# APPLICATION LIFE CYCLE COST ANALYSIS IN THE BUILDING SECTOR IN SAUDI ARABIA

**A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY**

**By**

**MOHAMMAD SAMI A. QABAJA**

**In Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering**

**NICOSIA, 2017**

MOHAMMAE SAMI
A. QABAJA

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NEU
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**Approval of Director of Graduate School of Applied Sciences**

**Prof. Dr. Nadire Çavuş**
**Director**

**We certify that, this thesis is satisfactory for the award of the degree of Master of Science in Civil Engineering**

**Examining Committee in Charge:**

| | |
|---|---|
| Prof. Dr. Ata Atun | Supervisor, Department of Civil Engineering, NEU |
| Assist. Prof. Dr. Alireza Rezaei | Department of Civil Engineering , CIU |
| Dr. Shaban Ali Zangena | Department of Civil Engineering, NEU |

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Mohammad Qabaja
Signature:
Date:

# ACKNOWLEDGEMENTS

This thesis would not have been possible without the help, support and patience of my principal supervisor, my deepest gratitude goes to Prof. Dr. Ata Atun, for his constant encouragement and guidance. he has walked me through all the stages of the writing of my thesis. Without him consistent and illuminating instruction, this thesis could not have reached its present from.

I would like to thank Assist. Prof. Dr. Ali Danandeh Mehr and Dr. Shaban Ali Zangena for their very helpful through the duration of my thesis.

Above all, my unlimited thanks and heartfelt love would be dedicated to my dearest family for their loyalty and their great confidence in me. I'm greatly indebted to my father Mr. Sami Qabaja who is indeed my inspiration and the man who led me to the treasures of knowledge. I would like to thank my mom for giving me a support, encouragement and constant love have sustained me throughout my life. I would like to thank my sister and my brothers for providing me unfailing support and great patience at all times. This achievement would not have been possible without them.

Eventually, there is a long list of friends that I would like to thank. I can't mention them all but I would like to thank them from all of my heart for their valuable help and support since I was in my early study until now.

**To my Parents…**

**ABSTRACT**

Life Cycle Cost Analysis is necessary for different sectors and especially in the buildings sector. The Life Cycle Cost analysis improving and supplying in different categories of buildings life like controlling the works in projects that will be saving money and time. Also, it is focusing on the different stages of the life of projects from construction stage until to end of life. The aims of the study to know the applicability of the Life Cycle Cost Analysis in Buildings projects in Saudi Arabia and to spread awareness about it. The hypothesis of the study is "Applying Life Cycle Cost Analysis (LCCA) in construction building adds more cost-effective, management and controlling the works of facilities".

The questionnaire was the tool of the study by asked about the methods, cost parameters and general questions about Life Cycle Cost Analysis. The questionnaire was done by meeting the engineers in the constructions projects or by online. The study was done on 120 engineers from different companies to achieve the aims of the study.

The study found a lack of knowledge about the methods and cost parameters of the Life Cycle Cost Analysis. Also, most of the engineers did not know the difference between the types of cost parameters. Most of the engineers agree with the hypothesis of the study after they get an idea about this subject. In general, it is hard to apply the Life Cycle Cost Analysis in the construction sector for the reasons that mentioned.

***Keywords*:** Life Cycle Cost Analysis; Cost Parameters; Methods; Buildings Sector; Saudi Arabia

# ÖZET

Yaşam Döngüsü Maliyet Analizi, farklı sektörler için ve özellikle bina sektöründe gereklidir. Yaşam Döngüsü Maliyet analizi, binaları para ve zamandan tasarruf sağlayacak projelerde işlerin kontrolü gibi farklı kategorilerinde geliştirir ve tedarik eder. Ayrıca, inşaat aşamasından ömrünün sonuna kadar olan projelerin hayatının farklı aşamalarına odaklanır. Çalışmanın amacı, Suudi Arabistan'daki Binalar projelerinde Yaşam Döngüsü Maliyet Analizi'nin uygulanabilirliğini bilmek ve bu konudaki farkındalığı artırmaktır. Çalışmanın hipotezi, "inşaat binasında Yaşam Döngüsü Maliyet Analizini uygulamak, tesislerin çalışmalarını daha maliyet-etkin, yönetim ve kontrol altına aldığıdır".

Çalışmanın yöntemi olan anket, Yaşam Döngüsü Maliyet Analizi ile ilgili yöntemler, maliyet parametreleri ve genel sorular hakkında sorular sormuştur. Ve inşaat projelerinde mühendislerle buluşarak ya da çevrimiçi olarak anket göndererek yapılmıştır. Çalışma, araştırmanın amaçlarına ulaşmak için farklı firmalardan 120 mühendis üzerinde yapıldı.

Çalışma, Yaşam Döngüsü Maliyet Analizi yöntemleri ve maliyet parametreleri hakkında bilgi eksikliği bulmuştur. Ayrıca, mühendislerin çoğu maliyet parametrelerinin farklı aşamaları arasındaki farkı ve her aşamadan neyden oluştuğunu bilmiyordu. Mühendislerin çoğu, bu konuyla ilgili bir fikir edindikten sonra, çalışma hipoteziyle hemfikir. Genel olarak, sözü edilen nedenlerle inşaat sektöründe Yaşam Döngüsü Maliyet Analizi uygulamak zordur.

