This will give valuable data that will help decision-makers in selecting more environmentally friendly materials and systems, Kathleen Snodgrass (2008).

3.2.5 LCCA Applications

Using life cycle cost analysis is very useful and worthy for any stakeholders in planning their projects. LCC can be used in different applications like buildings (purchase or new construction), a new automobiles, commercial aircraft, new product lines, defence systems. Using the LCCA method can remarkably reduce the total life cycle cost of such applications, evaluate investment options, and select among the project's alternatives. Moreover thus, it has the potential to reduce future project cost overruns.

The National Cooperative Highway Research Program (NCHRP) conducted a survey in 2015 that focused on the highway sector in the United States. Finding out how to utilise LCCA in their decision making and management of highway assets. Forty-one state highway agencies had responded to the survey, as shown in Figure 8.

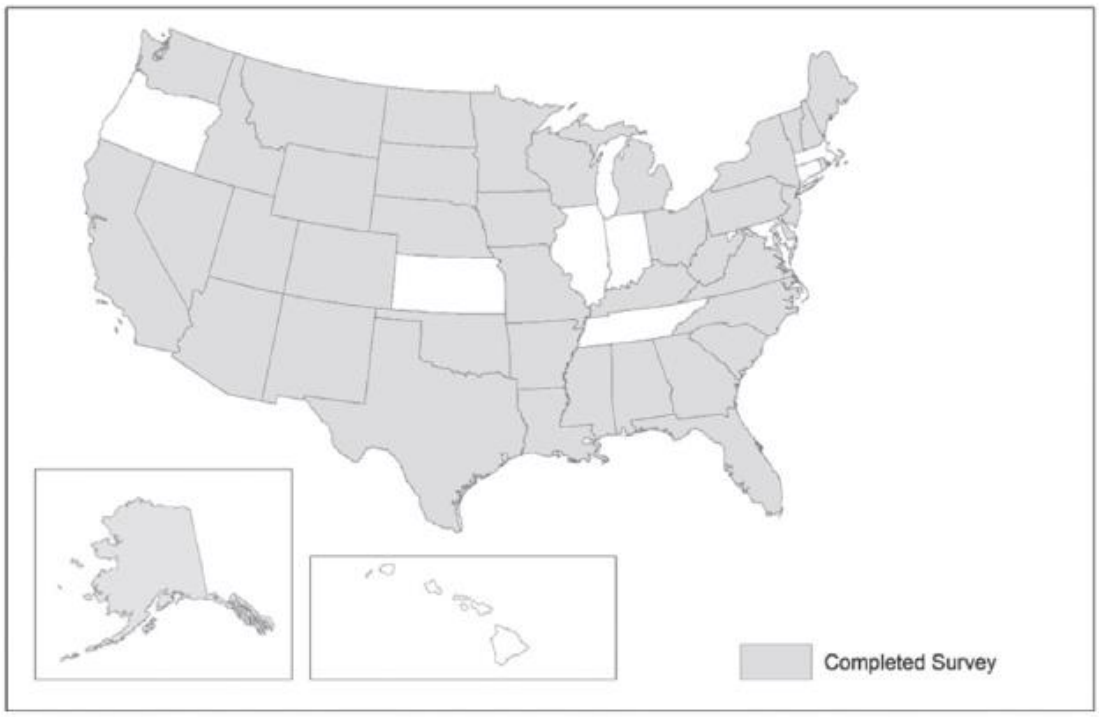


Figure 8 LCCA Use Survey Completed

As shown in Figure 9, 30 out of 41 states indicated they are using LCCA to support the decision making process for analysing design alternatives. According to this survey, the major participants used LCCA to design pavement only, bridges only, or pavement and bridges together.

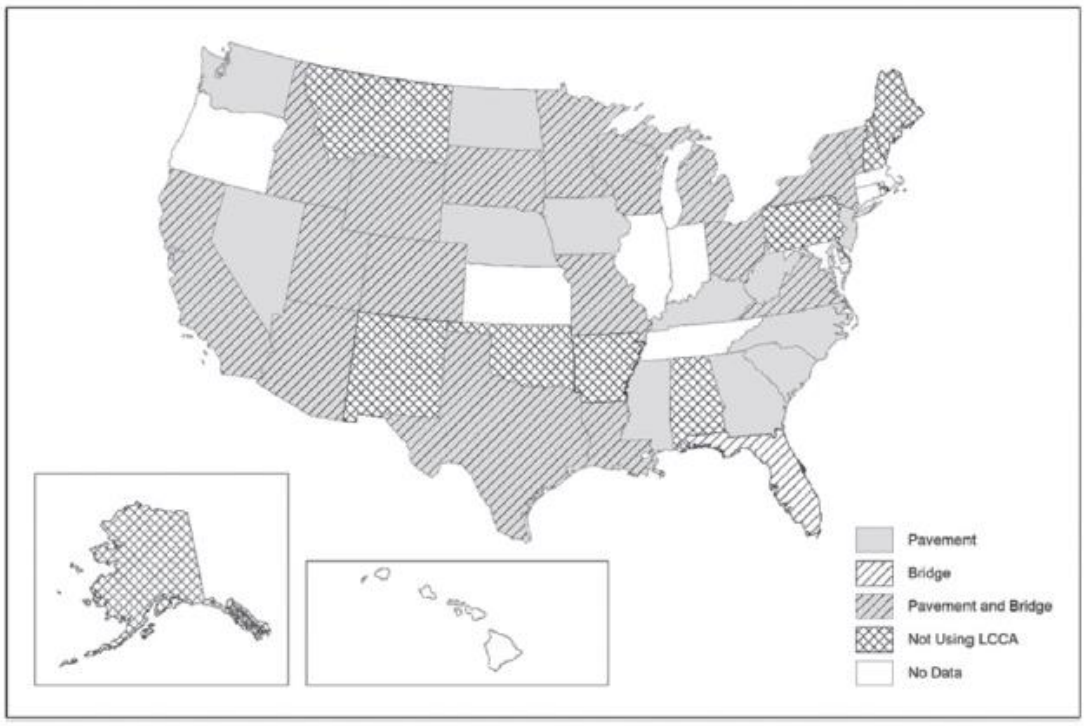


Figure 9 LCCA At the Decision Making Process for Analysing Design Alternatives

3.2.6 LCCA Process

To calculate LCCA, we will go through different stages. First of all, list all design options that achieve the same quality and performance goals, define each option and set its schedule for all initial and future activities. After that, using the eliminating method, evaluate the costs of each alternative and calculate the present value of each. Examine the results at the end and select the most effective option.

3.2.6.1 Design Alternative

Two or more similar options must be defined and developed with a similar purpose, assuming that the difference between them is the total cost. Collect all the details and information about the alternative using technical knowledge, traditional practice, and other ways to derive the desired information.

3.2.6.2 Determine Project Timing

Using the information collected from the first stage, maintenance and repairing plan must develop for each alternative to know all the details about the time required for such a project with the costs concerned.

An excellent understanding of the project is essential, knowing what it might go through as the use, age, and other factors. This information can be collected from administration records of existing projects, company specifications, suppliers, and national sources.

3.2.6.3 Estimate Costs

Check the prices for each alternative developed previously. These costs include ordinary things such as raw materials cost like fuel, annual fees to replace spare parts, procurement costs, maintenance costs, safety and operational costs, and more. Only the prices that vary are required for the LCCA; other ordinary expenses can be removed for all alternatives. The examination will be complicated but more secure and accurate. The remaining service life (RSL) is one of the main concerns when estimating the project's estimation costs after finishing the examination. Making wrong evaluations for such expenses or not even include it might twist the results. So, accurate estimates of such charges will give a successful analysis.

3.2.6.4 Compute Life Cycle Costs

To calculate life cycle costs, determine the net present value (NPV) of each option. There are two ways for determining the net current value of future spending: the first is the deterministic way, and the second is the probabilistic way.

The deterministic way is straightforward; it assigns a fixed and discrete value to each variable based on the analyst's historical evidence or professional judgment. The probabilistic way is difficult because it requires improving a sampling distribution of possible values for each input parametre using random draws from probabilistic distributions.

3.2.6.5 Analysis

A direct comparison of all costs associated with each option can be made after calculating the net present value of all expenses for each option. The lowest current value means this alternative is the ideal one for the project.

Another factor that might affect selecting the choice is the preferred risk level, which takes into account the level of uncertainty as well as the lower present value. A life cycle cost analysis aids in determining the lowest cost option. However, many critical factors such as available budgets, political and environmental concerns, potential diversification, and other critical factors are not considered when deciding between various options. It gives crucial information that supports decision making, but it is insufficient to choose unless costs are the only factor considered.

3.2.7 Examples of Applied LCCA in Different Countries

LCCA has been used worldwide, a long time ago and till today. This part will represent examples of different countries that apply life cycle cost analysis when doing a project.

3.2.7.1 LCCA in the United States

The Colorado Department of Transportation (CDOT) began employing life cycle cost analysis to aid investment decisions in the late 1970s.

In 1981, CDOT's pavement office ordered that an LCCA be conducted during the design phase for all significant projects in order to mitigate the impact of the economic environment's effects. These early analyses included specific input values, which produced deterministic results. The goal was to implement techniques that made the most use of available resources. CDOT has discovered that using LCCA helps the agency execute its purpose better and serve the public more effectively. CDOT has demonstrated that the use of LCCA can be cost-effective.

In 1994, the Georgia Department of Transportation (GDOT) adopted the first LCCA guidelines. In 1998 GDOT took part in the Advanced FHWA LCCA course, which introduced the FHWA RealCost LCCA software and participated in Federal Highway Administration's (FHWA) Demonstration Project 115, "Life-Cycle Cost Analysis in Pavement Design". The FHWA and GDOT collaborated to identify ways for GDOT to improve its LCCA practices. This work has also allowed FHWA to improve the RealCost LCCA software, making it an even more appealing tool for states conducting LCCAs.

3.2.7.2 LCCA in the United Arab Emirates

Afshari, Nikolopoulou, and Martin researched the life cycle analysis of building retrofits at the urban scale in Abu Dhabi in 2014, evaluating the energy impact and estimating its saving for different retrofits through numerical simulation in a typical building. Moreover, an analysis prepared for abatement potential of CO_2 from each alternative and a life cycle analysis of retrofit cost. A Marginal Abatement Cost Curve (MACC) is presented for Abu Dhabi's Emirate, focusing on demand side air-conditioning load impact measures.

3.2.7.3 LCCA in Turkey

In 2016, Adem Atmaca investigated buildings in Gaziantep city and found that energy efficiency is highly reduced in residential houses, ranging from 3 to 8 G.J./m2, primary energy use, and carbon emissions in residential buildings worldwide the range of 10 to 40 G.J./m2. Moreover, this research assessed the residential building's cost, emissions, and life cycle energy requirements. It demonstrated the characteristics and differences in using energy for rural and urban residential buildings, CO_2 emissions, and life cycle cost implications. Also, it studied the area in the southeast of Turkey and assisted in identifying building energy and cost-cutting strategies in the face of rapid urbanisation.

3.3 Life Cycle Cost (LCC) Phases

Once one of the alternatives is chosen, and after carrying out a feasibility study, it is time to begin planning and organising the project's investment. Then the expenses begin.

The term "life cycle cost" refers to the total costs of the project over its entire life cycle. So to get an accurate price for the project, cost estimation should be made for each phase. The project life cycle depends on three main phases, the first phase is designing and construction, the second is operation and servicing, and the third phase is decommissioning. There is a cost related to each stage that needs to be defined, analysed, and estimated to use in LCC calculation to get the total to consider the total life cycle cost of the project.

$$LCC = C_I + C_{O\&M} + C_D$$

Therefore, authorities, stakeholders, and anyone else involved in the project will be aware of the costs of each phase as well as the overall project cost. According to that, the budget for the project will be arranged right.

Figure 10 Phases of life cycle cost

3.3.1 Initial Cost (IC)

The initial cost is the cost incurred during the first stages of the project's life, which means the charges incurred in the short term, from the initial concept to the project's handover to the concerned stakeholder. The initial cost can be divided into three main parts: land cost, designing cost and construction cost. Furthermore, all the three-part are the most manageable parts to be controlled and estimated correctly in most projects.

The land cost is the first thing to put the money in when start planning to build. Design cost includes the total design costs from the initial concept design to the detailed design stage. Construction costs transfer a design plan into a project ready for operation with all the materials, equipment, labour, and testing required, direct and indirect.

The work breakdown structure (WBS) technique is a simple way to identify the work and activities in this phase. This method is used to break the job down into smaller tasks to make the job more manageable and approachable. By creating a detailed WBS tree based on drawings and specifications, all activities can be identified. Each WBS activity will be costed by identifying the resources required, estimating the duration, and calculating the total cost. After that, the total cost of all activities will be calculated to determine the project's initial cost, which will be used for LCC calculations later on.

However, to get a proper and accurate estimation of the project life cycle, project managers should calculate the other phases costs and not depend on the initial cost only.

3.3.2 Operation and Maintenance Cost (O&MC)

Following the completion of the project's construction and delivery to the project's concerned stakeholders, this phase begins, which is the longest and includes all costs associated with operating, repairing, and maintaining the project over its entire lifetime. Some expenses in this phase, such as energy, labour, spare parts, and transportation costs, must be carefully considered during the planning phase to reduce project running costs.

The majority of the company's strategies are geared toward increasing profits and reducing costs. This could be determined during the planning stage by estimating the operation and maintenance costs. The LCCA will use these costs to calculate the project's LCC and choose the best project alternatives.

When compared to the total cost of a structure, design and construction costs are minor. A large proportion of the total cost will occur during the service life; typically, the earlier design, development, construction, and manufacturing activities may be as little as 20% to 50% of the total life cycle cost and from 50% to as much as 80% for the operation and maintenance, (Griffin, 1993). Figure 11 depicts the relative expenses of the various life cycle phases.

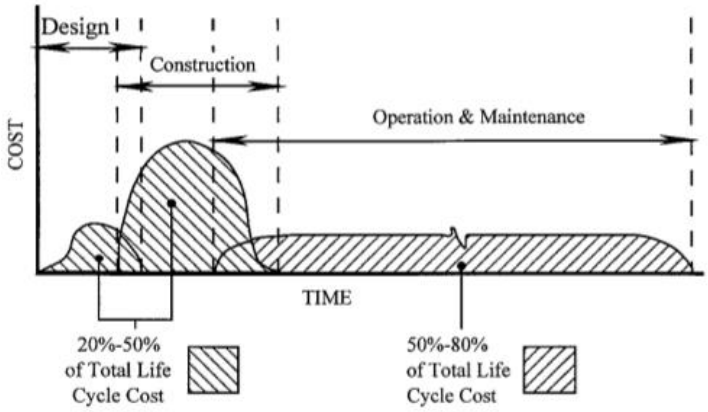


Figure 11 Life Cycle Costing Profile (Adapted from Griffin 1993 cited in Dunston & Williamson 1999)

3.3.3 Decommissioning Cost (DC)

The cost of decommissioning at the end of the asset's life cycle is the final step of the life cycle. Decommissioning may have a monetary value, such as the item being sold, or a monetary cost, such as demolition, dislocation, and removal. There are several expenditures associated with the disposal stage, which includes a smooth transition to the new system as well as the removal/recycling of the old one.

Salvage value is another phrase used in the literature related to the expense of decommissioning. The salvage value of a component or system is defined as its market worth at the end of its useful life. For example, such a value can be calculated by developing a depreciation schedule for a system, including physical and functional depreciation categories. Due to physical impairment, physical depreciation lowers a system's capability to deliver its intended service. This sort of depreciation causes asset or system performance to deteriorate, as well as high maintenance costs. Functional depreciation is the other type of depreciation. It happens due to organisational or technological developments that reduce or eliminate the necessity for a system. For instance, depreciation occurs when a present system becomes outdated due to

technological advancements or the system's inability to fulfil the rising demand for quantity or quality.

As a result, during the planning phase, the decommissioning expenses of the project must be factored into the design. Because the affected parties will be aware of such expenses, this consideration may result in future savings when disposing of the project.

Furthermore, the system should be constructed such that, if necessary, it can be disposed of in the least expensive and ecologically responsible manner possible. Not only costs but also environmental factors must be addressed. Environmental problems are becoming increasingly important to consider while developing a building. Therefore, the decommissioning phase should not have any adverse environmental consequences since it will result in additional unanticipated costs to recover the situation. Adequate considerations must be created throughout the decommissioning stage, such as remanufacturing and recycling, as well as environmentally beneficial techniques.

The decommissioning cost may be difficult to get during the planning phase since it is difficult to quantify; nevertheless, if found, it will be extremely valuable to include in the LCCA. Thus, a total cost estimate for the entire project can be determined, and the budget may have adhered. Whole life costs take into account all expenditures connected with a building's life cycle, from conception to construction, occupation, and operation, as well as final disposal. This is seen to be a better means of evaluating value for money, as it results in reduced short term expenditures but more significant long term expenditures.

3.4 LCC Limitations

- LCC is not an exact science; many answers might be varied; none of it is right or wrong; it is just a matter of logic or non-logic. Because the subject has a wide range, there is no specialisation in the LCC field.
- LCC models work with a minimal database that is hard and costly to locate in the operating and supporting areas.
- LCC requires too many details and extensive extrapolations for the data; thus, obtaining facts is difficult. Details required are the cost processors' function, model age over time, the number of years the model will survive.
- LCC outputs are just estimations, and it is not accurate as the intervals and inputs are. The cost-risk analysis is one primary example of this.
- LCC models must be standardised and calibrated to be extremely helpful.
- LCC results are functional as a comparison way only, not as a budgeting tool.
- LCC is less used in commercial areas because of the few practitioners of LCC, but it is more common in the military projects
- LCC models require too much data that is not available; unfortunately, most of them are suspect.
- LCC estimation has an accuracy shortage. Errors in accuracy are hard to calculate because of the significant variances obtained by statistical methods.

CHAPTER 4: FINANCIAL ANALYSIS, LCCA METHODS, AND PROGRAMS

4.1 Overview

This chapter clarifies all the main principles of financial analysis, steps, techniques, and models. It also aims to show the importance of economics and how it reflects on the engineering side. The inflation rate, interest rate, and discount rate are values that have a significant effect when analysing a project. This chapter also looks at LCCA evaluation methods such as net present value (NPV), average annual cost (AAC), internal rate of return (IRR), and payback technique. Finally, some LCCA calculations software was presented with some details about each.

4.2 Financial Analysis

Estimating the company position, performance, and successful investment using its financial statement is called "financial analysis". Many things can assist the financial analysis process, such as knowing its resources, source of profitability, future earning power, etc.

4.2.1 Financial Analysis Fundamental Concepts

- Present Value (PV)

  Present value is the present-day value of an amount that is received at a future date. It takes the future value and applies an interest rate or discount rate that could earn if this money is invested. Blank & Tarquin (2005), give another formula for calculating present value, which is the basic one:

$$PV = \frac{FV}{(1+r)^n}$$

  Wherein:

  PV- Present Value, FV- Future Value, r- real discount rate, n- the life of a project in years

- Future Value (FV)

  Future value is the present-day value based on a growth rate that is assumed. It is an important concept and value for the investors and decision-makers to decide how much a current investment will be worth in the future. This data can help in making sound investment decisions.

  Simple yearly interest and compounded yearly interest are two methods for determining future value:

  - Future Value Using Simple Annual Interest

$$FV = I \times (1 + (R \times i))$$

  - Future Value Using Compounded Annual Interest

$$FV = I \times (1 + i^{T})$$

  Wherein:

  I- Investment amount, i- interest rate, T- Number of years

- Time Value of Money (TVM)

  Money today worth more than the future; in other words, they are not equal because of the potential earning capacity.

  Some terms must be considered while calculating the time value of money, such as interest rate, time frame, number of compounding periods throughout each time frame, present value, and future value. To calculate the time value of money:

$$FV = PV \text{ x } [\ 1\ +\ (\text{i} / \text{n})\ ]^{(\text{n x T})}$$

  Wherein:

  i- interest rate, n- number of compounding periods per year, T- number of years

- Inflation Rate

  The inflation rate is defined as a decrease in buying power of a specific currency over time in conjunction with raising the prices for goods and services.