***Anahtar Kelimeler*:** Yaşam Döngüsü Maliyet Analizi; Maliyet Parametreleri; Yöntemler; Bina Sektörü; Suudi Arabistan

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| **ECA:** | Equivalent Annual Cost |
| **LCCA:** | Life Cycle Cost Analysis |
| **LCC:** | Life Cycle Cost |
| **WLC** | Whole Life Cost |

# CHAPTER 1
# INTRODUCTION

## 1.1 Background of the Study

Life Cycle Cost Analysis (LCCA) is an economic method used for evaluating the total cost of any project in the construction sector (Fuller, 2010). In order to achieve the lowest cost, the LCCA is one of the important consideration in building construction. LCCA is particularly responsible for the assessment of building design alternatives that meet a required for building performance. It is can be applied to any capital venture choice in which higher initial costs are traded for diminished future cost commitments. For the long-term cost-effectiveness of projects, using LCCA provides a better appraisal than alternative financial methods that focus on operating costs in the short run (Fuller, 2010).

Studies have shown that with the commercial building sector under heavy monetary stress, more and more engineers are looking to the LCCA across the world to assist reducing costs as a long way as they can (Dunk, 2004). Manager's role includes management and control of activities and achievement of the goals of the project such as conforming to budget, schedule, and quality.

The case study of this thesis is focused on the buildings in Saudi Arabia. This country is one of the biggest exporters of oil in the whole world and for this situation, Saudi economy for a long time was on rising in all fields and especially in the construction sector. The LCCA is important in this case because too many buildings are built and must be completed on time with less loss money. in this approach, LCCA is helping to reduce the cost of products, help in planning, control and quality of the construction products.

With this development in Saudi Arabia, it was necessary to develop the calculate of the costs of projects and that which make a lot of researchers to find alternatives and new systems to calculate the project costs. In this thesis, a questionnaire was distributed to several engineers who work in engineering companies to see the extent of their knowledge about LCCA and to know if the engineering companies used it or not.

## 1.2 Importance of Research

- Learn about the benefits of the LCCA and the extent of its contribution to the construction sector in Saudi Arabia.

- The use of LCCA is successful if it is used correctly by the project managers.

- The use of LCCA will affect the progress of the projects in a good way and to minimize the delay in the implementation of projects.

- Also, use of LCCA will affect the economy of the Kingdom of Saudi Arabia because if the particular sector was affected another sector will be affected.

- The study also aims to spread awareness among the engineers on the importance of LCCA.

## 1.3 Objectives of Research

This thesis provides research toward exploring the use of LCCA in general and in buildings specifically, in addition to developing a better understanding of the process of LCCA. Concerned with the investigation of engineer's information and knowledge about LCCA. Also, involves in the discipline of engineers with a concentration in the field of construction project management. Thus, the research objectives are:

- To recognize different methodologies that represent the life cycle cost can be used in building planning, design and management to supporting the minimized costs.

- To measure awareness of the Life Cycle Cost Analysis among engineers by the method of the questionnaire in order to prove the importance of LCCA.

- To identify the implications of life cycle cost decisions based on the results from case study and consequences for the management.

## 1.4 Research Question

Several studies were done in the construction sector in order to apply the sustainable development approaches in the construction industry. However, optimization models were developed for the aim of optimizing construction projects by using LCCA. These studies are not widely spread and their applications in the Arabic countries in general and in Saudi Arabia in specific are almost nonexistent.

To find an answer to this questions that based on the objectives and aims of the study, in various areas of interest must be investigated and examined. In order to perform an arranger investigation. Four questions are performed and every question contributes to the investigation of the various areas of interest to get an answer on the research question. The following questions are posed:

- What are the goals of LCCA?
- Which building components are analyzed?
- What are the methods used in LCCA?
- What constraints are faced with LCCA?

### 1.5 Methodology

The research methodology of this thesis has an empirical aspect as well as a theoretical component of the study. The theoretical aspect includes the necessary data in order to achieve the objectives of the research by using books, articles, journals, reports, research and previous studies that related to this research. The empirical aspect includes the phases of identifying the number of subjects to be conducting preliminary research toward the preparation of the questionnaire, execution the questionnaire, and reach conclusions then recommendations. The questionnaire consists of 24 questions and the data was collected from engineers who work in Saudi Arabia. The questionnaires were administered to engineers by online survey instrument and the other way by meeting the engineers face to face in the site or in the companies of constructions.

The target of this survey to study the includes practicing engineers. The participants were identified by engineers who work in the companies were selected randomly based on their work in Saudi Arabia. The reason of selection the engineers to discuss the related issues problems and to redound other engineer’s awareness about the LCCA. That is why the participants are quite important for this research. They answered the questionnaire of this research in order to evaluate their awareness degree of LCCA.

The questionnaire was designed in simple as a (put mark) format to general questions about LCCA. The questionnaire consists of 4 main parts, the first part is participants' statistical information including experience of engineers, scientific qualification (Bachelor, Master and PhD) also company classify (consultant, contractor and government agency). The experience of the sample group was ranged between 0-20 and more. The second part of the questionnaire was from methods of LCCA, there were six methods for LCCA It has been tried to reach participants use and knowledge of LCCA methods. These questions were answered in a format which is given as: (Never hear, hear, know, sometimes use, and often use)

The third part consists of LCCA calculation and at this part, if the participants use of LCCA parameters and costs included in their Life Cycle Cost Analysis forecasts. These questions were answered in a format which is given as: (Certainly use, partially use, uncertain, partially disuse and certainly disuse). At last part of the questionnaire, the questions were asked about their knowledge about LCCA and this part consist general questions. These questions were answered in a format which is given as: (Usually, often, sometimes, seldom and never). After communication with engineers and take advantage of these findings were interpreted using Excel and Statistical Package for the Social Sciences (SPSS) which provides a statistical analysis and data management system in the graphical environment. It has been used in compiling results obtained in the current research in order to arrive at clear conclusions with minimum error margin.

## 1.6 Hypothesis

The hypothesis of this research is focused on applying Life Cycle Cost Analysis and how it will affect in different fields like cost and controlling the works of the buildings. The basic hypothesis of this research is:

**"Applying Life Cycle Cost Analysis (LCCA) in construction building adds more cost-effective, management and controlling the works of facilities"**

## 1.7 Theoretical Approach

The data source in this research is considered on quantitative data that is quantifiable data involving numerical and statistical explanations. The properties of quantitative research are deductive, it begins from theory and use to test hypotheses. Also, the importance of quantitative research is more dependable and less detailed than qualitative data and may miss a desired response from the participant. Quantitative research is based on its original plans also the more easily to analyze and interpretation the results. The questionnaire will be used as a tool of study and its included a group of topics and paragraphs to determine stats results of study and analysis this results. The key characteristics of quantitative research are hypothesis testing, control, operational definition and replication.

## 1.8 Literature Review

Through research in the literature, books, and the Internet to find out studies and research dealing with topics close to this research. The previous studies are the following:

**1.8.1 A study (Sadi et al., 2002) that is titled: Assessment of the Problems of Application of Life Cycle Costing in Construction Projects in Saudi Arabia**. The objective of the study to identify the problems of applying the Life Cycle Cost Analysis for the construction buildings in Saudi Arabia. After the survey, they found cause for not applying LCCA in government agencies or the public sectors are, client or management pressure to meet deadlines for design approval and lack of human resources (qualified consultants and staff) and material resources (sufficient data).

**1.8.2 A study (Sterner, 2000) that is titled: Life cycle costing and its use in the Swedish building sector**. The objectives of this study were to know if the developers and clients use life cycle cost and in any phase, they use it. After the survey, he found the LCCA calculations are usually accomplished in the design phase of projects. Also, the use of LCCA is limited because the limited experience and lack of related input data in using LCCA calculations are major obstacle.

**1.8.3 A study (Sofat and Tyagi, 2008) that is titled: Life cycle costing – cost data bank.** This study done in India by central building research institute (CBRI) and the aim of the study was to build up a viable cost data bank for life cycle costing. The successful implementation of this method depends on the cost data. Initial steps have been taken up to build up information on the recurring costs and life of different components. Efforts should be continued to improve its value by developing a viable cost data bank on various types of construction with different specifications in different situations.

**1.8.4 A study (Tysseland, 2007) that is titled: Life cycle cost based procurement decisions: a case study of Norwegian**. The objectives of this study were to know the effect of project uncertainty on use of LCCA also to know the project leader's attitude and knowledge about LCCA. After the survey, he found those results firstly, negatively affects if use the LCCA on the uncertainty Project and less goal conflict exists between projects managers with a positive attitude about LCCA and the principle. Finally, lack of knowledge about the LCCA, that resulting to less use is empirically supported.

**1.8.5 A study (Swaffield and McDonald, 2008) that is titled: The contractor's use of life cycle costing on PFI projects Engineering.** The objective of this study was to investigate attitudes and opinions about the importance and use of life cycle costing within private finance initiative (PFI) projects. After the survey, they found participants had a good knowledge/understanding of PFI contracts and what is meant by the term LCCA. Also, the LCCA is a decision-making tool and there are different mechanisms available to estimate LCCA at the early stage of a project.

## 1.9 Structure of Chapters

- The first chapter consists the importance of research, general objectives of the study together with the research hypothesis and the methodology.
- The second chapter consists of the historical background of the Life Cycle Cost Analysis.
- The third chapter includes the definition, concept and elements of the Life Cycle Cost Analysis.
- The fourth chapter consists of the methods and processes used in the Life Cycle Cost Analysis.
- The fifth chapter consist of data analysis and discussion of the results.
- The sixth chapter includes the conclusions and recommendations.

# CHAPTER 2
# HISTORICAL BACKGROUND

## 2.1 Construction Sector in Saudi Arabia

The real estate sector in Saudi Arabia is witnessing high growth rates in all aspects, especially in housing construction and construction of public buildings (Saudi consolidated contracting, 2009). The investors tend to this sector because the type of safe for the money is high and the risk to lose your investment is usually low compared with other types of investments (Saudi consolidated contracting, 2009). Saudi Arabia has one of the largest construction markets with billions of dollars' projects by both public and private sector entities. The public sector mainly focuses on developing the infrastructure buildings and making new transportation facility, educational facilities, and healthcare facilities. The private sector is more active and positive role in the growth of constructions than public sector. Privately owned companies and individuals are investing in the development of the country in building residential and commercial estates, hospitals, tourism and retail outlets (Council of Saudi Chambers, 2010).

The real estate sector in Saudi Arabia is important for economic activities, and through its contribution to the gross domestic product, creates jobs and creates new investment opportunities for business owners to meet the growing demand for housing units work to reduce the costs of these units. There are many indications that have a role in this sector for the national economy clearly and the most important of these indications are (Council of Saudi Chambers, 2010):

1- Contribution of the construction sector in local production.
2- Increase the investment in the construction sector.
3- Increase the demand for property in many cities in Saudi Arabia.
4- Increase real estate sector jobs.

The future of the real estate sector, where is became a prosperous for the most attractive sectors in the investment considering the financial and economic conditions in Saudi Arabia. Therefore, this sector has become an unprecedented boom by providing liquidity, funding, availability of demand and the presence of huge investment initiatives. When talking about the growth opportunities of this sector, first thing to be taken into account the factors influencing the future of this sector, which could affect the growth greatly. The factors are (Council of Saudi Chambers, 2010):

1- Economic, population growth and composition of the population.
2- Continue to improve the investment environment.
3- Complete the process of promoting the construction sector.
4- Mortgage finance in Saudi Arabia.

However, this sector faces challenges that will define future of the sector. The most prominent of these challenges facing the real estate sector are success in meeting the growing of local demand for real estate in general and housing. This sector need to provide funding for the sector from multiple sources and flexible terms for investors, and the government must help the investors by offering loans (National real estate committee of Saudi Arabia, 2010). The investors must study the economic feasibility of the establishment construction projects to avoid many of the risks. Success in keeping the stability of prices of the construction materials such as cement and steel, to not affect the contractor’s contracts, so as in the end not affect the prices of constructions (National real estate committee of Saudi Arabia, 2010).