- Interest Rate

  An interest rate is a percentage calculated based on the total amount you save or borrow. So it is either the reward for saving money or the cost of borrowing it.

- Discount Rate

  The discount rate is the interest rate used in analysing discounted cash flow to figure out the present value of future cash flows to be time-equivalent.

4.2.2 Financial Analysis Parts

The financial analysis may be divided into three parts: profitability analysis, risk analysis, and analysis of money sources and uses.

4.2.2.1 Profitability Analysis

Making profits means earning more than spending, which is what every business owner wants for his company. That is why a careful study of the profits is essential and worthy.

In other words, profit is the remaining money from the capital after deducting all the overhead costs and analysing profit to keep the business's performance on the track. Profitability analysis gives companies the chance to maximise their profit; maximising the profit means higher growth opportunities and a better understanding of the markets, leading to helping the decision-makers see a more realistic picture of the company.

4.2.2.2 Risk Analysis

Risk analysis is assessing a company's capacity to fulfil its commitments. It involves assessing the company's circumstances along with its earnings variability. Risks are one of the premier worries of owners; it is essential to evaluate it all from the beginning, which will help maintain company performance and estimate its capital cost.

4.2.2.3 Analysis of Sources and Uses of Funds

Sources and uses of money relate to the flow of funds, which provides a methodology for determining how significant financing activities impacted and how the performance is during an accounting period influenced.

A good analysis begins with a good definition of the existing situation of the project. Definition considers the schedule of predicted costs, O&M costs, and other future costs.

4.3 LCCA Methods

For LCCA, there are three main economic evaluation methodologies. Net Present Value (NPV), followed by Equivalent Annual Cost (EAC) and Internal Rate of Return (IRR). These methods are proper with the LCC method because they are all based on the same stream of costs, savings, and period of time.

4.3.1 Net Present Value (NPV)

The discounted projected cash flow to present value focuses on the cost, considering the time value of money. In other words, It is the worth of its functionality in today's dollars over the specified timeframe. The net present value (NPV) is one of the most often used in financial analysis. When competing alternatives have different life durations, this strategy is ineffective.

The NPV technique for LCCA may be expressed as follows, Kaufman (1970):

$$NPV = C + R - S + A + M$$

Wherein:

C- investment costs

R- replacement costs

S- resale value (at the end of the study period)

A- Annually recurring operating, maintenance and repair costs

M- non-annually recurring operating, maintenance, and repair costs

The net present value approach calculates the current value of future costs for the operation & maintenance and decommissioning cost. Because the initial cost happens in the same year as the project's start, it cannot be converted. Obtaining the NPV is a dollar today that has a different value than one year later because of interest and inflation rates, Taylor (1981).

A positive NPV means that the project is economically feasible and profitable, and a negative NPV shows the amount of money that a project will lose.

Moreover, more variables must be considered when calculating LCCA to get an accurate evaluation, such as escalation rate, study period, staffing costs, and discount rate, Johnson (1990).

After calculating the present values of the project's future costs, the LCC can be determined by summing the C_I with the $C_{O\&M}$, and C_D present value. The same calculations must apply to all other alternatives. The decision can be made easily by choosing the lowest LCC, which combines all costs rather than only considering the initial expense, Woodward (1997).

"The rationale behind LCC is that while the initial cost of a product may be greater than a competing product, the total cost of ownership may be less because, over its useful life, it is less expensive to operate or maintain." writes Coe, (1981, p.564).

4.3.2 Average Annual Cost (AAC)

Another economic indicator takes into consideration the "present worth of annuity" into account. This approach can compare different alternatives with different life lengths, but it does not provide the actual cost each year. When there are different life periods for the alternative; It is more suitable to use it than the present value method.

Multiply the computed present value by a capital recovery factor to get the average yearly cost, Brown (1979):

$$AAC = PV * \frac{r(1+r)^n}{(1+r)^n - 1}$$

Wherein:

r- real discount rate

n- the life of a project in years

4.3.3 Internal Rate of Return (IRR)

Internal Rate of Return (IRR) or Return of Investment (ROI) determines an average return rate based on the assumption that all values are set to zero at the initial point of time.

Result gives an obvious interpretation. Higher ROI means a higher investment productive. Hastak (2015), has computed an equation to find the ROI:

$$ROI = \frac{[profit = project\ output - project\ costs(inputs)]}{project\ costs\ (inputs)} = x\%$$

ROI is a method used to compare investments profit, which will be worthwhile and economically feasible if it exceeds the owner's declared discount rate. However, as a disadvantage of this method, calculations must be done by trial and error. Furthermore, this strategy may only be implemented if the investments are profitable.

4.3.4 Payback

Another way of evaluating LCCA alternatives' cost-effectiveness is to check their "payback" against the base case. The payback term refers to the time the option takes till it reaches the base case. In other words, it measures how fast the initial investment can be covered. Applying payback is giving the option to find the cumulative cost for all options.

Payback can be calculated by Shtub, Bard & Globerson (2005):

$$Payback = \frac{P}{B_j}$$

Wherein:

P- initial investment

B_j- annual net undiscounted benefits in year (i)

The disadvantage of using this method is that it does not consider the project's condition initially, which leads to additional costs such as maintenance costs. Furthermore, the payback method ignores all costs and savings that occur after reaching the payback point; therefore, it does not measure profitability.

Therefore, selecting the best method to calculate LCC is the planner's and decision-makers responsibility, depending on their information and the information they want. Moreover, it should be noted again that selecting the alternative shall not depend on the initial cost only but

shall consider the lowest LCCA to reduce future cost overruns. The net present value (NPV), average annual Cost (AAC), internal rate of return(IRR), and playback are examples of the main common discounting methods.

4.4 LCCA Programs

Fortunately, many software is available in the market to help in calculating LCCA. Some examples of this software are:

4.4.1 eVALUator

The eVALUator is a Microsoft Windows program created by Energy Design Resources to calculate the life cycle benefits of investments that enhance building design by reducing energy costs and promoting employees' productivity.

eVALUator allows using multiple inflation rate assumptions for capital expenses, electricity and gas costs, operation and maintenance expenses, and other general expenditures. It is also flexible in studying different lifetimes of buildings. Moreover, this software takes into consideration the discount rate, capitalisation rate inputs, and occupant productivity.

Inserting data for the analysis is easy and quick, and the outcomes are simple, direct, and not complicated to compare the alternatives and examine results. On the other hand, one of the limiting factors for this software that the final reports and results do not have many details.

4.4.2 Building Life Cycle Cost (BLCC)

The National Institute of Standards and Technology (NIST) designed and developed the Building Life Cycle Cost programme to measure energy and water savings. However, it can handle and resolve any life cycle cost analysis.

BLCC is a straightforward software that allows considering as many details for the building type and size. Furthermore, it calculates life cycle costs, energy consumption, net savings, internal rate of return, and payback time for each option.

The reposts given by this program are also easy to read and study. Two main limiting factors can be found here: life cycle costs can not be found or calculated for more than 25 years; it is also not considering employee productivity when analysing data in this software.

Based on the brief explanation for each software and the use of both, eVALUator would be a better choice for simple buildings and projects. It is fast, easy, exact, and provides enough information to make the perfect decision. The Building Life-Cycle Cost (BLCC) program would be preferable for more complicated projects that require more extensive information on energy consumption and funding.

CHAPTER 5:

VALUE ENGINEERING

5.1 Overview

In the 1940s, and amid world war II, the concept of Value Engineering (VE) was raised at General Electric Company (GEC) in the USA by Lawrence Miles and some other engineers. Due to the circumstances, mainly due to war, there were shortages of materials and toil; many searches were made to find other alternatives. These alternatives, in turn, had often proved that they had less expenditure and even showed similar or even better efficacy.

In 1959, The Society of American Value Engineers (SAVE) was established in the United State. A professional organisation work on developing the VE concept. This organisation is known today as SAVE International. Some other organisations were engaged in spreading this unique technique around the world, such as:

- Institute of Value Management (IVM)-UK, 1971.
- Indian Value Engineering Society (INVEST), 1977.
- Society of Japanese Value Engineering (SJVE), 1980.
- The Institute of Value Management AUSTRALIA, 1991.
- Canadian Society of Value Analysis (CSVA), 1993.
- Hong Kong Institute of Value Management (HKIVM), 1995.

5.2 What is value engineering?

Value Engineering (VE) is "the process of reducing the cost of producing a product without reducing its quality or how effective it is" Cambridge Dictionary. VE or value analysis (VA) is a creative, organised effort that offers options for the developers to choose among, with the required functions in a project provided at the lowest cost.

The architecture handbook of professional practice describes value engineer as "the systematic application of recognised techniques that identify the facility's functions, establish the worth of those functions and provide the necessary functions to meet the required performance at the

lowest overall cost." It facilitates the replacement of materials, as well as methods through less expensive options without letting go of the functionality, quality, reliability, or safety. Overall, reducing costs and increasing functionality or benefits will increase the value of the product or project. Furthermore, one major point to highlighted that VE is not a cost-cutting.

Figure 12 Cost vs Value

A product's worth is usually the most cost-effective approach of producing an item, system, or service without sacrificing purpose. In other words, it is thought to be the ratio of two factors: function to cost. This ratio actively demonstrates that the value of a product can be elevated by either enhancing its function or diminishing its cost. The production, design, maintenance, as well as replacement cost, are all part of the analysis in value engineering.

$$Value = \frac{Function}{Cost}$$

The function is what the product or service does, and cost refers to the components needed to construct.

5.3 Value Engineering phases

Value engineering is divided into three phases: planning, design, and methodology phase.

5.3.1 Planning Phase

The planning phase is the initial stage regarding development. It is the base to maintain the best construction project. Setting up a plan is the best way to start the project, to reduce the number of changes and redesign, which will affect the cost and time.

5.3.2 Design Phase

In this phase, a review of the desired project is made together with all parties. This phase aims to review the project basics, such as the project's design plans, cost, and duration.

5.3.3 Methodology Phase

The last phase is the methodology, divided into seven steps: collecting information, function analysis, creative brainstorming, evaluation, development, presentation, and construction.

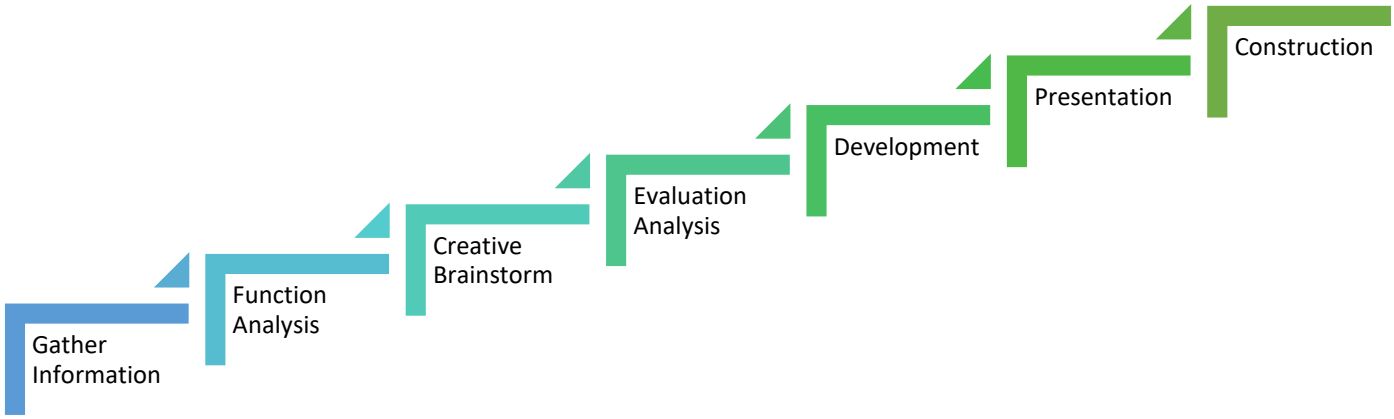


Figure 13 Value Engineering Steps

Each step involves critical analysis and elimination. A brief description of each step will be clarified.

5.3.3.1 Gather Information

This step is the start of the value analysis, which collects project information and sets the goals. Information can be gathered from similar projects to compare all possible alternatives. After that, data analysis must be done to set up the project priorities and improvement methods. This step will also identify the ways of evaluating project progress.

5.3.3.2 Function Analysis

The function analysis step defines each function in the project by setting the targets that need to be attained through the item's execution. Identifying and analysing each function will help in finding out if there are improvements to be made. The cost of each function must be assigned too in this step.

5.3.3.3 Creative Brainstorm

The creative stage involves exploring the various ways and ideas of performing each function defined in the previous step. This stage will allow creative thinking and finding out more alternatives and solutions for any problem faced at any point. Quantity is preferred over quality during the brainstorm, the more ideas, the better evaluation.

5.3.3.4 Evaluation Analysis

The evaluation step follows the creative stage; it will examine all alternative and solutions' advantages and disadvantages. If the disadvantages are more than the advantages, the alternative will be eliminated directly. After that, the remaining alternatives will be ranked, and the best will go to the next step.

5.3.3.5 Development

This fifth step involves conducting in-depth analysis for each alternative to determine the best way to perform and the cost involved. Many techniques can be used in this step, such as sketches, charts, design models, and cost estimation.

5.3.3.6 Presentation

This stage is where all information about the project is gathered and presented in front of the owners and decision-makers. The data shall be presented in detail using reports, flow charts, documentation and information needed, and other presentation materials, including associated costs, benefits, and potential challenges to convince them that the development stage's final ideas should be implemented.

5.3.3.7 Construction

The final step is project construction after taking the final decision. When implementing the project, the primary goal of increasing the project value shall be ensured to achieve. All cost savings that happened upon following the recommendations of the project should be determined.

5.4 When to Use Value Engineering?

There is no wrong time to use value engineering; it may be administered at whatever phase of the project, design, as well as construction. Nevertheless, applying VE as early as possible at the planning and design stage will save time and cost down the line giving a better investment return.

However, Value engineering is not helpful for the project if it causes a delay in the project. Figure 14 shows that value engineering sometimes can move from being financial gain to a financial loss.

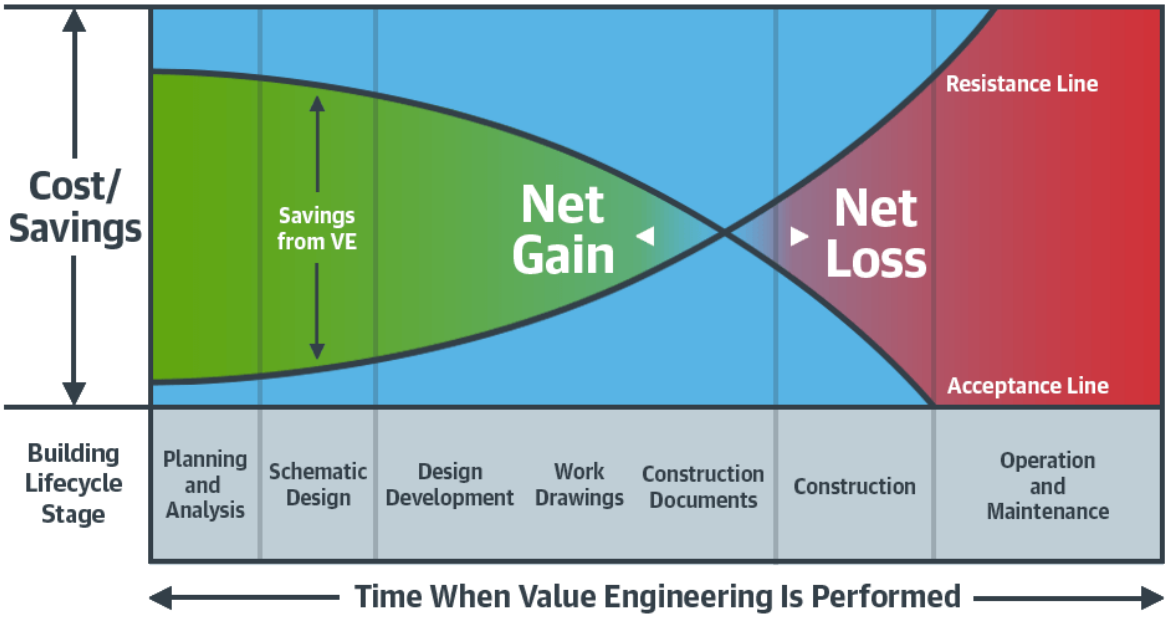


Figure 14 Potential Savings from Value Engineering

One main area that should never compromise or take it unseriously is safety. Any alternative that would not follow the standard building codes or hurt people who use the facility should be rejected directly.

Value engineering is not a way of lowering the cost; the goal is to maximise function at the lowest possible cost. In other words, it is a method guaranteed by the owner for not overpaying for quality when the exact specifications with less price can be earned.

5.5 The Future of Value Engineering

Applying this methodology is not limited to the construction industry only, but to many various industries too. Value engineering can help in solving any problem related to producing a new product or doing a service.

Every day new and improved technology is discovered, which gives many choices for solving the problems. Value engineering gives the chance to be creative and discover new ideas to maximise functionality, and that will improve the project performance in conjunction with financial benefits.

CHAPTER 6:

METHODOLOGY

6.1 Overview

Subsequent to the thorough literature review in the preceding chapters regarding the use of life cycle cost analysis in addition to value engineering for assessing the projects, this chapter will be related to the research framework, which depends on numbers, facts, and values to help the researchers, investors, and landlords to make the best decisions.

6.2 Research Methodology

The methodology of this research will hand the answer to three main questions: How was the data collected? How was it analysed? How to ensure valuable and reliable results that address the aims and objectives of the study?

A mixed method was used in this research by utilising qualitative and quantitative methods to provide better insight. Such a type of research strategy is usually described as a multitrait-multimethod matrix, Campbell and Fiske (1959) or "triangulation", Webb et al. (1966).

Denzin (1978) has defined triangulation as "the combination of methodologies in the study of the same phenomenon." The metaphor of triangulation is based on navigation in addition to the military strategy, which uses many reference points in order to determine an object's exact position. Taking into account the fundamentals of geometry, numerous viewpoints permit for better precision. Likewise, organisational researchers are also able to amend their verdicts through building up diverse data-bearing on the same event.

Qualitative research refers to research that focuses on collecting and analysing words, whether written or spoken, non-numerical data, analysed by non-statistical methods such as records and interviews.

Whereas quantitative research focuses on measurement and testing, numerical data such as survey research, questionnaire, analysed using statistical software such as SPSS.

The mixed-method methodology that combines qualitative and quantitative methods will complement each other and show the complete picture.

6.3 Basics Data

One project was chosen to be the study case of this research. This project is located in the emirate of Sharjah, precisely in the Muwalih commercial area, overlooking a side street, consist of a ground floor, one and a half parking floor, and five typical floors.

The project studied and constructed by an unlimited engineering consultants office in Sharjah, established in 2007 by the researcher's father, who worked in this field as a civil engineer for more than 40 years and opened his office, which has more than 14 years of experience till today.

This type of project is considered under commercial type because it contains units for rent. The architecture design of the project has been done by one of the most talented architecture engineers in the field and under the researcher's father supervision. The architect-engineer worked on using each centimetre of the land and built-up area for the owner's benefit to get higher income in the future.

After the construction is done, the building name was chosen, and it was Al Hoor, the owner's youngest daughter name. Al Hoor building contains some shops and studios on the ground floor, one and a half parking floor for cars slots and a variation of 1 Bedroom and 2 bedroom flats on each floor, the exact numbers of each are mentioned in Figure 15.

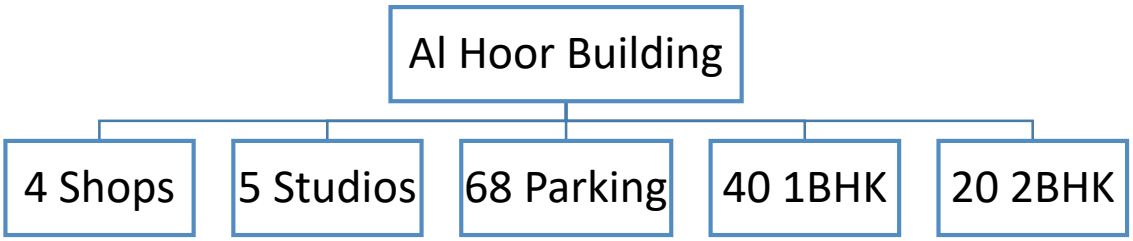


Figure 15 The Composition of the Building

Table 1 shows the gathered data for this project, plot area, number of flats on each floor, and bedrooms type on each floor.