Components of the real estate sector in the Saudi Arabia consist of elements of spatial, architectural elements, social elements and economic elements. The elements of spatial is like the existence of Saudi Arabia having border with eight countries also, the variety of topographic and climate that give catalyst for the establishment of various projects (National real estate committee of Saudi Arabia, 2010). For the architectural elements, like availability of land within the development plan for the real estate sector and the economic elements consist the of foreign investments.

## 2.2 Saudi Council of Engineers

In 1978, a symposium was held at King Saud University about the development of the engineering profession in Saudi Arabia and need for a council that interested for the of engineering (Saudi Council of Engineers, 2015). In 1980, the idea was re-discussed again in the second symposium, then a decision was issued in 1982 to form the Advisory Committee for Engineering. In 2002, the decision was made of King Fahd bin Abdul-Aziz Al Saud for establishment of the Saudi Council of Engineers (Saudi Council of Engineers, 2015).

Saudi council of engineers is a scientific professional body that aims to promote the engineering profession and do whatever may be necessary to develop and upgrade its standards and practicing (Saudi Council of Engineers, 2015). The primary obligations of the council are setting criteria and guidelines of practicing and building up this profession including licensure terms and conditions, describe necessary rules, regulations, and examinations for acquiring professional degrees, preparation and distribution of studies and researches. Organization of the conferences, gatherings, courses, and symposia relating to the profession, and submission of technical advice in its area of specialization by councils of directors (Saudi Council of Engineers, 2015).

The vision of the Saudi council of engineering to promote the profession and to make the engineering institutions to have access to the best solutions also, increase performance and innovation to achieve the level of prestigious international stature. The objectives of the Saudi council of engineering are (Saudi Council of Engineers, 2015):

1- Building extraordinary engineering efficiencies for the economic growth of Saudi Arabia.
2- Creating helpful environment for advancement, improvement, and creativity that serve the prerequisites of the society.
3- Empowering building firms and engineers to develop their competitive capabilities.

The strategies of the Saudi Council of Engineers (Saudi Council of Engineers, 2015):

1- Contribute to raising the level of engineering education in the academic, training and professional fields in order to achieve the ratification of the education outputs.
2- Upgrading the capabilities of engineers and technicians to adopt training curricula that enable them to professional practice.
3- Encourage the adoption of basics and regulations that govern the licenses, engineering basics, and ethics of the profession.
4- Promoting research, development, creativity and advancement in all sectors of engineering.
5- Providing attractive and effective services to companies, engineering offices, and engineers.

6- Review of decisions and regulations in the public and private sectors related to the profession of engineering sector and propose appropriate amendments contributing to achieving the aims of the Saudi council of engineering.
7- Active participation of Saudi Arabia companies in the public and private sector projects and the development of a genuine work of the partnership between Saudi and foreign engineering institutions to achieve capacity development.
8- Encourage integration between engineering firms and national institutions to enable them to implement major projects.
9- Support the small and medium engineering institutions, engineering offices and individual development.
10- Recognition with the aims and tasks of the Saudi council of engineering and the role of engineering sector in the execution of different improvement programs.

## 2.3 Historical Evolution of the Life Cycle Cost Analysis

The history of the evolution of Life Cycle Cost Analysis, is in fact indistinct. There are some certain events that mark significant developments in the concept as a means to estimate and control costs. The theory of the LCCA derives from the 1930s in USA and its implementation was first developed in the mid-1960s to support the US Department of Defense for assessment of using the devices of alternative military (Gluch and Baumann, 2004).

In 1929, the General Accounting Office made decisions that mentioned the need to consider total costs in contracts let by the government, not just acquisition costs (Washington U.S Logistics Management Institute, 1974).

In 1947, applicability to Department of Defense procurements was tentatively identified. In the armed services procurement regulations issued that year there was reference to the fact that contracts should be awarded on a basis of price and "other factors". Review of the supporting report from the senate committee on the armed services indicated that the term "other factors" was to include consideration of "ultimate cost" in procurement activities (Washington U.S Government Printing Office, 1970).

In 1963, further development of Life Cycle Cost Analysis as a philosophy occurred. At that time the Assistant Secretary of Defense (Installations and Logistics) initiated a study of the effect that price competition could have on life cycle equipment costs. This initial effort was directed toward award of production contracts for minor subsystems, assemblies, subassemblies and parts (Washington Government Printing Office, 1970).

In 1964, the Total Package Procurement concept referenced the need to compete for production and support as well as development in system acquisition. This meant that estimates of the Life Cycle Cost Analysis associated with the total program needed to be identified (Charles and Robert, 1964).

In 1966, that serious efforts were begun to develop a methodology to use Life Cycle Cost Analysis as a mean to competitively procure specific items. The approach was to attempt to determine which contractor's product would have the lowest anticipated Life Cycle Cost Analysis as the item accomplished a specified objective. Consequently, a specific item might cost more to acquire, but over its lifetime cost less than a lower bid item. The initial application of this approach involved a purchase of non-reparable equipment on a price-per-unit-of-service-life basis rather than on the basis of unit price alone. The benefit of this approach would be to motivate contractors to use total life costs rather than merely acquisition cost to develop better items (Finan and William, 1968).

Although the idea or desirability of using total Life Cycle Cost Analysis had been espoused for many years, the history of the concept shows that the concept was still not much more than a desirable objective prior to 1966. It had been written about, but little effort had been expended in attempts to determine what actually comprised the total costs of a system, or even a specific item in the system. Initiation of a test program in 1966 designed to procure specific components based on long term benefits versus the short term least cost concept marked the first significant effort to use Life Cycle Cost Analysis as a criterion for procurement (Finan and William, 1968).