Plot area	**# flats on each Floor**	**1 Bedroom**	**2 Bedroom**
1368 m^2	12	8	4

Table 1 Case Study Data 1

Moreover, data about the AC system, lighting type, initial Cost, operation & maintenance Cost, and demolition cost will be explained later in the following sections.

The super built-up area or saleable area refers to the total summation of the built-up area (carpet area + wall area) in addition to the common areas such as corridors, entrance lobby, staircase, air ducts, elevator, generator rooms, electrical rooms, Garbage Rooms, gym, swimming pool, etc.

	Super Built-up area
Ground Floor	752 m^2
1st Floor	1086 m^2
2nd Floor	1036 m^2
3rd Floor	1036 m^2
4th Floor	1036 m^2
5th Floor	1036 m^2

Table 2 Super Built-up Area for Each Floor

6.4 Service Life

Building Code Requirements for Structural Concrete (ACI-318) does not make any specific lifespan demands. Moreover, other codes giving Eurocode, for example, are based on a design life that is 50 years old.

The use of inexpensive construction materials so far has shortened the lifespan of buildings in the United Arab Emirates to whats almost about 20 years. To elaborate, the old buildings' life expectancy in UAE is not more than 20 years or 30 years at the very best. The life expectancy of these buildings is low due to the reason that to this very present day, the concrete structure is still not compatible with the local environment in almost all cases. However, durable concrete that is compatible and goes well with the local environment is a bit high in price, Zubaidi (2001).

It is known, that nothing will last forever, but in the case of a well-built structure and good maintenance, the structure will survive for many years, at least for the designed life span of the structure.

In some cases, the landlords are not aware of the fact that if they invested a little more amount, the life expectancy of their properties could probably increase by several years more. "If only 10 million Dhs were invested in the construction of such a building, its life would increase up to 50 years", Zubaidi (2001).

Al Hoor building was designed to have about 40 years of service life. The primary objective of this study is to demonstrate the scenario of investing more money to increase the service life to 60 years instead of 40 years.

6.5 Fundamental Costs

As mentioned in chapter 3, there are three cost phases to go throw in any project; initial cost, operation & maintenance cost, and finally, demolition cost. We will go into details for each one.

6.5.1 Initial Cost (IC)

Project's initial costs refer to all initial stages required to run a project. The initial cost we are talking about can be summarised in the land, the design, the construction, and authorities approval & services connection costs.

6.5.1.1 Land Acquisition

The first thing to think about when planning to construct a building is the land lot. Choosing the best land depends on the price, the size, the location, the orientation, the nature of the ground, the project type, and the authority's approval. Choosing suitable land will profoundly influence construction's possibilities or limits, overall construction cost, and long-term maintenance.

The price of a land plot and the landlord budget is most often the first-choice standard. The land rate relies on its size, shape, configuration, market status in the city or outside (suburbs).

The size of the land plot is a major factor in its price. When buying any plot, exact defined boundaries and areas should be legally measured by an expert surveyor. UAE has guaranteed this right for the landlord by giving official ownership from the Real Estate Registration Directorate (RERD).

The land location has an essential effect on daily activities, The weather, the residential, transportation availability, schools, shops, workplace, beautiful views. The landlords and developers shall be careful about this point because it will affect the rent requirements in future.

The sun's orientation will have a massive effect on maintenance costs over the years, especially for cooling requirements here in UAE, as the temperature is very high during most months of the year. Doing a good design might help avoid some disadvantages and minimise its shortcomings to improve comfort and reduce the energy bills.

The nature of the soil is important to be known before buying the land. Poor soils might increase the construction costs because of the foundations, imperative draining, or groundwater presence. Rocky or sandy soil is good to build without worries unless if there will be a basement. However, clay soil might be a source of troubles that need to be addressed during the design. Appendix 1 shows a map of the UAE with the ten great groups of soil found. The soils of UAE are made up of 2 orders, which are Aridisols and Entisols. In turn, these two orders are further divided into six more suborders, ten major groups (Emirates soil museum).

The city of Sharjah consists of a linear coastline that is separated by canals or creeks. Superficial deposits comprised of beach dune sands along with marine sands and silts. (Al Madeena Engineering Laboratory for Soil & Material Test)

The cost of the land is usually around 5% of the project's total cost. Department Of Town Planning and Survey (DTPS) in Sharjah controls the project planning along with some conditions and rules, whether it is a residential, commercial or agricultural project.

6.5.1.2 Design Cost

Design cost mainly goes to the engineering consultant work, which the owner assigns in order to do the job. A consultant is responsible for the design from A to Z. Drawing of the architecture, structure, drainage, gas, water, telephone, electricity, as well as a civil defence must be represented on paper. Moreover, the consultant is the one who approves the subcontractors after reference with the owner. The consultant will provide expert opinions, analysis, and recommendations based on their expertise.

Usually, the consultant office takes between 2.5 to 5% of the project's total cost for the design and supervision work under construction fees. However, the percentage will vary depending on the market in addition to some other factors.

6.5.1.3 Construction Cost

Construction cost is the cost of the whole project construction designed and estimated previously by the consultant that depends on the market rate. Construction cost includes all supervision, materials, labour, supplies, tools, equipment, transportation, and other facilities used or consumed. Construction of the project must be done by the main contractor and other subcontractors at a specified period. A typical range of the construction cost is 75% of the project's total cost.

6.5.1.4 Authorities Approval & Service Connection Cost

Doing a project anywhere requires government and authority's approval, and for this approval, there are general charges. Moreover, project acceptance requires the municipality and the mutual services department's approval for connecting electricity, water, gas, and telephone. Ordinarily, the authorities and service connection charges are 15% of the total cost of the project.

6.5.2 Operation & Maintenance Cost (O&MC)

After finishing the construction, connecting all the services, and deliver the building to the client, operation and maintenance costs will start to occur. Three parts of costs will take place in this phase; utility, maintenance and replacement.

6.5.2.1 Utility Cost

Utility cost is the expenses incurred for using utilities such as electricity, water, gas, and sewage. These expenses are calculated every month.

6.5.2.1.1 Electricity Cost

Electricity cost is divided into two major parts, the owner part and the tenant part. The owner part is related to the electricity consumed for the building's services like operating the elevators, external and internal lights of the building, and AC in the entrance and corridors. This bill of services will come under the owner's name.

The tenant part is related to the electricity consumption in his/her flat. That will come in a separate bill under the tenant's name; even though it is the tenant responsibility, the owner has to minimise the future cost as much as possible so the tenant will not have difficulty paying the bill every month.

A different tariff rate is specified from Sewa on the bills depends on nationality. For the service bill, if the owner is local, the electricity tariff rate will be 30 fils per Kilowatt, and non-local will have 45 fils per Kilowatt.

However, for the tenant bill also the rate for the local is different than non-local. Table 3 shows the tariff rate for each.

	Consumption (kWh)/ month	Tariff (fils/kWh)
National	No limit	7.5
Expatriates	0-2000	30
	2001-4000	33
	4001-6000	37
	6001 & Above	43

Table 3 Electricity Tariff for Nationals & Expatriates in Residential

The amount of electricity consumption is many related to the Air Condition system and lighting type. AC system varies from one project to another, depending on the project type and use of it. In Al Hoor building, the AC system used was Split Ducted (S/D). This type of system gives an average and regular consumption.

Previously, we used only the standard type of lighting, the incandescent light bulb. However, to this day, we have fluorescent lamps (FL) along with light-emitting diodes (LED). Regarding our project, the LED lighting type was chosen.

Magnificent longevity signifies that there might never be any need to change to another light again. Fifty thousand hours means 50 times more than the life of an ordinary and typical incandescent bulb, not to mention also five times the lifetime of an average FL. This in term means significantly lower maintenance and labour costs. The production of LEDs, as well as the use of them, require way less energy in comparison to incandescent light or even FL, to a large extent. LED lighting products are mercury free and don't contain other toxic materials, which amplifies a clear green win for the environment and excellent benefits.

Lumens, in simple words, is the brightness. Table 4 shows how many watts of power are needed in each light bulb type in order to bring on that level of brightness. The less the wattage that is required, the better.

Lumens (Brightness)	LED	FL	INC.
400 – 500	6 – 7W	8 – 12W	40W
650 – 850	7 – 10W	13 – 18W	60W
1000 – 1400	12 – 13W	18 – 22W	75W

Table 4 Lumen & Wattage Comparison

LED bulbs demand way less wattage in comparison to FL or Incandescent light bulbs, which is the reason why LEDs are further seen as energy efficient in addition to long lasting.

	LED	FL	INC.
Average cost per bulb (AED)	15	8	4
Bulbs needed for 25,000 hours	1	3	21

Table 5 LED vs FL vs Incandescent

After considering the average cost per bulb and the amount needed from each type for 25,000 hours, it is clear that the best choice in any project will be the LED type.

Therefore, LED lighting was chosen for this project due to the reasons that it is more efficient and has a longer lifespan than all the other types of light sources. LED products are designed to last for approximately as long as 50,000 hours.

6.5.2.1.2 Water Cost

Water cost is the consumption of water for flats and services. It will come with the electricity bill for each tenant and owner. Different tariff rates for the local than non-local, Table 6 shows the rate for each.

	Tariff (fils / IG)
National	1.5
Expatriates	3

Table 6 Water Tariff Rate for Nationals & Expatriates for residential

And for the service bill, the rate will vary according to the consumption amount per month. Table 7 present the tariff rate for each.

Consumption/ month (IG)	Tariff (fils / IG)
0-10000	3.5
10001-20000	4
20001 & above	4.6

Table 7 Water Tariff Rate for Commercial and Industrial Entities

6.5.2.1.3 Gas Cost

The gas system is divided into two types, gas cylinder system and gas pipe system. The cost of the first type depends on changing the cylinder and how long it will stay. The cylinder system is no more used or accepted by the gas authority. On the other hand, the gas pipe system will cost an initial specific amount of 300 Dhs to be paid with the first tenant bill, this is for connecting the pipe from SEWA, plus monthly charges will come with the SEWA bill for consumption.

According to the first quarter report 2020 generated by Sharjah Electricity Water & Gas Authority, the number of consumers in the emirate of Sharjah increased slightly from October 2019 to March 2020 for electricity, water and natural gas. (Figure 16)

Sharjah City مدينة الشارقة			Cities المدن
غاز طبيعي Natural Gas	مياه Water	كهرباء Electricity	الشهور Months
243,060	333,967	357,207	Oct 2019 أكتوبر
243,348	334,161	357,088	Nov 2019 نوفمبر
243,767	334,207	357,205	Dec 2019 ديسمبر
244,413	334,862	358,007	Jan 2020 يناير
245,463	336,284	359,237	Feb 2020 فبراير
244,961	335,481	358,336	Mar 2020 مارس

Figure 16 Number of Consumers in Emirate of Sharjah

6.5.2.1.4 Sewage Cost

This utility is offered free of charge in Sharjah for most areas. Some areas are not covered because of the sewage system issue, such as Muwailih area, where our project is located. So private companies used to remove the sewage water for some charges. The owner will carry this amount, which is approximately 150 Dhs/trip. The number of trips depends on the size and occupancy of the building. For Al Hoor building, the number of trips is between 25 to 35 per month when it is fully occupied. An average of 30 trips per month was considered for each year in the project service life. Except for the first year because it was the beginning of the rent.

6.5.2.1.5 Survey

Two surveys were conducted to get an overview of the relation between the utility charges of both parties, owners and tenants, and their relation with the area of the flat/building, also the effect of AC and the lighting type on the bill. The surveys were given to 50 owners who have a property in Sharjah and 50 tenants living in Sharjah too. Appendix II shows questions that were asked and their results.

We can find from the first survey that the participants were 44% local and 56% non-local, which will give a variation of answers related to the service bill amount. A/c type varies from split to wall decorative to package system; the window unit is no more used or allowed in Sharjah; this is why it has a very small percentage.

In the other survey, from the 50 participants, only 10% were local, and 90% were non-local. We can see that most people nowadays are using LED lights for the benefits mentioned previously.

6.5.2.2 Maintainance Cost

The term maintenance expense refers to any cost incurred to keep the building in good working condition. Neglecting regular maintenance may result in higher maintenance costs and, even worse, replacement costs for the building itself.

6.5.2.2.1 Facility Management

Usually, investors give their buildings to a separate company that can handle all maintenance required—this kind of companies called facility management (FM). Facility management refers to the professional management that is dedicated to providing efficacy along with the delivery of support services for the organisations that it serves.

In other words, facility management is an organisational function that assimilates people, place, and process within the built environment in order to enhance the quality of life of people in addition to the productivity of the core business - The International Organisation for Standardisation (ISO).

The cost of such private companies will vary according to their level firstly and the building size secondly.

6.5.2.3 Replacement Cost

During the life cycle of the building, some items required a repurchase and replacement. Replacement of the items depends on their age when worn out and no longer work, in other words, "productivity". Equipment life depends on preventive maintenance and the amount of use.

Table 8 shows the expected replacement items in this case study. Each item has specific years of warranty; after that, the item/work is vulnerable to damage. However, some items can exceed the warranty period and still work; this is why an extra column has been added to the table that

shows the expected life span; this was estimated according to the engineers' field experience. Replacement cost was calculated according to the percentage of items that can damage after the warranty ends.

Replacement Cost						
#	Expected Replacement Items	Warranty Years	Life Span	Original Cost (Dhs)	% to be replaced after the warranty ends	Replacement Cost (Dhs)
Carpentry Works						
1	Kitchen Cabinet	2	5	228,845	10%	22,885
2	Wooden Doors	2	5	470,000	5%	23,500
3	Ironmongery Equipment	3	5	22,620	5%	1,131
MEP Works						
1	A/C units	5	5	1,170,000	3%	35,100
2	Lighting Fitings	5	5	20,000	5%	1,000
3	LED Lighting	3	5	20,000	5%	1,000
4	Mixers	5	5	63,000	10%	6,300
5	GRP Water Tank	10	10	8,000	100%	8,000
6	Booster Pump & Transfer P	1	3	10,000	50%	5,000
7	Bathtub	5	5	15,000	10%	1,500
8	Water Heater	5	5	31,150	10%	3,115
Other Works						
1	GRP Insulation	10	10	3,000	100%	3,000
2	Roof Combo System	25	25	102,500	100%	102,500
3	Gate Barrier	1	3	19,150	25%	4,788
4	Anti-termite treatment	20	20	3,000	100%	3,000
5	Stone Cladding Work	10	10	150 Dhs/m2	-	20,000
6	SMATV System	1	3	23,350	10%	2,335
7	Garbage Chute Sytem	1	3	35,000	10%	3,500
8	Paint	2	10	50 Dhs/m2	-	16,500
9	Lifts	2	5	290,000	5%	14,500

Table 8 Expected Replacement Items

6.5.3 Demolition Cost

Building demolition is a serious mission. Demolition costs can vary widely depending on the building location and square footage. Many related costs need to be considered when starting this phase, such as debris removal, foundation removal, machine rental, transportation cost to a landfill and safety requirements. What will specify these costs is the debris type, such as concrete, wood, metal or plaster, and how far away the building site is from the closest disposal facility.

Demolition permits are required for all buildings. However, it is always preferred to rehab instead of building demolition; this is why the demolition permit will sometimes be high. Some demolition subcontractors can take care of permits and the whole procedure from A to Z for a lump sum. Most of the time, the demolition cost is not high because the subcontractor will sell the waste and benefit from it.

The demolition cost for the Al Hoor building was assumed to be 50,000 Dhs approximately, according to its location and the ease of access, this amount came after investigating with some demolition contractors.

6.6 Interest Rate

An interest rate is a percentage charged on the total amount borrowed. Any difference in interest rate can have a large effect. For example, you can borrow money from the bank to build your project today and pay it later. So the interest is the extra amount to pay for having this privilege.

For our project, the owner did not take any loan from the banks to build his project; this means that the interest rate, in this case, is equal to zero.

6.7 Inflation Rate

As explained in chapter 4, the inflation rate refers to the percentage of increase or decrease in prices during a specified period of time.

United Arab Emirates economy relies heavily on oil. The UAE possesses major stable oil reserves, as well as crude oil production that is uniformly increasing. Although the oil can keep everything afloat, it also can drag everything down. The times when oil prices decreased, the trade surplus decreased; accordingly, inflation showed this through shooting up from around one per cent to over four per cent in a duration of just three years. Three years later, that is, in 2018, it skyrocketed one more time at more than 3.5 per cent – another response due to dropping oil prices (Figure 17). Having a different economic income is the best way to reduce oil dependence, such as the tourism sector, as it was for the past few years and could stabilise inflation if one more oil price slump rockets.

For this study, the inflation rate considered to be 1.62% for the 2016 year, according to IMF.

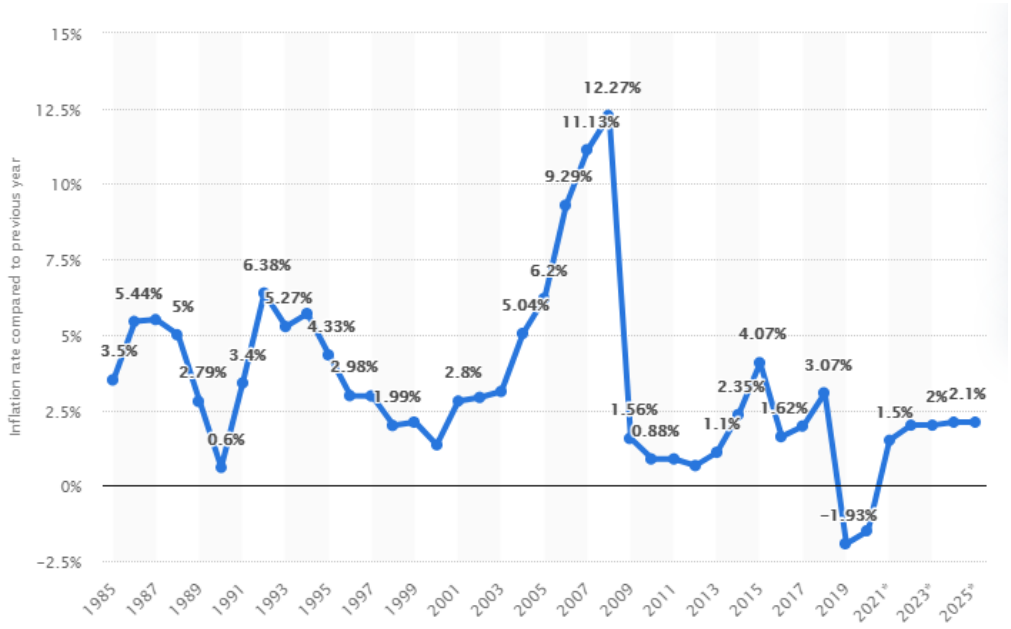


Figure 17 Inflation Rate from 1985 to 2025- UAE

6.8 Escalation Rate

Escalation rate is the change in cost for a particular good or service related to one asset over a period, the same concept as the inflation rate, however, inflation considered for all goods and services.

To calculate the escalation, inspecting the changes in price index measures for a good or service must be made. Using econometrics can help in estimating the future escalation. Escalation calculation is easy if the project will be completed within a year; escalate from the base year of the cost estimate to the year of construction.

Nevertheless, suppose the project is constructed over multiple years. In that case, the escalation calculation will be complicated because the equipment, labour and materials took place in different years, so different escalation rates will occur. In such cases, to get accurate results, a developed cash flow must be made and calculate escalation for each year. When multiple years case, escalation is compounded, not added.

Escalation is one of the main elements in a project cost estimate and should be analysed for volatile elements in prices such as concrete, aluminium and reinforcement steel. The escalation rate is considered risky in cost engineering and should be included in project estimates and budgets.

For the initial phase, the escalation rate did not vary during the construction period from 2016 to 2019. Because the construction contract was a lump sum amount, it means if the materials increase more than 30% of their original price, a variation can be submitted only, and this case did not happen. However, for the operation and maintenance phase, 2% was the escalation rate.