In 1970, the next major developments in Life Cycle Cost Analysis were Procurement Guide (LCC-1) and Casebook Life Cycle Costing in equipment procurement (LCC-2). In fact, the procurement guide stated "This guide represents the first attempt of the Department of Defense to establish procedures for employing the Life Cycle Cost Analysis concept in acquisition of material below the level of complete weapon systems" (Washington U.S. Government Printing Office, 1970).

The guide also identified items which should be considered for Life Cycle Cost Analysis these included:

1. Items not subject to repair, for which the anticipated annual buy exceeds $350,000.

2. Items subject to repair, for which the anticipated annual buy exceeds $100,000.

3. Standard commercial items.

4. Items having undesirably high failure rates.

5. Items recognized as needing or being susceptible to improved reliability/maintainability.

In 1973, specific guidance concerning the use of the Life Cycle Cost Analysis concept in system acquisition was provided with the publication of the Life Cycle Cost Analysis guide for system acquisition, this document presents guidelines, including representative detailed procedures for applying of the Life Cycle Cost Analysis concept while getting of complete defense systems. It completed the evolution from LCC-1 and LCC-2 which were concerned with estimating costs of material below the level of a complete system.

In 1974, the final evolutionary document which should be identified is the Operating and Support Cost Development Guide for Aircraft Systems. It was prepared by the Cost Analysis Improvement Group and was dated May 1974. It is aimed at specifically improving the Department of Defense capability to quantify operating and support cost impacts of new systems and to consider those cost effects in the system process of acquisition (Washington U.S. Government Printing Office, 1974). It offers a detailed process for estimating, operating and providing support costs for aircraft systems. Similar guides for missile systems and other major systems were to be developed.

In this section, significant events in the development of Life Cycle Cost Analysis as a concept to be used in acquisition strategies, both for systems and components. There was no try to be inclusive and the dates cited and the documents referenced show that Life Cycle Cost Analysis has developed from a vague goal to reduce total costs over a system's lifetime into a comprehensive concept. It is a concept which, if used carefully can significantly reduce the cost growth associated with ownership of a system.

### 2.4 General View on the Life Cycle Cost Analysis

Life Cycle Cost analysis is a strategy utilized for the appraisal and assessment of a building or an asset in general along its entire life that relates to monetary value of the investment. It is utilized basically, for the comparison between the life cycle costs of two products or more.

It can be utilized in any or all phases of a product/asset (New South Wales Treasury, 2004). It helps interested parties in decision-making apparently, comparison between different assets and alternatives. Which is a more economic investment components and gives information on which is more economic along the whole life of product. In the consultancy study on life cycle energy assessment of building construction, it is expressed that LCCA is a quantitative method which helps in the decision-making process as it gives data about the payback period of an item or an asset and in addition the cost of the life cycle of an investment from initial cost to end of life cost including discounting rates of money (Chow and Wong, 2007). Generally, stakeholders and the owners settle on the more economic investment by comparing only between their initial capital investment costs. May this is misleading the costs of operation, maintenance and rehabilitation of a building make up to 80% of its total life cycle cost (Guoguo, 2008). LCCA technique goes back to the 1930s by the US government, however but there was no genuine application on structures till the mid-1960s (Chow and Wong, 2007). It was first utilized in North America and then after that begun to be known as a topic of study and research in the 1950s when the building research establishment undertook a research on cost-in-use (Chow and Wong, 2007). According to ISO 15686, LCCA is defined as “A manner in which empowers comparative cost assessments to be made over a predetermined timeframe, considering into all relevant economic factors both in regarding of initial capital costs and future operational costs. Specifically, it is an economic appraisal considering all the expected relevant cost flows over a period of analysis expressed in monetary value. It can be defined as the present value of the total cost of an asset over the period of the analysis” (Task Group 4, 2003).

# CHAPTER 3

# DEFINITIONS AND COST PARAMETERS

## 3.1 The Concept of the Life Cycle Cost Analysis

This section will develop a definition for life cycle costs, may be considered to describe the total costs associated with a certain system, component or more than one item over the evolution of the product from origination to end of life (Busek, 1976). The U.S. Department of Energy (2014) defined LCCA as the strategy used for determination of the most cost-effective option among options, and to fully document the selection process. In many cases, the objective of the LCCA is to eliminate a problem. LCCA is a procedure of estimating the economic performance of construction over its whole life (Stanford University Land and Buildings, 2005). Also, it is known as “whole cost accounting” or “total cost of ownership. LCCA balances initial monetary investment with the long-term expense of owning and operating the building (Stanford University Land and Buildings, 2005).

LCCA is focused on the assumptions of the various building design options that can meet the program requirements needs and reach the standards of performance and these options have differing initial costs, operating costs, maintenance costs and mostly different life cycles. For a specific design, LCCA estimates the total cost of the construction from beginning through operation and maintenance, for parts of the life cycle of the construction (kinch, 1992). Air Force Regulation (1973) has defined the term as follows "Life Cycle Cost is the total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership (operation, maintenance, support, etc.) and where applicable disposal". Also, the Air Force Regulation (1972) explain more about Life Cycle Cost Analysis as "The use of life cycle cost is not Intended to make minimum cost the predominant decision factor, but to ensure a proper balance between cost and system effectiveness". This definition identifies what life cycle costs should include when evaluating the cost of a piece that used for the equipment also, the intended use of the term was more clearly.

Another view of the concept itself was stated in a general accounting office study of Life Cycle Costing as "Life Cycle Costing is a technique for estimating the total cost of a product over its useful life, including the expected costs of acquiring the item and its absorption into inventory. The latter are frequently referred to as ownership costs" (Comptroller General of the United States, 1974). The concept should be considered a technique to be used in estimating the total costs of a product. Finally, the U.S. Government Printing Office, Washington (1973) had the following definition for the term life cycle cost is "Total cost to the government of acquisition and ownership of a system over its full life. It Includes the cost of development, acquisition, operation, support and where the applicable must disposal".

## 3.2 Why to Use Life Cycle Cost Analysis

The assurance of costs is an indispensable part of the asset management process and is a typical component for a lot of the asset manager’s tools and it is especially economic evaluation, financial evaluation, value management, risk management and demand management. Previously, comparisons of benefit choices for the idea or design mainly based on initial capital costs. Increasing pressure to accomplish better results from assets means that continued operating and maintenance costs must be taken into account as they consume more resources over the life of service (New south wales treasury, 2004).

Each of the equity capital and the continued operation and maintenance costs must be considered in anywhere asset decisions include costs are made. Finally, the Life Cycle Costing is a procedure to decide the sum of all the whole costs associated with an asset or part of it, including acquisition, installation, operation, disposal costs and maintenance. It is crucial to the asset management process as an input to the assessment of alternatives via economic appraisal, financial appraisal, value management, risk management and demand management (New south wales treasury, 2004).

The study was done by Stanford University (2005), figure 3.1 explains over 30 years of a building’s life. The current value of maintenance, operations, and utility costs are almost great the initial project costs. This study was done on the campus buildings in the presence of shortfalls in their annual budgets and that lead to deferred maintenance and finally, retreat the benefits and performance of the building. The considering of maintenance and operating costs for new buildings or renovated buildings will save more costs. Finally, the using the guidelines for LCCA of the buildings or products will help project group to calculate the costs and using it to the planning, design, and construction decisions.

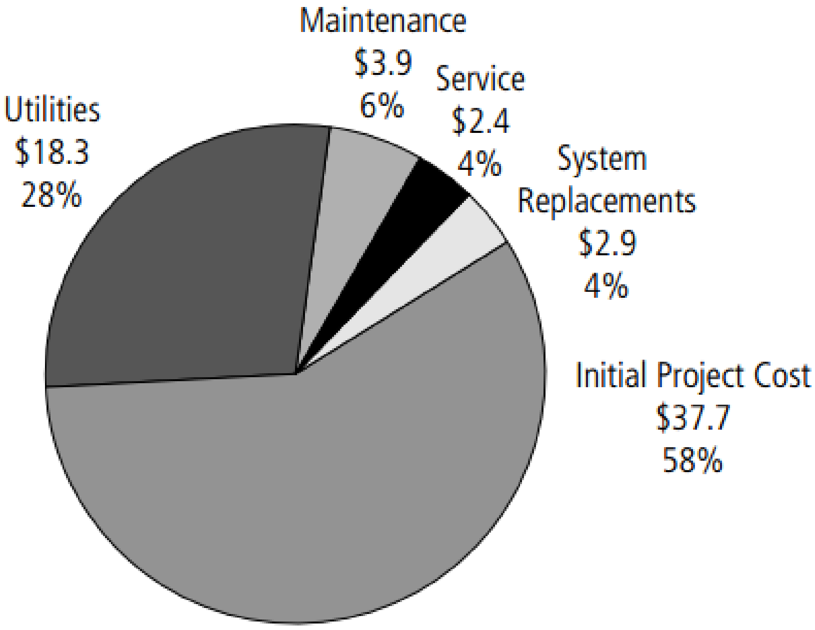


**Figure 3.1:** Gates Computer Science Building 30-Year Life Cycle Cost (in millions of dollars). (Stanford University Land and Buildings, 2005)

### 3.3 Objectives of Life Cycle Cost Analysis

The main objective of LCCA is to provide a technique for the financial in order to an assessment of buildings and replace the traditional methods built on the basis of the initial costs of the building. LCCA objectives can be put in order as follows (Flanegan and Norman, 1987):

1- Estimating the full total cost as opposed to focus just on the initial capital costs.
2- Facilitating an effective choice between alternative methods of achieving a stated objective.
3- Showing details and the current operating costs of assets such as individual building elements or complete building systems.
4- Identifying those areas in which operating costs might be reduced, either by a change in operating practice e.g. hours of operation, or by changing the relevant system.
5- Determining the factors of maintenance costs in order to lessen it.

In the light of these objectives, it can be classified that users and suppliers of equipment can use life cycle costs for (Flanegan and Norman, 1987):

1- Affordability studies: impact of a system or project's LCCA on long term budgets and operating results can be measured.
2- Source selection studies: by using LCCA can be estimated between rival systems or supplying goods companies and services can be compared.
3- Design trade-offs: its impact the design ways of buildings and equipment that directly effect on LCCA.
4- Repair level analysis: for this type of studies, LCCA determines the size of maintenance needs and costs instead of using rules of thumb such as "... maintenance costs must be less than ‘x’ % of the cost of capital for the equipment".
5- Warranty and repair costs: suppliers of goods and services along with end-users be aware the cost of early failures in the selection of equipment and use.
6- Suppliers' sales strategies: it can also integrate specific equipment grades with general operating experience and end-user failure rates using LCCA to sell for best benefits rather than just selling on the specification of low first cost.

### 3.4 Cost Breakdown Structure

The LCCA assessment includes the costs of the studied product asset from its primary investment cost to its end of life cost. However, the costs that must be included in the Life Cycle Costing study are different from one standard to another as they differ between countries and projects. As well, the cost breakdown structure included differing according to the nature of the study. The level of the cost breakdown depends on the field and the aim of the LCC study (New south wales treasury, 2004)

According to BCIS and the British Standards Institute (2013), LCCA includes construction costs, operation costs, maintenance costs, end of life costs and finally the environmental costs which is optional. It is clear from the literature that there is confusion between the concept of the whole life cost and the life cycle cost, as in various papers they are considered as one. However, as shown in figure 3.2 and according to ISO 15686, whole life cost consists of externalities, non-construction costs, life cycle cost (LCC) and income (BCIS and the British Standards Institute, 2013). Cost breakdown structure (CBS) of LCC is customized according to the country it is applied in.