CHAPTER 7:

RESULTS &

DISCUSSION

7.1 Overview

The results of this research are all presented in this chapter. Al Hoor building will be analysed, evaluated, and discussed in this chapter. after that, a comparison will be conducted between the two cases, 40 years and 60 years of service life to find out which case was a better option for the owner.

7.2 Pre-analysis

The completion date of Al Hoor building was on 16-5-2019, according to the Sharjah municipality. However, the building was not operated till 1-7-2019 because of some complications from the contractor side. So, the age of the building till today is almost two years. Data in the analysis is based on accurate numbers, starting with land cost to what was spent in these two years, because it was collected from its source, the landlord, and the consultant office. The future data will be estimated according to those two years back and some other factors & rates.

7.3 Al Hoor Building Life Cycle Cost

Initial costs were divided into four main parts: Land Acquisition, design cost, constriction cost and authorities & service costs. Also, Utility costs summarised into two parts: Sewa costs, which represent electricity, water and gas costs, and the sewage cost because its charges will be paid separately. After that, the facility management cost will be calculated considering the inflation rate. The final part of the maintenance & replacement cost is the replacement divided into three main categories: carpentry work, MEP work & other works.

The life cycle cost for the operation & maintenance cost and investment cost was calculated based on the initial cost and maintenance percentage.

A comparison between the actual design of 40 years of life span and other proposed alternatives of 60 years of life span for the same project will be introduced in the following sections. This comparison aims to show if there will be any benefit if the owner has invested more in the construction phase by improving the materials used and construction methods to increase service life.

Using one of Microsoft office software, Microsoft excels, two worksheets were prepared for that. The first worksheet is for a service life of 40 years, and another worksheet for a 60 years service life.

7.3.1 Service Life: 40 years

Table 9 shows the first worksheet, which is for the existing condition, the 40 years of service life:

Life Cycle Cost Analysis

Building Name	Al Hoor		Service Life	40 years		Maintainance Cost	1% , 1.05%
Location	Muwalih		Inflation Rate	1.62%		Interest Rate	0%
Construction Year	2016-2019		Escalation Rate	2%		Year Cycle	1-9-2019 to 31-8-2020

Year	Initial Cost				Operation & Maintenance Cost							Demolition Cost	LCC		Total LCC
	Land Acquisition	Design Cost	Construction Cost	Authorities Approval & Service Connection Cost	Utility Cost		Maintainance Cost	Replacement Cost			Total O&M Cost		Operation & Maintenance Cost	Investment Cost	
					SEWA Cost	Sewage Cost	Facility Management	Carpentry Works	MEP Works	Other Works					
0,0,0	4,895,250	156,149	15,542,887	1,488,601	0	0	0	0	0	0	0	0	0	22,082,887	-
1	0	0	0	0	37,282	30,508	22,513	0	609	0	90,912	0	220,829	0	-
2	0	0	0	0	37,352	54,000	25,320	0	61	0	116,733	0	220,829	0	-
3	0	0	0	0	37,317	54,000	75,000	0	5,000	10,623	181,940	0	220,829	0	-
4	0	0	0	0	37,317	54,000	75,000	0	0	0	166,317	0	220,829	0	-
5	0	0	0	0	37,317	54,000	75,000	47,516	48,015	14,500	276,348	0	220,829	0	-
6	0	0	0	0	37,317	54,000	81,275	0	5,000	10,623	188,215	0	220,829	0	-
7	0	0	0	0	37,317	54,000	81,275	0	0	0	172,592	0	220,829	0	-
8	0	0	0	0	38,063	54,000	81,275	0	0	0	173,338	0	220,829	0	-
9	0	0	0	0	38,825	54,000	81,275	0	5,000	10,623	189,722	0	220,829	0	-
10	0	0	0	0	38,444	54,000	81,275	47,516	56,015	54,000	331,250	0	220,829	0	-
11	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	220,829	0	-
12	0	0	0	0	38,444	54,000	88,075	0	5,000	10,623	196,142	0	220,829	0	-
13	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	220,829	0	-
14	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	220,829	0	-

15	0	0	0	0	39,213	54,000	88,075	47,516	53,015	25,123	306,941	0	220,829	0	-
16	0	0	0	0	39,997	54,000	95,444	0	0	0	189,441	0	220,829	0	-
17	0	0	0	0	39,605	54,000	95,444	0	0	0	189,049	0	220,829	0	-
18	0	0	0	0	39,605	54,000	95,444	0	5,000	10,623	204,672	0	220,829	0	-
19	0	0	0	0	39,605	54,000	95,444	0	0	0	189,049	0	220,829	0	-
20	0	0	0	0	39,605	54,000	95,444	47,516	56,015	57,000	349,580	0	220,829	0	-
21	0	0	0	0	39,605	54,000	103,430	0	5,000	10,623	212,657	0	220,829	0	-
22	0	0	0	0	40,397	54,000	103,430	0	0	0	197,827	0	220,829	0	-
23	0	0	0	0	41,205	54,000	103,430	0	0	0	198,635	0	220,829	0	-
24	0	0	0	0	40,801	54,000	103,430	0	5,000	10,623	213,853	0	220,829	0	-
25	0	0	0	0	40,801	54,000	103,430	47,516	48,015	117,000	410,761	0	220,829	0	-
26	0	0	0	0	40,801	54,000	112,083	0	0	0	206,884	0	231,870	0	-
27	0	0	0	0	40,801	54,000	112,083	0	5,000	10,623	222,507	0	231,870	0	-
28	0	0	0	0	40,801	54,000	112,083	0	0	0	206,884	0	231,870	0	-
29	0	0	0	0	41,617	54,000	112,083	0	0	0	207,700	0	231,870	0	-
30	0	0	0	0	42,449	54,000	112,083	47,516	61,015	64,623	381,686	0	231,870	0	-
31	0	0	0	0	42,033	54,000	121,461	0	0	0	217,494	0	231,870	0	-
32	0	0	0	0	42,033	54,000	121,461	0	0	0	217,494	0	231,870	0	-
33	0	0	0	0	42,033	54,000	121,461	0	5,000	10,623	233,117	0	231,870	0	-
34	0	0	0	0	42,033	54,000	121,461	0	0		217,494	0	231,870	0	-
35	0	0	0	0	42,033	54,000	121,461	47,516	48,015	14,500	327,525	0	231,870	0	-
36	0	0	0	0	42,874	54,000	131,623	0	5,000	10,623	244,120	0	231,870	0	-
37	0	0	0	0	43,731	54,000	131,623	0	0	0	229,355	0	231,870	0	-
38	0	0	0	0	43,303	54,000	131,623	0	0	0	228,926	0	231,870	0	-
39	0	0	0	0	43,303	54,000	131,623	0	5,000	10,623	244,548	0	231,870	0	-
40	0	0	0	0	43,303	54,000	131,623	47,516	56,015	57,000	389,456	50,000	231,870	0	-
Total	4,895,250	156,149	15,542,887	1,488,601	1,603,915	2,136,508	3,939,791	380,124	481,790	520,593	9,062,721	50,000	8,998,776	22,082,887	31,131,663

Table 9 LCCA for Al Hoor Building (40 years)

Table 10 summarises the total cost for each phase and its proportion to the initial cost in order to see the weight of each cost and how much per cent it carries overall the project cost during the project's life cycle. The operation and maintenance phase carries around 41% of the initial cost, and demolition cost is almost nothing compared to the IC. Utility Cost from the O&MC phase is around 17%, which is more than the quarter, 7% for the electricity and water charges and 10% for the sewage charges. Maintenance cost-shares the highest percentage, which is 18% of the initial cost.

Costs	Total cost over 40 years	Ratio
Initial Cost	22,082,887	
Operation & Maintenance Cost	9,062,721	41%
Utility Cost	3,740,423	17%
SEWA Cost	1,603,915	7%
Sewage Cost	2,136,508	10%
Maintainance Cost		
Facility Management	3,939,791	18%
Replacement Cost	1,382,507	6%
Carpentry Works	380,124	2%
MEP Works	481,790	2%
Other Works	520,593	2%
Demolition Cost	50,000	0%

Table 10 Ratio of Each Cost to The Initial Cost (40 years)

Figure 18 represents the investment cost percentages of each part; construction cost is the highest percentage, with 70%, which is normal. The design cost is low because this case of study was for the owner of the consultant office, so we can assume that there was no design charge notable.

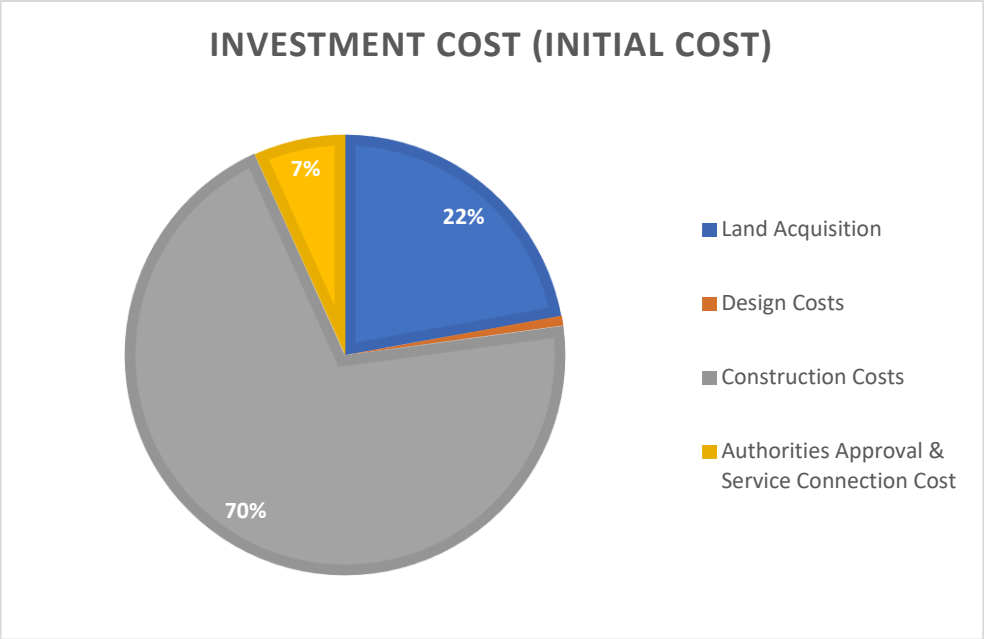


Figure 18 Initial Cost Breakdown (Subdivisions)

Likewise, Figure 19 shows the operation and maintenance cost percentages for its three main parts: utility costs, maintenance costs and replacement costs. Replacement costs took the lowest percentage with 15%. the utility cost and maintenance cost shares the highest portion by 41%, 44%, respectively.

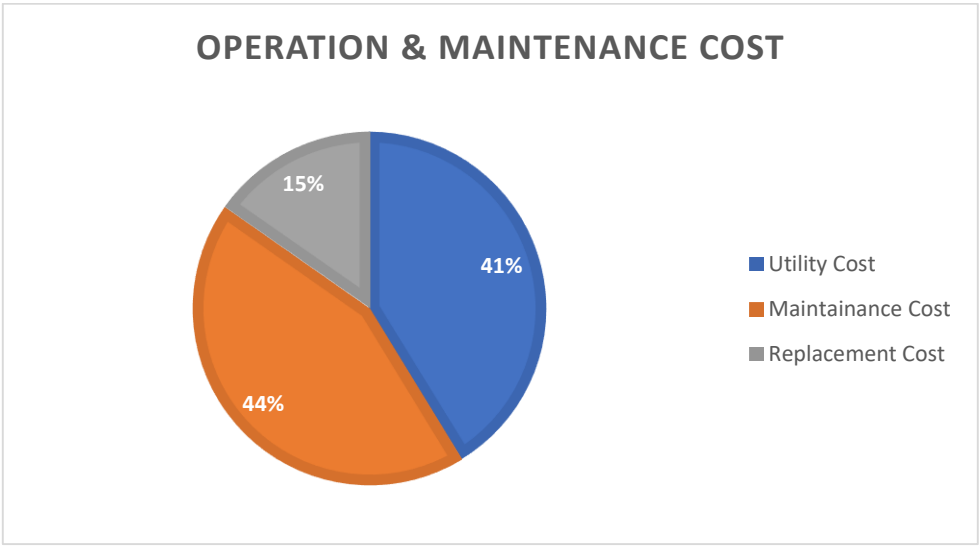


Figure 19 Operation & Maintenance Cost Breakdown (40 years)

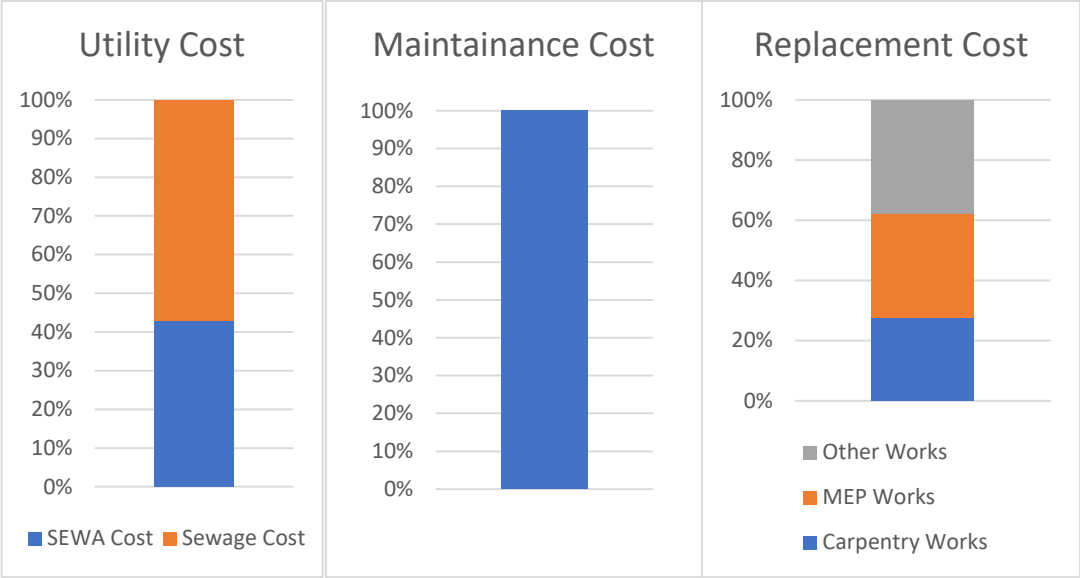


Figure 20 Sections of Operation and Maintenance Costs (40 years)

Figure 20 shows the weight of each section in the maintenance & operation cost. In the utility cost, the weight of the sewage cost is more than the Sewa cost. Only facility management is taking place for the maintenance part, which covers all maintenance contracts and services. Carpentry works take the lowest portion of the replacement cost, comes after it the MEP works and the other type of replacement work with almost the same portion.

Moreover, figure 21 demonstration the cumulative costs of the operation & maintenance stage starting from year 1 to year 40, with a total cost of 9,062,721 Dhs when reaching the end life of this project.

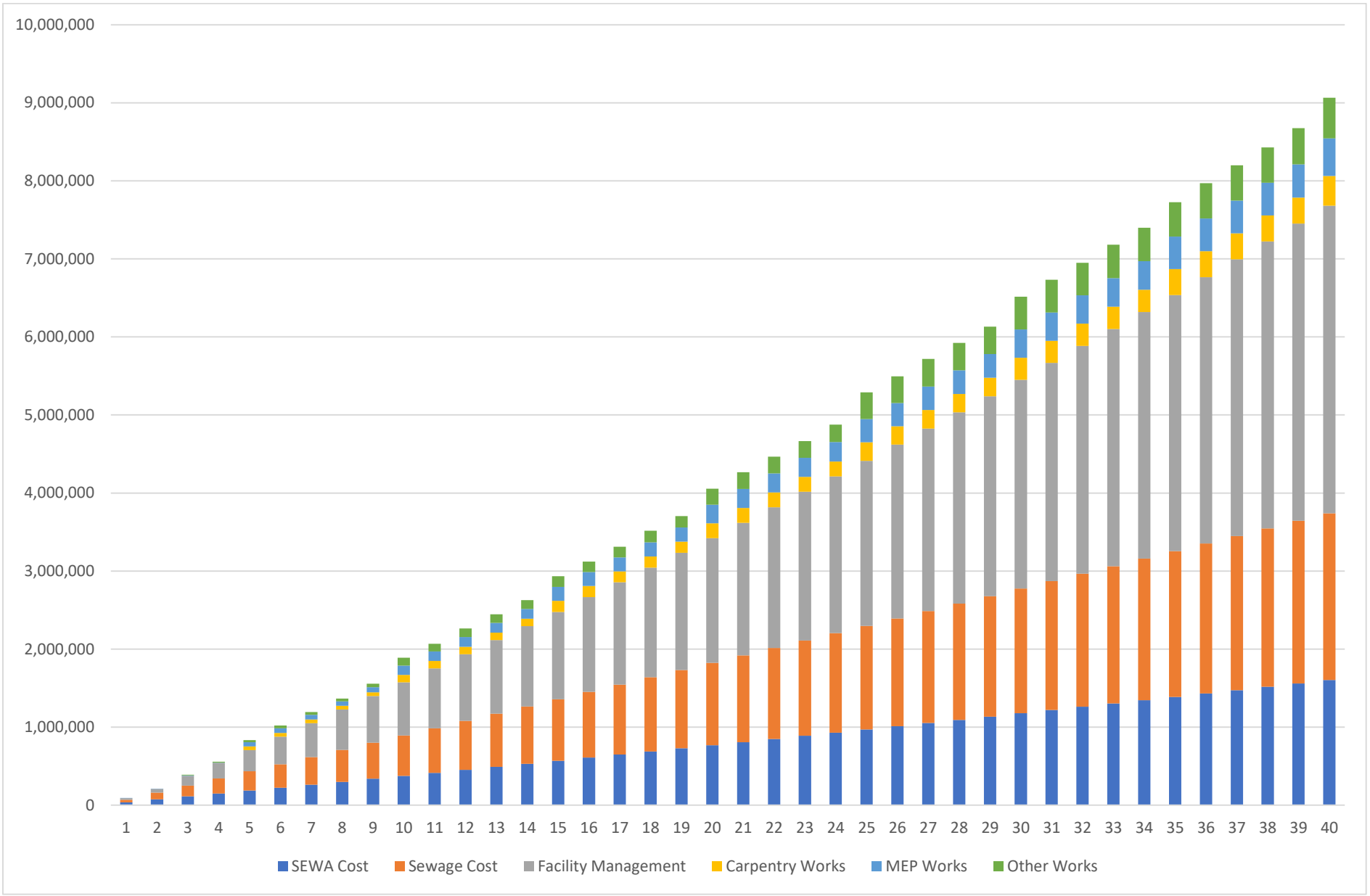


Figure 21 Total Operation & Maintenance Cost (40 years)

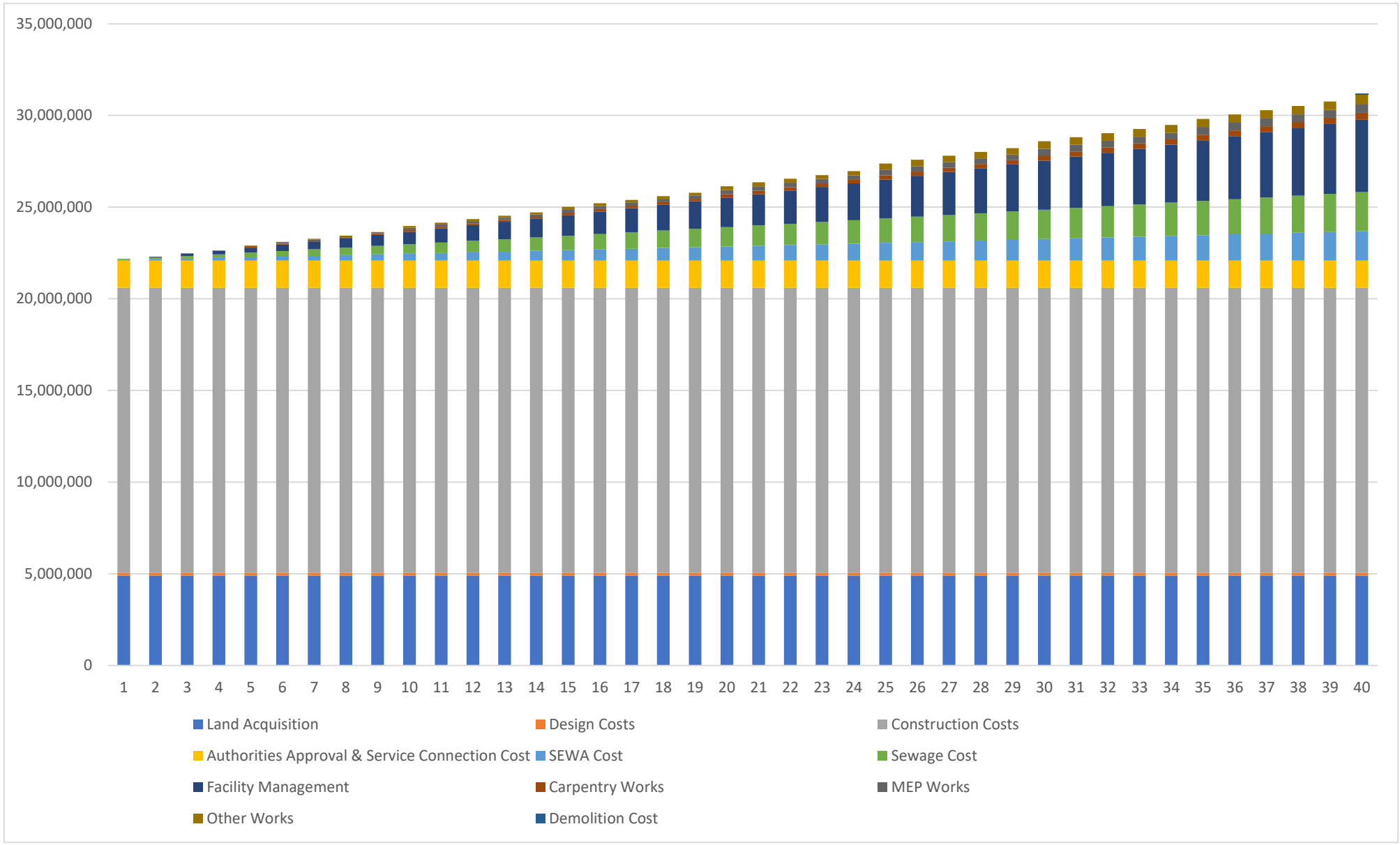


Figure 22 Life Cycle Cost (40 years)

Total life cycle cost consists of operation & maintenance cost and investment cost; both were computed in the first worksheet (Table 9). Figure 23 represents the total life cycle cost, including all costs spent on the project until it is demolished; the total life cycle cost is 31,131,663 Dhs.