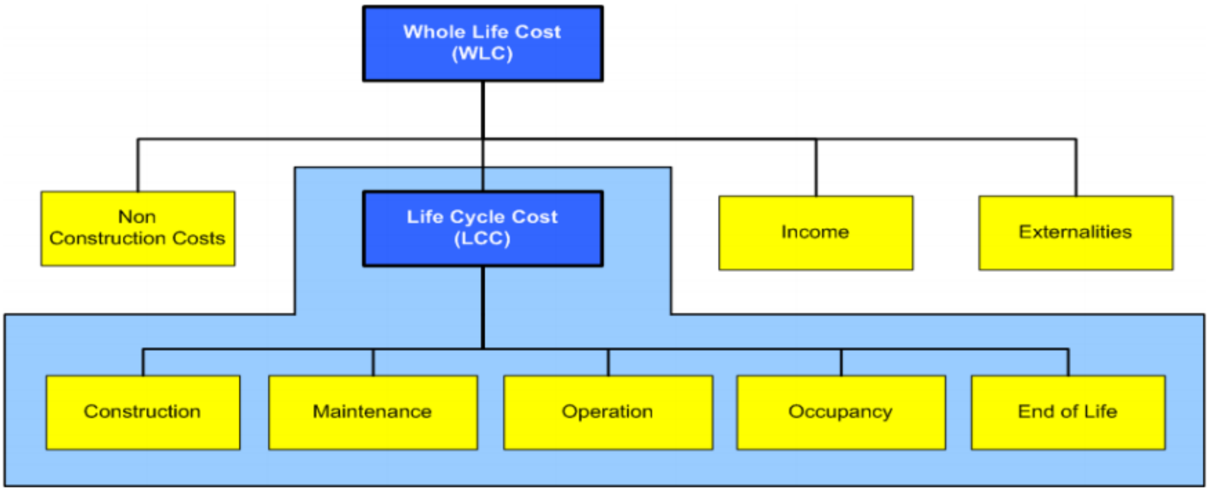


**Figure 3.2:** Whole life cost (WLC) and life cycle cost (LCC). (BCIS and the British Standards Institute, 2013)

### 3.4.1 Initial investment cost

Initial investment cost means all costs of the asset before occupancy. Life Cycle Costing Manual for the Federal Energy Management Program explained the initial investment cost as "The costs consist of the planning, design, construction and/or acquisition phase of a project are classified as initial investment costs. it happens usually before the building is occupied or a system is placed into service" (Sieglinde and Petersen, 1996). According to ISO 15686-5 (2000), the construction costs include building works and all costs pay by the client for the building/ asset like consultancy fees, infrastructure charges, licenses and permits, marketing costs, rights to light costs and project risk register contingency.

Construction costs vary according to the project type. For example, the construction costs of a hospital may include several items that are not to be used in the implementation of a residential building; this in addition to the construction method. Initial investment costs are mainly the costs which almost all investors give attention (BCIS and the British Standards Institute, 2013). For LCC analysis, all of these issues are generated in the process of a building project. It is shown in Figure 3.3 for the earlier of applying the LCCA will be more possibility of cost reduction and the lower of the cumulative costs of the project (Kirk and Dell'Isola, 1995). These processes consist:

• **Inception process**

First impression about building and interaction between a customer and the engineer defines this process. It evolved as an idea in a design process (Kirk and Dell'Isola, 1995).

• **Design process**

It includes idea/conceptual phase, planning phase applying preliminary design, design phase, implementing the design, drawings and procurement phase including documentation (Kirk and Dell'Isola, 1995).

• **Construction process**

After planning, design, site selection, financing and marketing, construction process of building project exists by bidding the project and getting started. This process contains an implementation of project, building or assembling of infrastructure. It can be defined as the translation of paper or computer based designs into reality (Kirk and Dell'Isola, 1995).