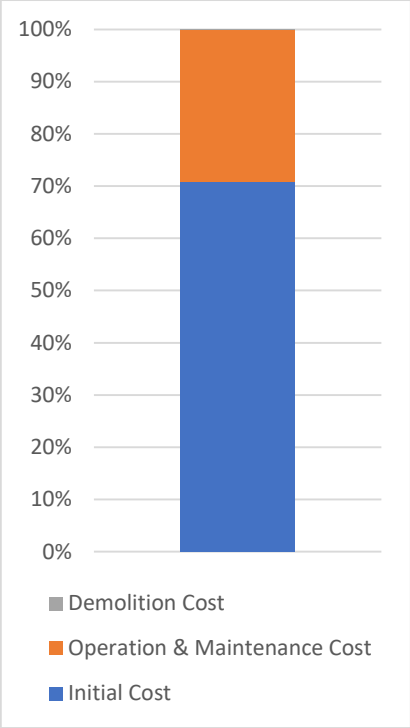


Figure 23 Life Cycle Cost Phases (40 years)

Life cycle cost phases weight are shown in figure 23; initial cost takes the highest portion, followed by the operation & maintenance cost, lastly, the demolition cost which is nothing compared to the first two phases and can be ignored.

Figure 24 is a breakdown of the percentage of each cost to the overall cost of the project. As mentioned before, the design cost and demolition cost does not weigh anything. In the second place comes MEP and carpentry replacement works. Land acquisition is high, but this is because of the great location that this project is located in, which is full of universities and schools.

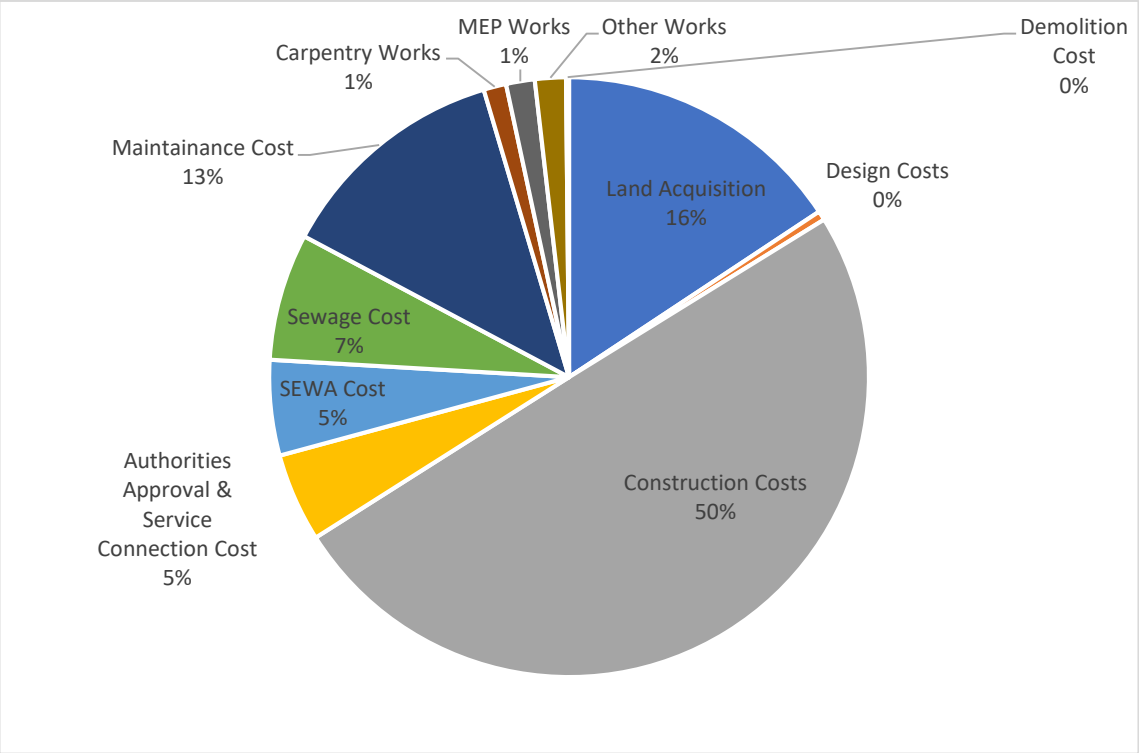


Figure 24 Breakdown Life Cycle Cost (40 years)

The following table will show how much will be the income over 40 years of service life. These numbers were not assumed but confirmed according to the rents that happened first two years. For sure, the market might vary and not have constant rates, but at least we will get a visualise the picture.

Income			
Type	#	rate/year (Dhs)	Total Income/year (Dhs)
Shops	4	50,000	200,000
Studio	5	20,000	100,000
1 BHK	40	30,000	1,200,000
2 BHK	20	40,000	800,000
Total	69	-	2,300,000
Total income over 40 years life span			92,000,000

Table 11 Total income over 40 years life span

$$\text{Total profit over 40 years service life} = \text{Total income} - \text{LCC}$$

$$= 92{,}000{,}000 - 31{,}131{,}663$$

$$= 60{,}868{,}337\ Dhs\ \approx 60{,}700{,}000\ Dhs$$

7.3.2 Service Life: 60 years

Table 12 shows the second worksheet for the proposed condition, the 60 years of service life.

The same tables and charts will be presented for the service life of 60 years.

Life Cycle Cost Analysis

Building Name	Al Hoor		Service Life	60 years		Maintainance Cost	1% , 1.05% , 1.1%
Location	Muwalih		Inflation Rate	1.62%		Interest Rate	0%
Construction Year	2016-2019		Escalation Rate	2%		Year Cycle	1-9-2019 to 31-8-2020

Year	Initial Cost				Operation & Maintenance Cost							Demolition Cost	LCC		Total LCC
	Land Acquisition	Design Costs	Construction Costs	Authorities Approval & Service Connection Cost	Utility Cost		Maintainance Cost	Replacement Cost			Total O&M Cost		Operation & Maintenance Cost	Investment Cost	
					SEWA Cost	Sewage Cost	Facility Management	Carpentry Works	MEP Works	Other Works					
0,0,0	4,895,250	156,149	25,542,887	1,488,601	0	0	0	0	0	0	0	0	0	32,082,887	-
1	0	0	0	0	37,282	30,508	22,513	0	609	0	90,912	0	320,829	0	-
2	0	0	0	0	37,352	54,800	25,320	0	61	0	117,533	0	320,829	0	-
3	0	0	0	0	37,317	54,000	75,000	0	5,000	10,623	181,940	0	320,829	0	-
4	0	0	0	0	37,317	54,000	75,000	0	0	0	166,317	0	320,829	0	-
5	0	0	0	0	37,317	54,000	75,000	47,516	48,015	14,500	276,348	0	320,829	0	-
6	0	0	0	0	37,317	54,000	81,275	0	5,000	10,623	188,215	0	320,829	0	-
7	0	0	0	0	37,317	54,000	81,275	0	0	0	172,592	0	320,829	0	-
8	0	0	0	0	38,063	54,000	81,275	0	0	0	173,338	0	320,829	0	-
9	0	0	0	0	38,825	54,000	81,275	0	5,000	10,623	189,722	0	320,829	0	-
10	0	0	0	0	38,444	54,000	81,275	47,516	56,015	54,000	331,250	0	320,829	0	-
11	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	320,829	0	-
12	0	0	0	0	38,444	54,000	88,075	0	5,000	10,623	196,142	0	320,829	0	-
13	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	320,829	0	-

14	0	0	0	0	38,444	54,000	88,075	0	0	0	180,519	0	320,829	0	-
15	0	0	0	0	39,213	54,000	88,075	47,516	53,015	25,123	306,941	0	320,829	0	-
16	0	0	0	0	39,997	54,000	95,444	0	0	0	189,441	0	320,829	0	-
17	0	0	0	0	39,605	54,000	95,444	0	0	0	189,049	0	320,829	0	-
18	0	0	0	0	39,605	54,000	95,444	0	5,000	10,623	204,672	0	320,829	0	-
19	0	0	0	0	39,605	54,000	95,444	0	0	0	189,049	0	320,829	0	-
20	0	0	0	0	39,605	54,000	95,444	47,516	56,015	57,000	349,580	0	320,829	0	-
21	0	0	0	0	39,605	54,000	103,430	0	5,000	10,623	212,657	0	320,829	0	-
22	0	0	0	0	40,397	54,000	103,430	0	0	0	197,827	0	320,829	0	-
23	0	0	0	0	41,205	54,000	103,430	0	0	0	198,635	0	320,829	0	-
24	0	0	0	0	40,801	54,000	103,430	0	5,000	10,623	213,853	0	320,829	0	-
25	0	0	0	0	40,801	54,000	103,430	47,516	48,015	117,000	410,761	0	320,829	0	-
26	0	0	0	0	40,801	54,000	112,083	0	0	0	206,884	0	336,870	0	-
27	0	0	0	0	40,801	54,000	112,083	0	5,000	10,623	222,507	0	336,870	0	-
28	0	0	0	0	40,801	54,000	112,083	0	0	0	206,884	0	336,870	0	-
29	0	0	0	0	41,617	54,000	112,083	0	0	0	207,700	0	336,870	0	-
30	0	0	0	0	42,449	54,000	112,083	47,516	61,015	64,623	381,686	0	336,870	0	-
31	0	0	0	0	42,033	54,000	121,461	0	0	0	217,494	0	336,870	0	-
32	0	0	0	0	42,033	54,000	121,461	0	0	0	217,494	0	336,870	0	-
33	0	0	0	0	42,033	54,000	121,461	0	5,000	10,623	233,117	0	336,870	0	-
34	0	0	0	0	42,033	54,000	121,461	0	0	0	217,494	0	336,870	0	-
35	0	0	0	0	42,033	54,000	121,461	47,516	48,015	14,500	327,525	0	336,870	0	-
36	0	0	0	0	42,874	54,000	131,623	0	5,000	10,623	244,120	0	336,870	0	-
37	0	0	0	0	43,731	54,000	131,623	0	0	0	229,355	0	336,870	0	-
38	0	0	0	0	43,303	54,000	131,623	0	0	0	228,926	0	336,870	0	-
39	0	0	0	0	43,303	54,000	131,623	0	5,000	10,623	244,548	0	336,870	0	-
40	0	0	0	0	43,303	54,000	131,623	47,516	56,015	57,000	389,456	0	336,870	0	-
41	0	0	0	0	43,303	54,000	142,636	0	0	0	239,939	0	336,870	0	-
42	0	0	0	0	43,303	54,000	142,636	0	5,000	10,623	250,561	0	336,870	0	-
43	0	0	0	0	44,169	54,000	142,636	0	0	0	240,805	0	336,870	0	-

44	0	0	0	0	45,052	54,000	142,636	0	0	0	241,688	0	336,870	0	-
45	0	0	0	0	44,610	54,000	142,636	47,516	53,015	25,123	313,884	0	336,870	0	-
46	0	0	0	0	44,610	54,000	154,570	0	0	0	253,180	0	336,870	0	-
47	0	0	0	0	44,610	54,000	154,570	0	0	0	253,180	0	336,870	0	-
48	0	0	0	0	44,610	54,000	154,570	0	5,000	10,623	263,803	0	336,870	0	-
49	0	0	0	0	44,610	54,000	154,570	0	0	0	253,180	0	336,870	0	-
50	0	0	0	0	45,503	54,000	154,570	47,516	56,015	156,500	458,088	0	336,870	0	-
51	0	0	0	0	46,413	54,000	167,502	0	5,000	10,623	278,537	0	343,287	0	-
52	0	0	0	0	45,958	54,000	167,502	0	0	0	267,460	0	343,287	0	-
53	0	0	0	0	45,958	54,000	167,502	0	0	0	267,460	0	343,287	0	-
54	0	0	0	0	45,958	54,000	167,502	0	5,000	10,623	278,082	0	343,287	0	-
55	0	0	0	0	45,958	54,000	167,502	47,516	48,015	14,500	329,475	0	343,287	0	-
56	0	0	0	0	45,958	54,000	181,517	0	0	0	281,474	0	343,287	0	-
57	0	0	0	0	46,877	54,000	181,517	0	5,000	10,623	293,016	0	343,287	0	-
58	0	0	0	0	47,814	54,000	181,517	0	0	0	283,331	0	343,287	0	-
59	0	0	0	0	47,346	54,000	181,517	0	0	0	282,862	0	343,287	0	-
60	0	0	0	0	47,346	54,000	181,517	47,516	61,015	67,623	398,000	50,000	343,287	0	-
Total	4,895,250	156,149	25,542,887	1,488,601	2,513,879	3,217,308	7,170,915	570,186	724,850	837,450	15,034,588	50,000	19,875,348	32,082,887	52,008,235

Table 12 LCCA for Al Hoor Building (60 years)

Again, table 13 shows how much each phase is the cost compared to the initial cost weight by a percentage. Typically, in the life cycle of 60 years for the same project, all the percentages will increase. However, it still does not exceeds the initial cost, which is an excellent indicator.

Costs	Total Cost over 60 years	Ratio
Initial Cost	32,082,887	
Operation & Maintenance Cost	15,034,588	47%
Utility Cost	5,731,187	18%
SEWA Cost	2,513,879	8%
Sewage Cost	3,217,308	10%
Maintainance Cost		
Facility Management	7,170,915	22%
Replacement Cost	2,132,486	7%
Carpentry Works	570,186	2%
MEP Works	724,850	2%
Other Works	837,450	3%
Demolition Cost	50,000	0%

Table 13 Ratio of Each Cost to The Initial Cost (60 years)

Figure 25 shows the operation and maintenance cost percentage. Same as the existing condition, the replacement cost will take the lowest percentage with 14%. In the second place, the utility cost will come with 38%, and maintenance cost will be the highest percentage of 48%.

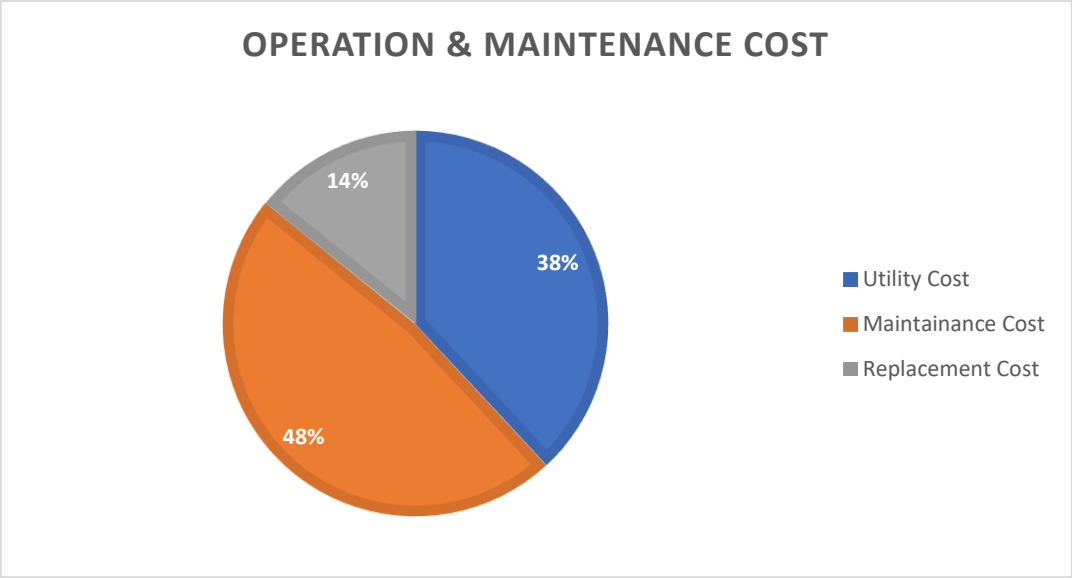


Figure 25 Operation & Maintenance Cost Breakdown (60 years)

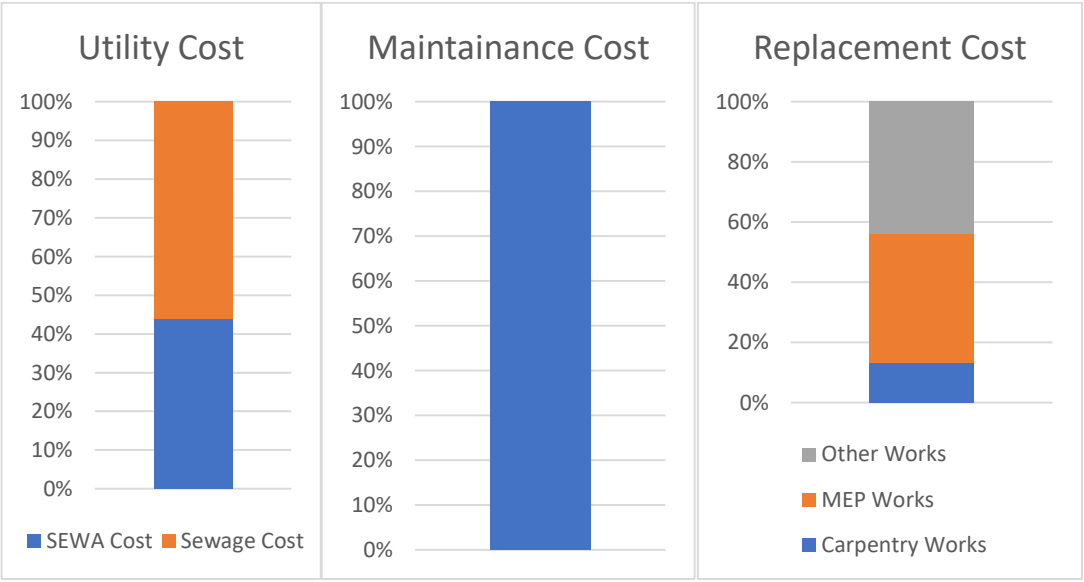


Figure 26 Sections of operation and maintenance costs (60 years)

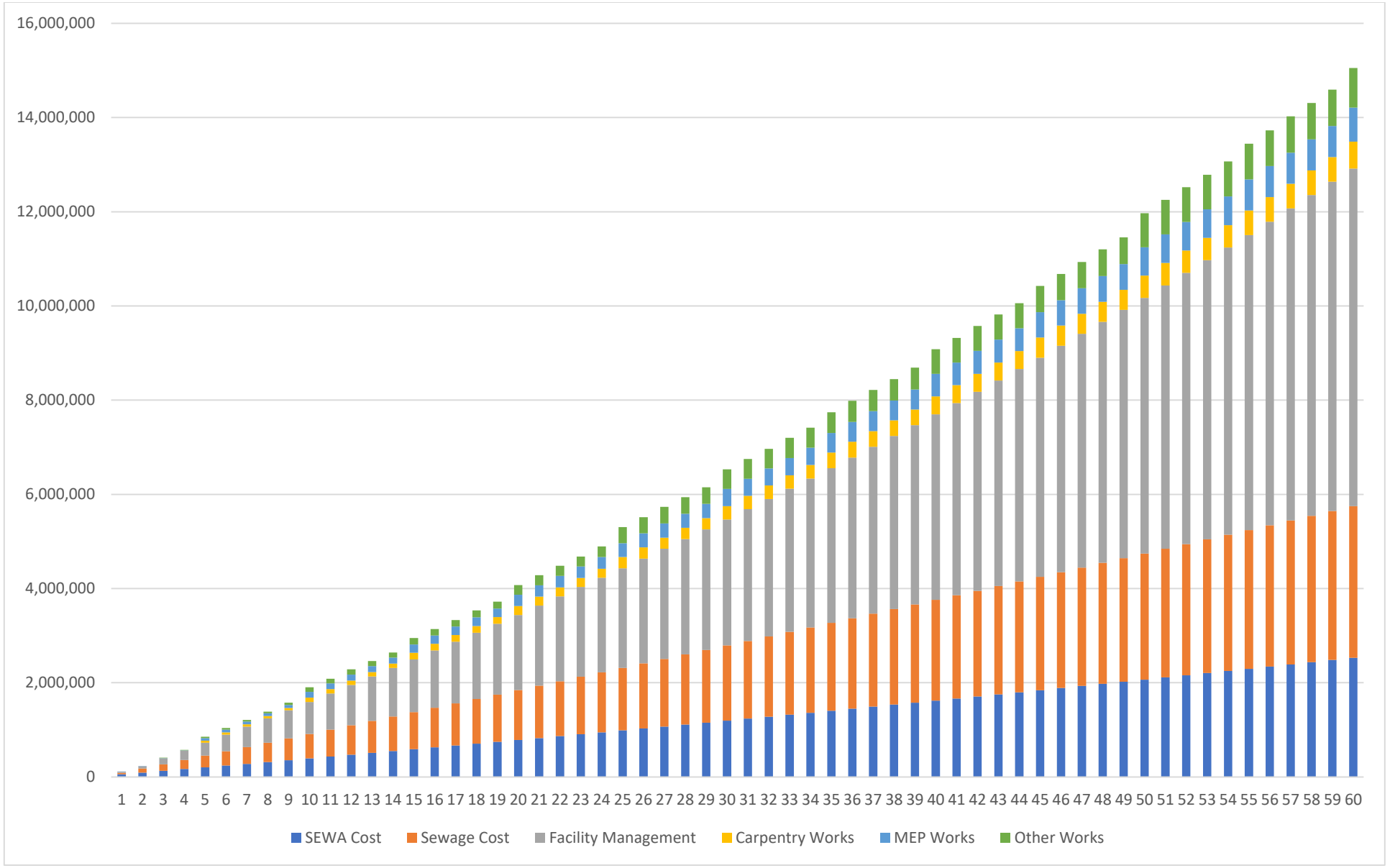


Figure 27 Total Operation & Maintenance Cost (60 years)

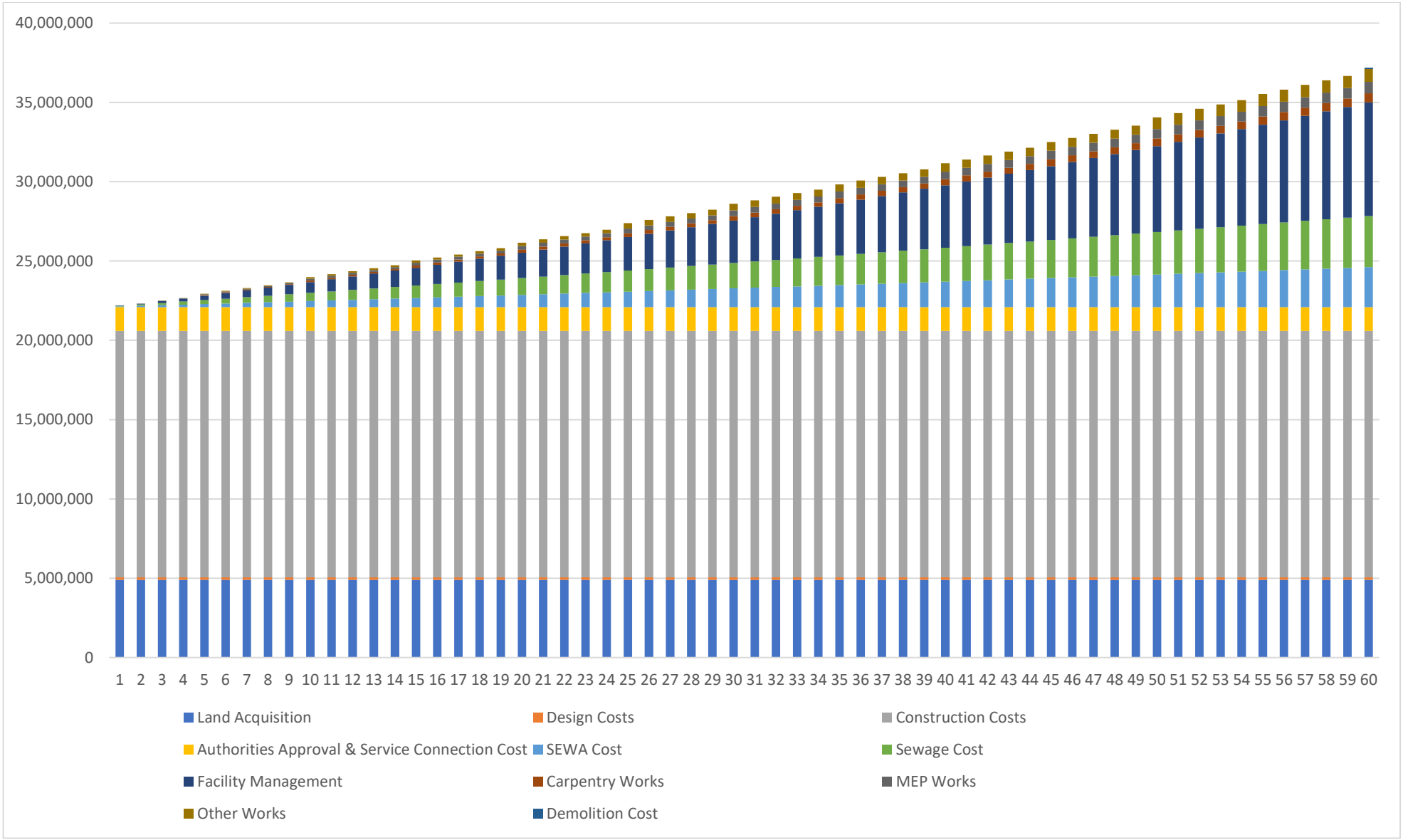


Figure 28 Life Cycle Cost (60 years)

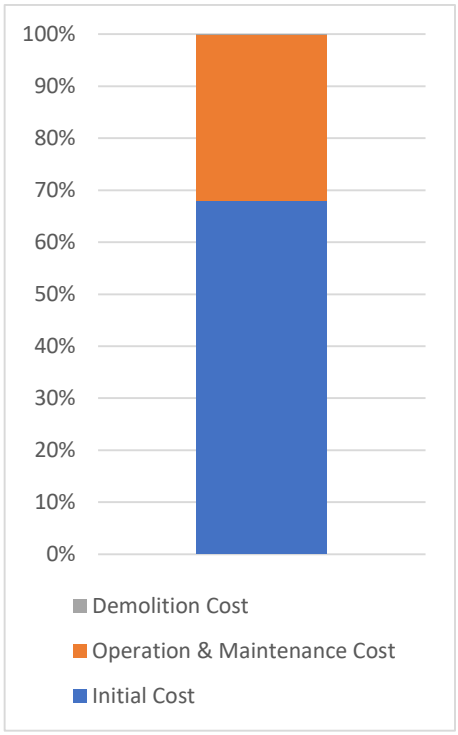


Figure 29 Life Cycle Cost Phases (60 years)

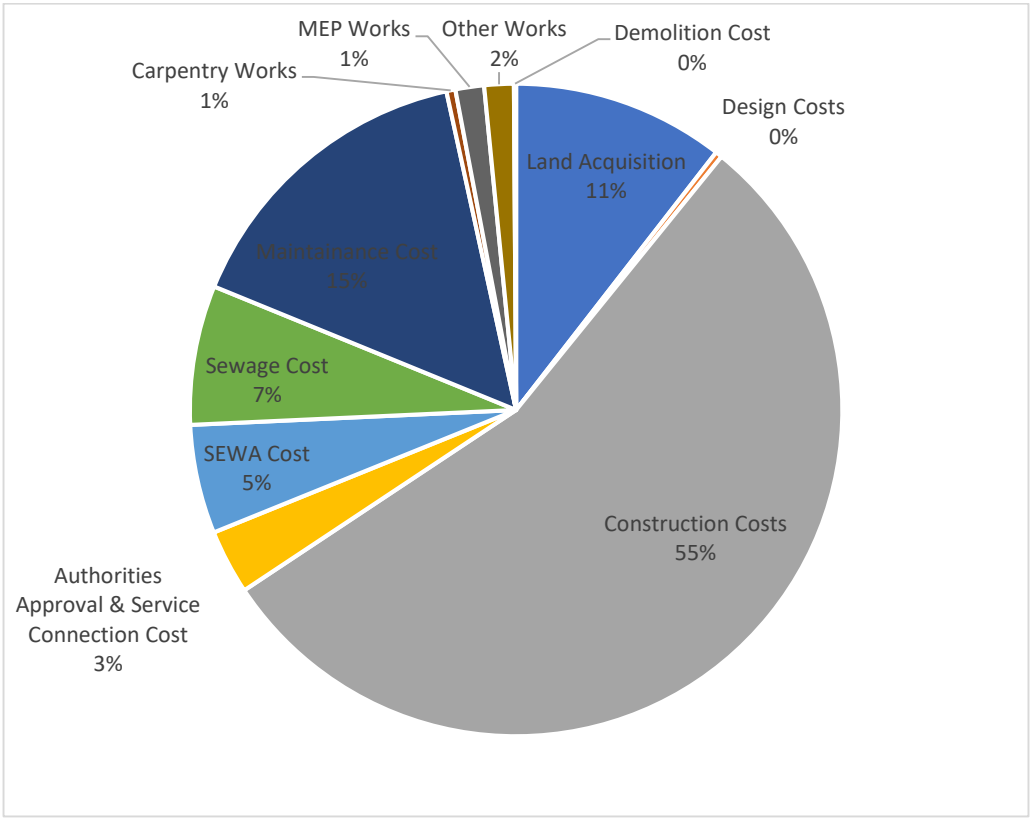


Figure 30 Breakdown Life Cycle Cost (60 years)

Figure 30 shows that the construction percentage has increased to 55%, which is predictable because we desire to increase the service life. To achieve this goal, we shall increase the quality of the materials utilised to construct this project. A well understanding of the importance of high-quality materials will give the ability to build safer buildings with a high life span.

Income			
Type	#	rate/year (Dhs)	Total Income/year (Dhs)
Shops	4	50,000	200,000
Studio	5	20,000	100,000
1 BHK	40	30,000	1,200,000
2 BHK	20	40,000	800,000
Total	69	-	2,300,000
Total income over 60 years life span			138,000,000

Table 14 Total Income Over 60 Years Life Span

$$\text{Total profit over 60 years service life} = \text{Total income} - \text{LCC}$$

$$= 138{,}000{,}000 - 52{,}008{,}235$$

$$= 85{,}991{,}765\ Dhs \approx 86{,}000{,}000\ Dhs$$

The income over 60 years of service life for the same project is 138,000,000 Dhs. However, the profit will be around 86,000,000 Dhs, which is around 41% more than the existing condition.

7.4 (40) years Vs (60) years Service Life

The service life of a structure is defined as the period of time that it can perform without facing any unplanned repairs or replacement. Thus, choosing the proper service life must be after considering the level of the initial costs & future maintenance costs that the owner will take care of and accept.

The service life of the current case study in this thesis is 40 years. The same project was studied by investing more money in the initial stage to increase its service life to 60 years. The ability to extend the service life of a building or parts of it depends on different factors.

The investment amount for the first alternative was 22,082,887 Dhs that gives a 40 years service life, and an amount of profit equals 60,700,000 Dhs over these 40 years.

For the second alternative, the investment amount was 32,082,887 Dhs, 10 million more, which gives a service life of 60 years, and an amount of profit equals 86,000,000 Dhs.

Improper maintenance can drastically reduce the structure lifespan. some broad guidelines and advice are mentioned below to assist you to extend the life of the structure:

- Materials quality can make a huge variance. the structure is not expected to survive as long in case it's constructed using substandard materials.
- Construction methods can highly affect the service life. professional techniques must be used when constructing buildings.
- A foundation's lifespan design should be maximised because if the foundation fails, the structure is pretty much gone.
- An annual inspection can help in detecting the major issues before they become major issues.

- Clean building tends to last longer, as it will not attract pests, bugs, termites and rats. Algae, mould, and fungus also have a proclivity for infesting unclean surfaces and causing a slew of issues. Algae will hold water and cause more wear and tear on the exterior of the house whereas Fungi and mould will eat the surface of wooden items and other materials.
- The quality of the maintenance will impact the service life of the building. The better the maintenance, the higher the service life will be achieved. (Figure 31)

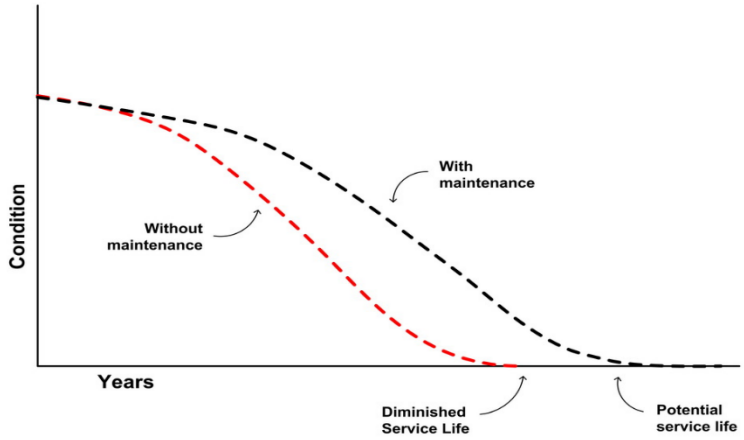


Figure 31 Maintenance impact on the service life of assets

- Water damage is the worst, when there is leak occurs immediate action must be made and properly addressed since not all materials used are water-resistant.
- Humidity should be controlled at all times and not exceed 65%, where it can ruin the wood and rot more easily while metal will rust more rapidly in a humid climate.

Figure 32 shows a comparison between the costs for the first and second alternatives. There will be no increase in any cost in the initial phase except for the construction cost. Operation and maintenance costs will increase because the project will survive for extra years. However, the demolition cost will remain the same because the building is the same size.

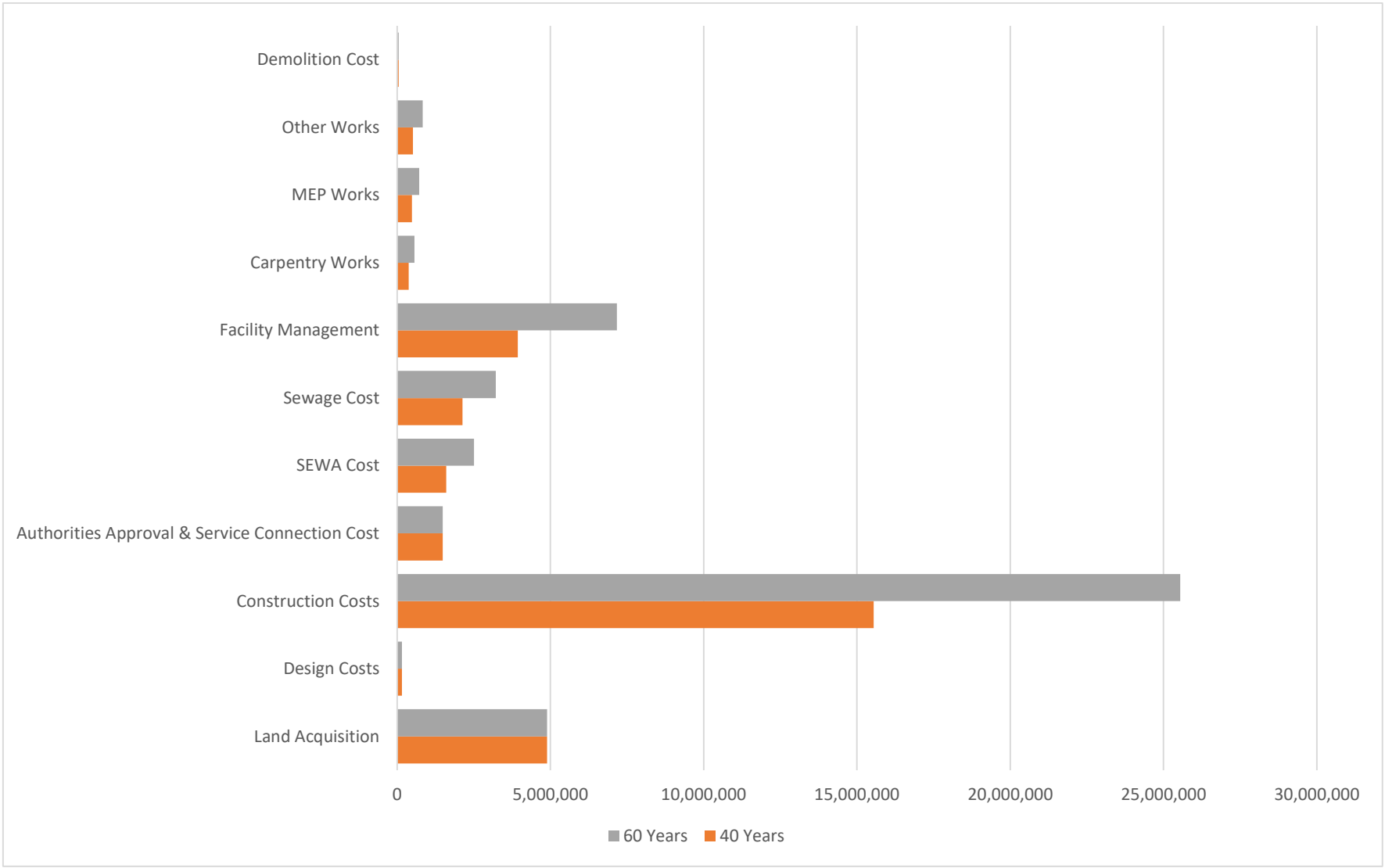


Figure 32 (40 years) Costs Vs (60 years) Costs

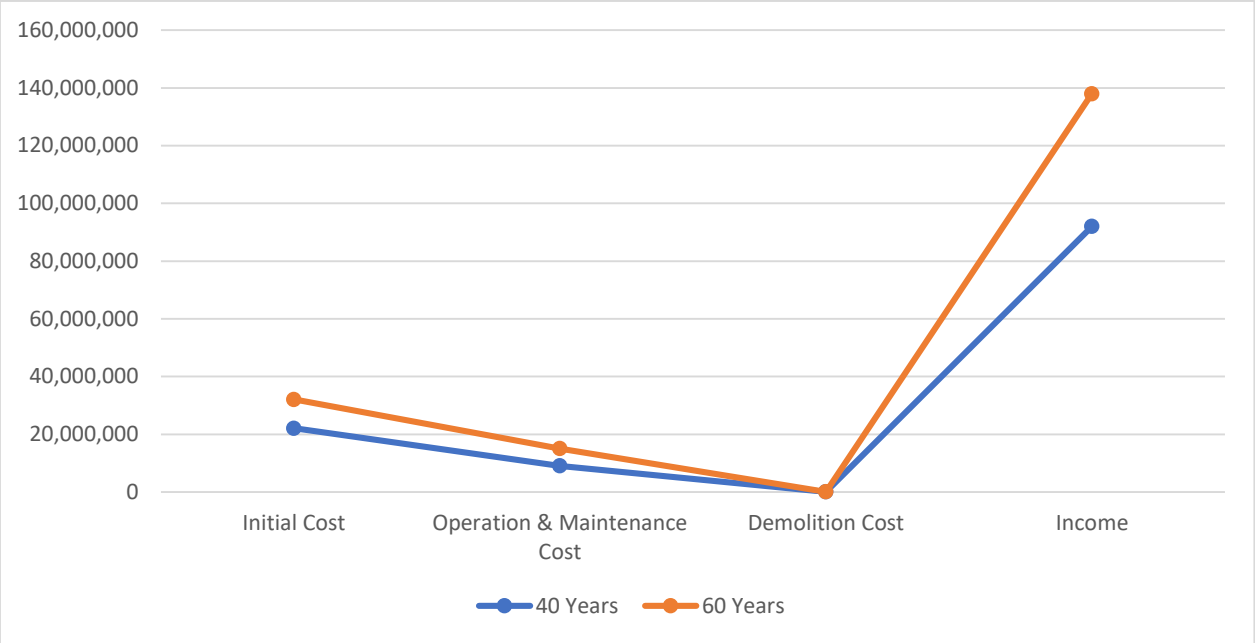


Figure 33 (40 years) Vs (60 years) – LCC Phases Comparison With its Income

Overall, we can conclude that investing extra money at the initial phase of the project to improve the quality of materials used can increase the project's life span in case of a good predicting of all costs during the project's life cycle.

7.5 Net present Value

The Net Present Value (NPV) is a financial analysis approach that calculates the present value of future cash flows and compares it to the initial investment to determine the feasibility of an investment in the project.

NPV method can not be used to compare two projects which are not of the same period. Our two alternatives in this research have different life lengths, 40 years and 60 years service life, so NPV will not be usable.

CHAPTER 8:

RECOMMENDATIONS &

CONCLUSION

8.1 Conclusion

To sum everything that has been stated so far, we need to understand that replacing structures is expensive, so it is worth finding out whether their service life can be extended. However, what will be more efficient is to design the structure from the beginning to survive as much as possible, considering the safety requirements.

Designers are constantly attempting to consider the impact of different design alternatives on service life while making design decisions in order to maximise service life performance. Accordingly, in the project's design stage, the life cycle cost-benefit analysis of various design possibilities must be given appropriate concern. Designers are utilising the resources at their disposal to increase longevity and minimise maintenance costs.

In addition, Materials suppliers are constantly working on developing the rebars specifications and cementing materials in order to enhance concrete characteristics and admixtures to prevent other deterioration processes. Contractors also have a significant role in this field by developing quality control procedures and improving construction practices such as curing, crack control and cover thickness to improve durability.

Value Engineering was applied to this study case during the initial phase. Most of the savings identified in the VE were related to the design cost.

The qualitative method relies on the descriptive narrative for data analysis, such as case studies. Such approaches aim to decipher the hidden meanings of behaviours and relationships. Quantitative approaches, on the other hand, identify hypotheses and statistically test variables against such hypotheses. However, using the two methods together (mixed method) is always the best way in analysing any project.

8.2 Observations & Recommendations

- During the design phase of projects, owners and stakeholders should pay more attention to service life expectations. No strategy can replace proper initial design, construction, and maintenance practices for the desired service life.
- According to the case study building of this research, the initial cost in both alternatives was almost half of the operation and maintenance cost, which means that the value engineering was effectively applied when designing this project.
- It is well known that electricity cost in the emirates of Sharjah is very high. The owner has decided to remove the AC units from the corridors in Al Hoor building in the design phase to prevent high electricity charges in the future. This is why the electricity cost for the service mentioned before was acceptable.
- Construction of the building is a serious stage. The life span of the project will be affected by the quality of the construction. Workmanship, concrete composition, cover thickness to the reinforcement, crack width limitations, and concrete curing are examples of important works controlling the quality.
- Avoid deterioration can be approach by separating the environmental effect from the structure using non-reacting materials.
- Good maintenance is essential. The work does not end once the structure is constructed or the repairs are complete. As we can see in most cases, the typical situation during the operation of the structures is that maintenance and repairs are mostly reactive and not proactive. Reactive repairs mean waiting till the issue float on the surface, which is an ineffective way. Maintenance should be proactive and regular without delay to keep the building in good condition always.

- Doing small changes in the design phase can maximise the savings in future in the operation and maintenance phase. Such as using LED lights was very useful for the tenants and owners for their electricity bills.
- Individual bias and criticisms directed at each methodology individually can be overcome using a mixed-methods approach. Mixed methods research appears to be playing an increasingly important role in future research.

REFERENCES

Afshari, A., Nikolopoulou, C. & Martin, M., 2014. *Life cycle analysis of building retrofits at the urban scale —A case study in United Arab Emirates.*

American Society of Civil Engineering (ASCE) and Eno Center for Transportation. *Maximizing the value of investment using life cycle cost analysis.* ASCE, Reston, Va., 2014.

Arumsari, P. & Tanachi, R., 2018. *Value engineering application in a high rise building - A case study in Bali.*

ASM International Materials Life Cycle Analysis Committee,1997. *Life cycle engineering and design.* ASM Handbook, Volume 20: Materials Selection and Design, p 96-103.

Atmaca, A., 2016. *Life cycle assessment and cost analysis of residential buildings in south east of Turkey: part 1 — review and methodology*. Heidelberg: Springer.

Bari, R. D., Belleri, A., Marini, A., Horn, R. & Gantner, J., 2020. *Probabilistic life cycle assessment of service life extension on renovated buildings under Seismic Hazard.* Switzerland: MDPI.

Buys, A., Bendewald, M., Tupper, K., 2011. *Life cycle cost analysis: is it worth the effort?.*

Changmo, K., 2015. *Automated sequence selection and cost calculation for maintenance and rehabilitation in highway life cycle cost analysis (LCCA),"* International Journal of Transportation Science and Technology.

Clemons, T.J., *Life cycle cost analysis, The Colorado Experience.*

Demos, G. P.,2006. *Life cycle cost analysis and discount rate on pavements for the Colorado department of transportation.* Springfield: NTIS.

Diependaele, M., 2018. *A guide on the basic principles of life cycle cost analysis (LCCA) of pavements.* Brussels: EUPAVE.

Driessche, L. V., 2016. *The construction sector in the United Arab Emirates.* Flanders Investment & Trade.

El-Akruti, K., Dwight, R., Zhang, T. & Al-Marsumi, M., 2013. *The role of life cycle cost in engineering asset management.*

El Haggar, S.M.,2005. *Rural and developing country solutions*, Ch. 13, p 313-400.

Environmental protection agency, 1977. *Value engineering, case studies and formats for proposal and reports.*

Extending the service life of civil structures. Amsterdam, 2014.

Fuller, S. K. & Petersen, S. R., 1995. *Life cycle costing manual for the federal energy management program.*

Galar, D., Sandborn, P. & Kumar, U., 2017. *Maintenance costs and life cycle cost analysis.* CRC Press.

Hayes, R. L., 2014. *The architect's handbook of professional practice*. The American Institute of Architects. — Fifteenth edition. New Jersey: John Wiley & Sons.

Hoseini, M. *Extending the service life of concrete structures in harsh environment: how long each strategy may last?.* Canada.

Janz, D, Westkamper, E. (2008). *Value oriented decision support for design to life cycle,* LCE 2008: 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings, Sydney, Australia.

Jick, T. D., 1979. *Mixing qualitative and quantitative methods: triangulation in action.* Cornell University: Johnson Graduate School of Management.

Kale, N. N., Joshi, D. & Menon, R., 2016. *Life cycle cost analysis of commercial buildings with energy efficient approach.*

Kshirsagar, A.S., El-Gafy, M.A. & Abdelhamid, TS, 2010. *Suitability of life cycle cost analysis (LCCA) as asset management tools for institutional buildings.* Michigan: Emerald.

Lee, C., Hong, T., Lee, G. & Jeong, J., 2012. *Life cycle cost analysis on glass type of high Rise buildings for increasing energy efficiency and reducing CO2 emissions in Korea.*

Mandelbaum, J. & Reed, D. L., 2006. *Value engineering handbook.* Virginia: IDA.

Marteinsson, B., 2005. *Service life estimation in the design of buildings a development of the factor method.* Sweden.

Mostafaeipour, A., 2015. *A Novel innovative design improvement using value engineering technique: A case study.*

Mukhopadhyaya, A. K., 2009. *Value engineering mastermind.* India: Response.

National Academies of Sciences, Engineering, and Medicine 2016. *Life cycle cost analysis for management of highway assets.* Washington, DC: The National Academies Press.

Norris, G. A., 2001. *"Integrating life cycle cost analysis and LCA",* The International Journal of Life Cycle Assessment.

North Dakota guidance for Life cycle cost analysis of water supply projects, 2020.

NORSOK Standard, 1996. *Life cycle cost for systems and equipment.*

O'Connor, J., 2004. *Survey on actual service lives for north american buildings.* Las Vegas.

Ran, H., 2015. *The investigation and analysis on the life span of residential buildings.* ICEMAESS.

Rauf, A. & Crawford, R. H., 2014. *Building service life and its effect on the life cycle embodied energy of buildings.* Australia: Elsevier.

Rossman, G. B. & Wilson, B. L., 1985. *Combining quantitative and qualitative methods in a single large scale evaluation study.* Pennsylvania: Sage Publications.

Saqan, E., Nagi, M. & Al Mutawa, A, 2012. *Extending the service life of reinforced concrete in the UAE – preliminary results of experimental study.* AUS: UAE.

Schultz, L.I. & Weber, S.F., 2003. *Guide to computing and reporting the life cycle cost of environmental management projects.* Gaithersburg.

Sharma1, A. & Srivastava, H., 2011. *Case study analysis through the implementation of value engineering.* India: IJEST.

Single large-scale evaluation study. Sage Publications, Inc.

Snodgrass, K., 2008. *Life cycle cost analysis for buildings is easier than you thought.* Missoula.

Stanford University Land and Buildings, 2005. *Guidelines for Life cycle cost analysis*.

Subramanyam, K. R., 2014. *Financial statement analysis.* New York: McGraw.

The Association for the Advancement of Cost Engineering, 2004. *Skills & knowledge of cost engineering*. United States of America: AACE International.

The Report UAE: Dubai 2018. *Dubai becomes a leading regional force in construction activity, regulation and arbitration*

Thompson, R., 2021. CONSTRUCTION THINK TANK - *Recommendations to build a better construction industry in the UAE,* Vol 3.

Thompson, R., 2019. CONSTRUCTION THINK TANK - *Recommendations for change from the UAE Construction Industry Think Tank.*

Venkataraman, R. R. & Pinto, J. K., 2008. *Cost and value management in projects.* New Jersey: John Wiley & Sons.

Zhang, C., Hu, M., Laclau, B., Garnesson, T., Yang, X., Li, C. & Tukker, A., 2020. *Environmental life cycle costing at the early stage for supporting cost optimization of precast concrete panels for existing building retrofit.* Elsevier.

APPENDICES

Appendix I

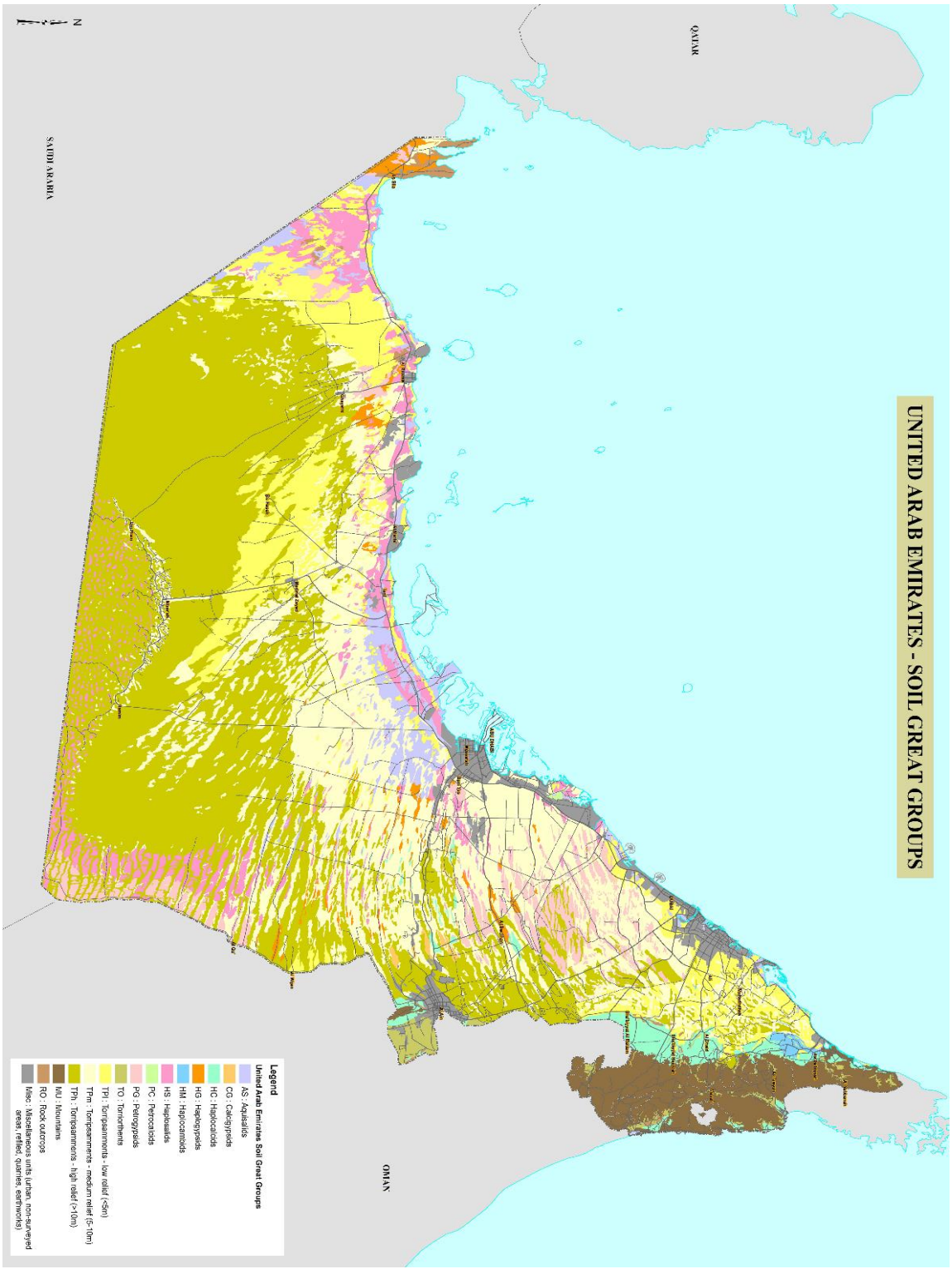


Figure 34 UAE SOIL MAP

Appendix II

Questionnaire 1

1*) Are you a UAE citizen? // هل أنت مواطن اماراتي؟

A. Yes / نعم
B. No / لا

2*) What is your building height? // ما هو ارتفاع المبنى الذي تملكه؟

A. G+1 (Villa) / أرضي + اول (فيلا)
B. G+5 / أرضي +5

3*) What is the built-up area? (m^2) // ($م^2$) ما هي مساحة البناء؟

A. less than 500 / أقل من 500
B. less than 1000 / أقل من 1000
C. bigger or equal 1000 / أكثر من 1000

4*) How many flats in each floor? // كم عدد الشقق في كل طابق؟

A. 1 Villa / فيلا 1
B. 2 to 5 flats / إلى 5 شقق 2
C. 6 to 10 flats / الى 10 شقق 6
D. more than 10 flats / أكثر من 10 شقق

5*) What is the AC system? // ما هو نظام التكييف المستخدم في المبنى؟

A. Split Ducted
B. Wall Decorative
C. Packaged System
D. Window Type

6*) What is the lighting system? // ما هو نوع الاضاءة المستخدمة في المبنى؟

A. Incandescent Light
B. Fluorescent Lights (FL)
C. Light Emitting Diode (LED)

7*) What is the average service bill/month? // ما هو متوسط قيمة فاتورة الخدمات كل شهر؟

A. less than 1000 Dhs / أقل من 1000 درهم
B. less than 2500 Dhs / أقل من 2500 درهم
C. less than 4000 Dhs / أقل من 4000 درهم
D. higher or equal 4000 Dhs / أكثر أو تساوي 4000 درهم

Results – Questionnaire 1

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	B	B	C	C	A	C	D
2	B	B	C	C	A	B	D
3	B	B	C	C	A	A	D
4	B	B	B	C	B	B	D
5	B	B	B	C	B	B	D
6	B	B	B	B	D	B	D
7	B	B	B	B	D	A	D
8	B	B	C	D	A	C	C
9	B	B	C	D	A	B	C
10	A	A	A	A	C	C	A
11	B	B	C	C	A	C	B
12	A	A	B	A	A	C	A
13	B	B	B	C	B	B	C
14	A	A	C	A	A	B	C
15	A	A	B	A	A	B	B
16	A	A	A	A	C	C	A
17	A	A	A	A	A	C	A
18	B	A	C	A	A	B	D
19	B	A	C	A	C	B	D
20	B	B	B	B	A	C	B
21	B	B	C	D	A	C	C
22	A	B	B	B	A	C	B
23	A	A	A	A	A	C	A
24	A	A	C	A	A	C	B
25	A	B	B	B	A	C	B
26	A	B	C	C	A	C	C
27	A	B	C	C	A	B	C

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
28	A	B	C	C	A	C	C
29	B	A	C	A	A	C	C
30	A	A	A	A	A	C	A
31	A	A	A	A	C	B	B
32	B	B	B	B	A	B	C
33	B	B	C	B	B	B	D
34	B	B	C	D	B	A	D
35	B	A	A	A	A	A	B
36	A	B	C	B	B	A	D
37	B	B	B	D	A	C	C
38	B	B	C	D	A	B	D
39	A	A	A	A	B	B	D
40	B	B	B	C	A	C	D
41	B	B	B	D	A	C	D
42	A	A	A	A	A	C	A
43	A	A	A	A	A	C	A
44	A	A	B	A	B	C	A
45	A	A	A	A	B	C	A
46	A	A	A	A	B	C	A
47	A	A	A	A	C	C	A
48	A	A	A	A	C	C	A
49	A	A	B	A	C	C	B
50	A	A	B	A	C	C	B

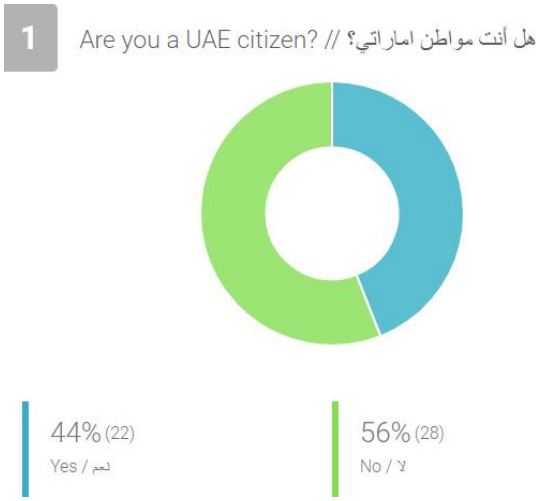


Figure 35 Questionnaire 1- Q1

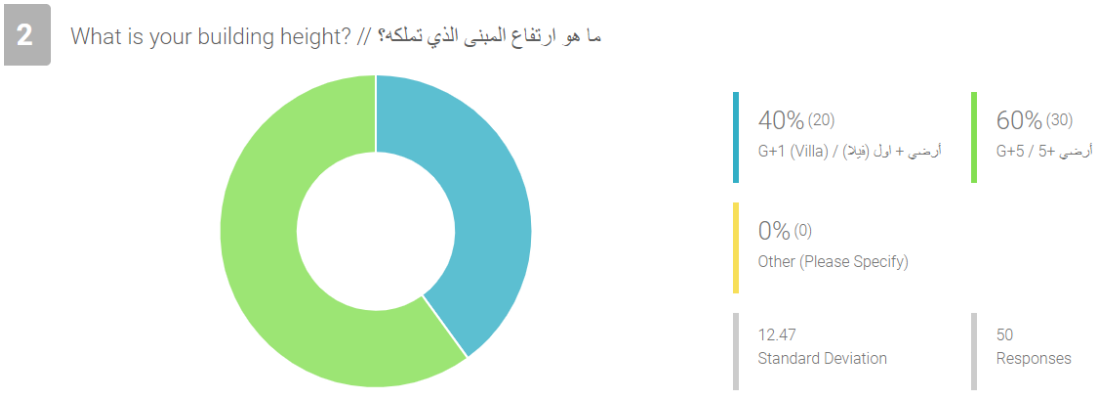


Figure 36 Questionnaire 1- Q2

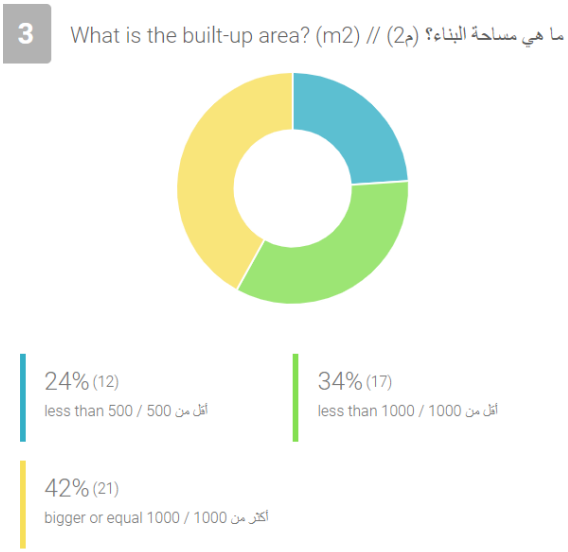


Figure 37 Questionnaire 1- Q3

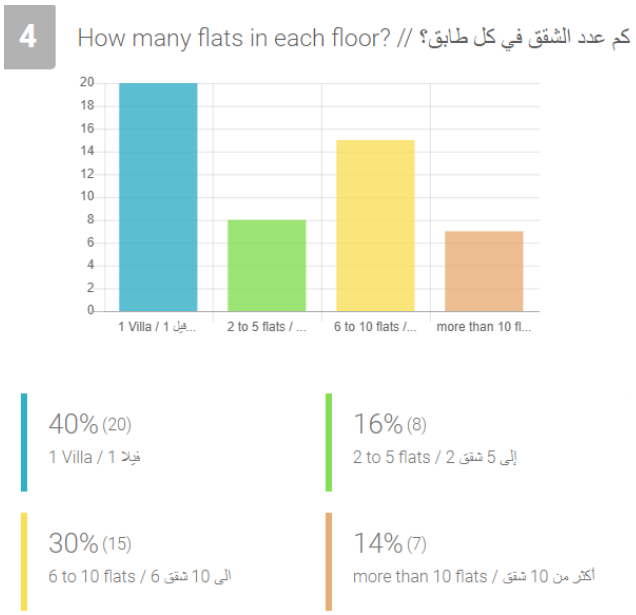


Figure 38 Questionnaire 1- Q4

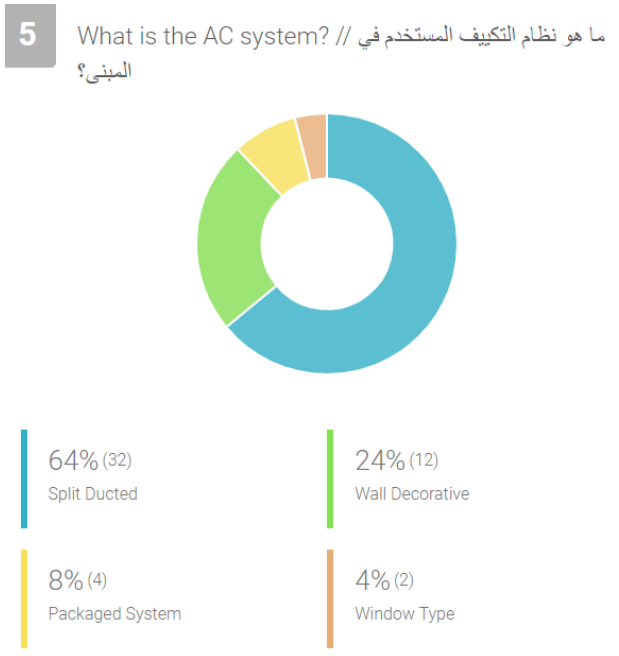


Figure 39 Questionnaire 1- Q5

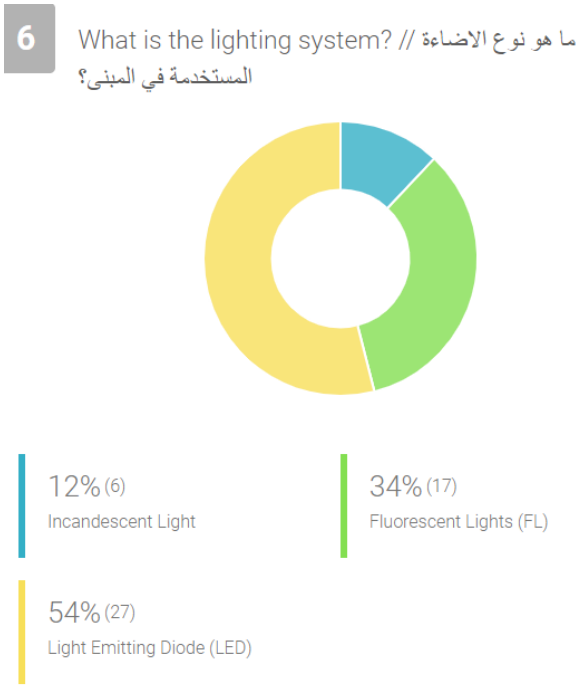


Figure 40 Questionnaire 1- Q6

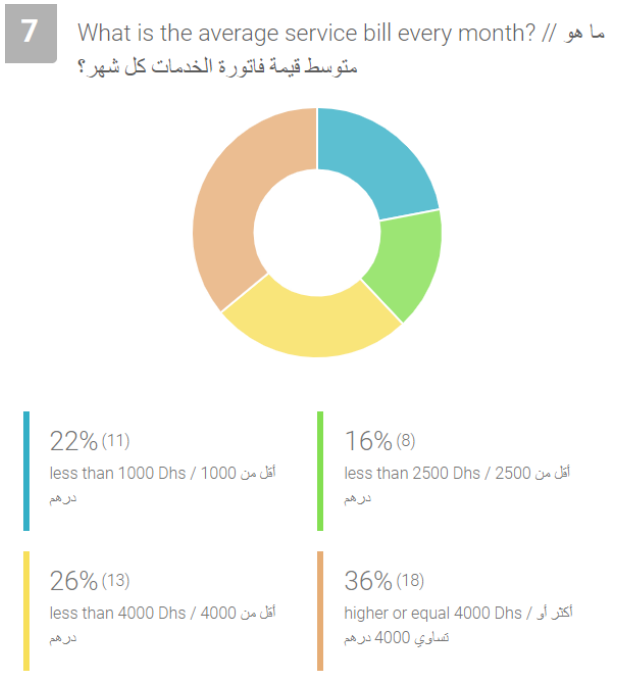


Figure 41 Questionnaire 1- Q7

Questionnaire 2

1*) Are you a UAE citizen? // هل أنت مواطن اماراتي؟

A. Yes / نعم
B. No / لا

2*) What is your flat area? (m2) // ما هي مساحة شقتك؟ (م2)

A. less than 50 / أقل من 50
B. less than 100 / أقل من 100
C. less than 150 / أقل من 150
D. bigger or equal 150 / أكثر من 150

3*) How many bedroom in the flat? // كم عدد غرف النوم في الشقة؟

A. 1 BHK / غرفة نوم 1
B. 2 BHK / غرفة نوم 2
C. 3 BHK / غرفة نوم 3

4*) What is the AC system? // ما هو نظام التكييف المستخدم في المبنى؟

A. Split Ducted
B. Wall Decorative
C. Packaged System
D. Window Type

5*) What is the lighting system? // ما هو نوع الاضاءة المستخدمة في المبنى؟

A. Incandescent Light
B. Fluorescent Lights (FL)
C. Light Emitting Diode (LED)

6*) What is the average service bill/month? // ما هو متوسط قيمة فاتورة الخدمات كل شهر؟

A. less than 500 Dhs / أقل من 500 درهم
B. less than 1000 Dhs / أقل من 1000درهم
C. less than 2000 Dhs / أقل من 2000 درهم
D. higher or equal 3000 Dhs / أكثر أو تساوي 3000 درهم

Results – Questionnaire 2

	Q1	Q2	Q3	Q4	Q5	Q6
1	B	B	A	B	C	B
2	B	B	B	B	B	B
3	B	B	A	B	B	B
4	B	A	A	B	B	A
5	B	B	A	A	C	A
6	B	B	A	B	C	B
7	B	B	B	B	A	A
8	A	B	A	C	C	A
9	B	D	B	B	A	C
10	B	B	A	B	B	B
11	B	B	B	B	A	B
12	B	B	A	B	A	B
13	B	D	B	B	C	C
14	B	B	A	B	A	B
15	B	B	B	A	C	A
16	B	B	B	A	A	B
17	B	B	A	B	A	A
18	B	B	A	A	B	B
19	B	B	B	A	C	B
20	B	A	A	B	A	A
21	B	C	B	A	A	C
22	B	B	A	B	A	A
23	A	B	A	B	C	A
24	B	B	B	A	C	B
25	B	D	B	A	C	B
26	B	C	C	A	C	C
27	B	C	C	A	C	B

	Q1	Q2	Q3	Q4	Q5	Q6
28	B	A	A	B	C	A
29	B	C	B	B	B	C
30	B	B	A	B	C	B
31	B	B	A	B	A	A
32	B	B	A	B	C	B
33	A	B	A	B	A	B
34	B	B	B	B	A	B
35	B	C	C	A	C	C
36	B	B	A	A	C	A
37	B	B	A	A	B	B
38	B	B	A	A	A	B
39	B	B	B	B	C	A
40	B	A	A	B	A	C
41	B	B	B	A	A	C
42	B	B	B	B	A	B
43	A	B	A	B	C	A
44	B	D	B	B	A	A
45	B	B	A	C	C	B
46	B	B	A	A	C	B
47	B	C	B	A	C	A
48	B	B	A	A	B	B
49	A	D	C	A	C	A
50	A	C	C	A	C	A

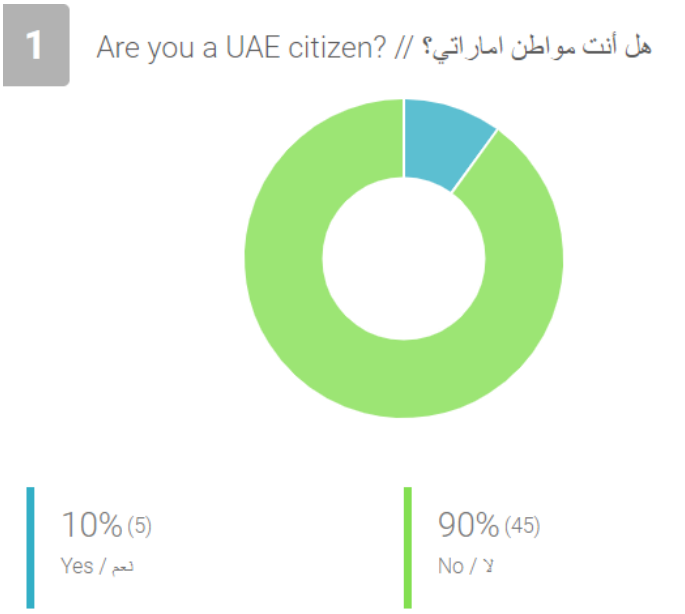


Figure 42 Questionnaire 2- Q1

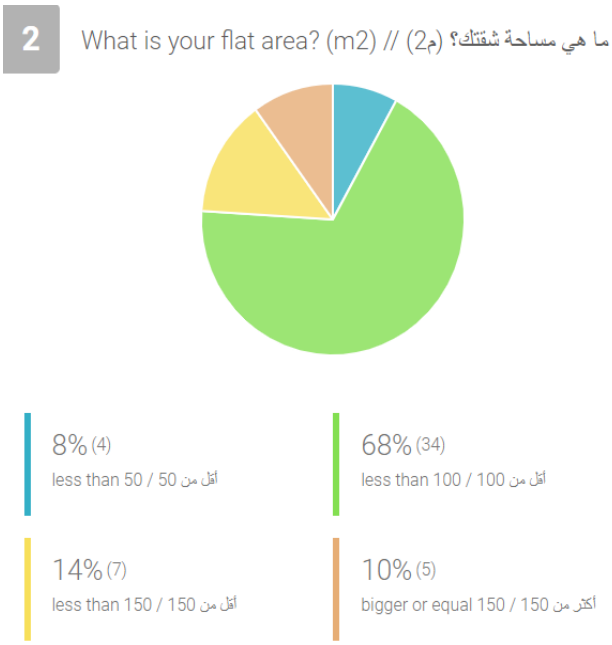


Figure 43 Questionnaire 2- Q2

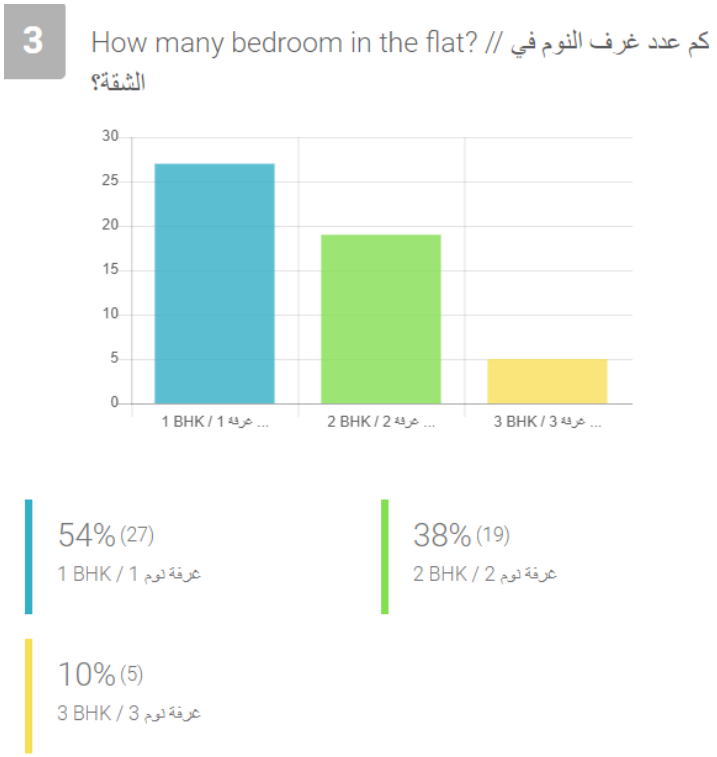


Figure 44 Questionnaire 2- Q3

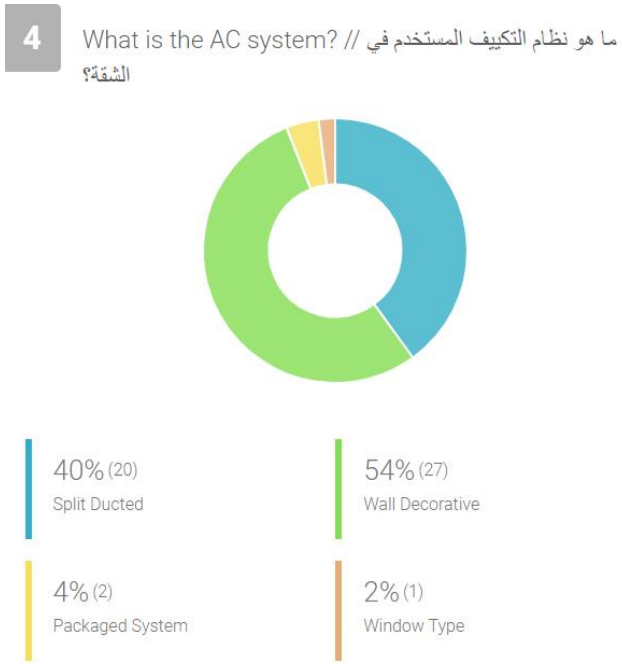


Figure 45 Questionnaire 2- Q4

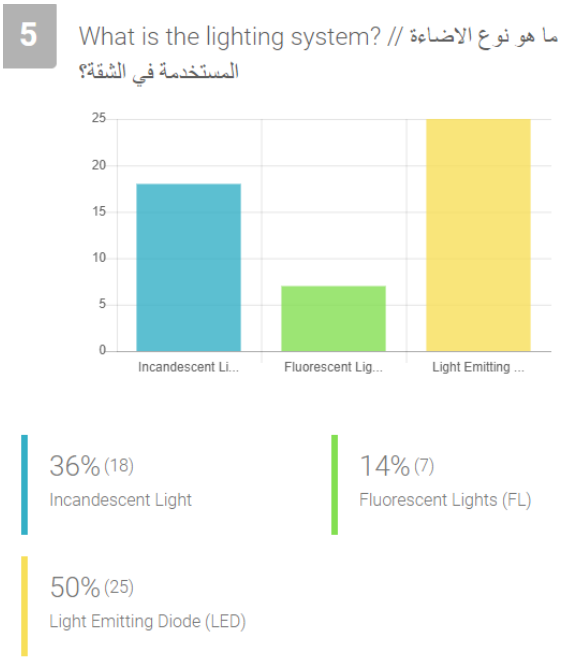


Figure 46 Questionnaire 2- Q5

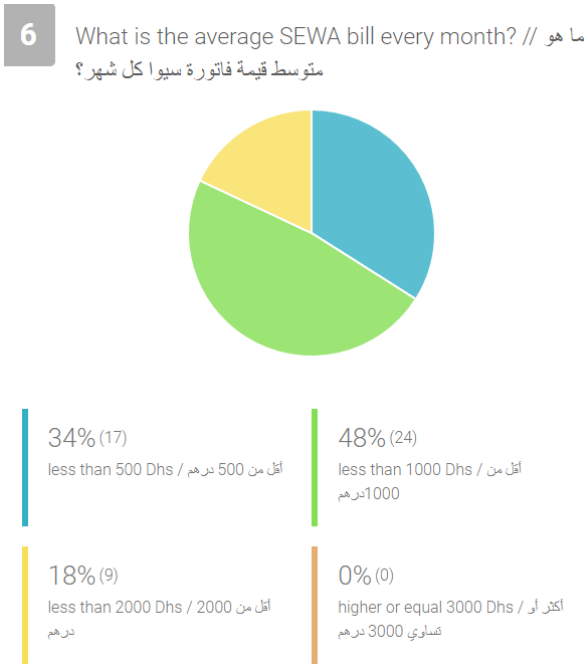


Figure 47 Questionnaire 2- Q6