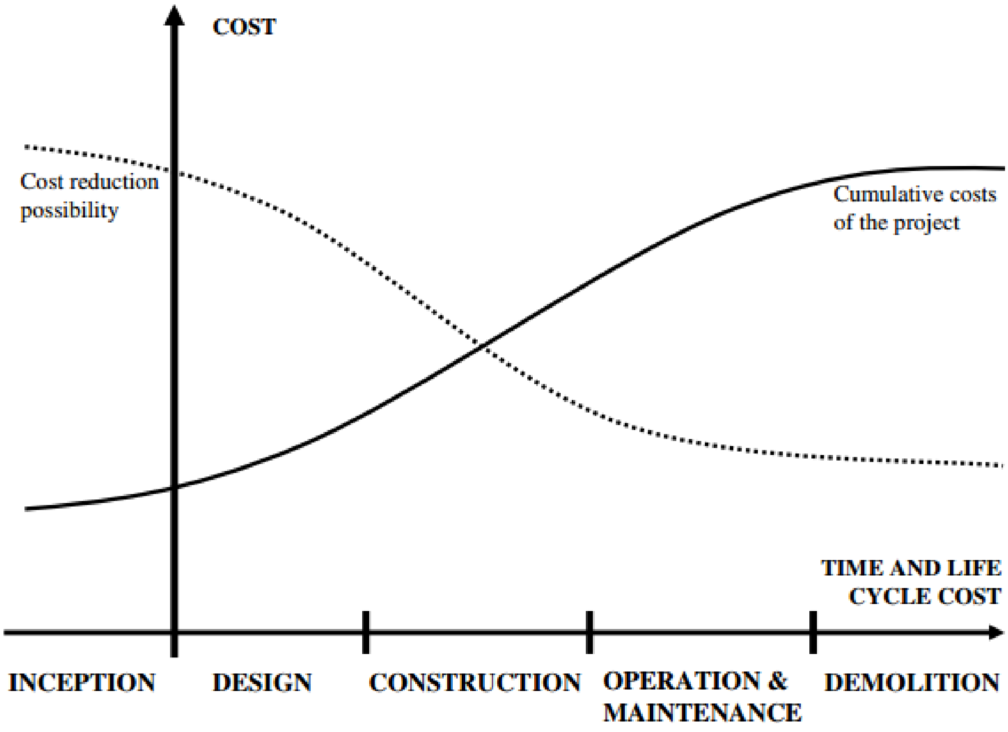


**Figure 3.3:** Phases of building project (Kirk and Dell'Isola, 1995)

As what Department of Education & Early Development Education Support Services (1999) and Heteba (2013) explained the initial investment costs contains the following:

- Land acquisition
- Planning costs
- Structural design costs
- Architectural design costs
- Excavation
- Foundations
- Structural costs (concrete and steel reinforcement)
- Masonry works
- Mechanical works
- Electrical works
- Plumbing works
- Finishing works
- Transportation charges
- Consultancy fees
- Special client costs – launch events and associated
- Marketing costs
- Water adoption
- Electricity adoption
- Gas adoption
- Light adoption
- Licenses and permits

### 3.4.2 Operation costs

Operation costs is defined according to the BCIS and the BSI published document "Standardized Method of Life Cycle Costing for Construction" as all the costs operating the building except for the maintenance costs; however, these costs are not arising from its occupancy but arising from the asset itself (BCIS and the British Standards Institute, 2013). Life Cycle Costing operation costs are those which are directly related to the asset itself; for example, costs of office materials are to be excluded from LCC operation costs (Department of Education & Early Development Education Support Services, 1999). Operation costs are periodic costs which include internal and external cleaning, utilities such as electricity, gas, water and drainage, administrative costs such as property management, waste management and disposal, and staff engaged in servicing the building, overhead costs such as insurance, lease, and finally taxes, rates and other local charges payable with owning the building. Operation costs contain the following (Heteba, 2013):

- Rent
- Internal cleaning
- External cleaning
- Water fees
- Electricity fees
- Gas fees
- Property management
- Staff engaged in servicing the building
- Waste management/ disposal
- Property insurance
- Taxes

### 3.4.3 Maintenance and replacement costs

Maintenance, replacement, repair and adaptation of the asset are either scheduled and anticipated costs or unscheduled and unanticipated future costs (Department of Education & Early Development Education Support Services, 1999). Maintenance and replacement costs include the scheduled replacements and maintenance of major and minor asset's components, scheduled redecorations, preventative maintenance plans, refurbishment and adaptation costs excluding those done during construction (BCIS and the British Standards Institute, 2013). Maintenance and replacements costs are either done annually or on a less frequent basis (Department of Education & Early Development Education Support Services, 1999). On the other hand, repair costs are those costs kept as an allowance for the unscheduled replacements, maintenance and repair costs (BCIS and the British Standards Institute, 2013). Maintenance and replacement costs include the following (Heteba, 2013):

- Major replacements
- Minor replacement, repairs, and maintenance
- Unscheduled replacement, repairs, and maintenance
- Adaptation and refurbishment
- Redecorations

### 3.4.4 Occupancy costs

According to ISO 15686-5 (2004), occupancy costs are classified as non-construction costs though it is normally included in the Life Cycle Costing calculation. They are costs arising from the usage of tenants to the asset (BCIS and the British Standards Institute, 2013). Occupancy costs include the following (Heteba, 2013):

- Internal moves
- Reception and customer hosting
- Manned security
- Help desk
- Telephones

- Post room – mail services
- Porters
- IT services
- Library services
- Catering
- Hospitality
- Vending
- Occupant’s furniture, fittings and equipment
- Internal plants and landscaping
- Stationary and reprographics
- Car parking charges

### 3.4.5 End of investment costs

According to the BCIS and the British Standards Institute (2013) the end of life costs are those costs which are payable at the end of the analysis period. It is known as the residual value defined as "The net worth of a building or building system at the end of the LCCA study period" (Department of Education & Early Development Education Support Services, 1999). Costs which include those of inspections carried out before demolition to the end of the period because of a contractual obligation to return the building on an agreed condition. Finally, the "end of life" term is in almost all LCCA calculations not the end of life of the asset, but it is the end of the study period (BCIS and the British Standards Institute, 2013). End of investment costs include the following (Heteba, 2013):

- Disposal inspections
- Demolition
- Reinstatement to meet contractual requirements

### 3.5 The Required Data for Life Cycle Cost Calculation

The collection of data is an important and a difficult step in the LCCA study. Since the LCCA study is built on the evaluation of future data so there must be a reliable method for data collection to reduce the uncertainties. To collect these data, there are several sources of data collection and estimation such as manufacturers, suppliers, clients, and contractors. In addition to engineering cost method, analogous cost method and parametric cost method which are used for cost data collection (New south wales treasury, 2004). The data required for the calculation of LCCA can be divided into five groups (Schade, 2007):

**1- Occupancy data:**

- Occupancy profile
- Functionality
- Hours of use
- Particular feature

**2- Physical data:**

- Superficial floor area
- Types of heating systems
- Window area
- Number of occupant
- Number of sanitary fittings
- Functional areas
- Walls and ceilings

**3- Performance data:**

- Maintenance cycles
- Cleaning cycles
- Thermal conductivity
- Occupancy time
- Electricity
- Gas

**4- Quality data:**

- Sanitary fittings
- Pipework
- Furnishing
- Boiler
- Decorations
- Fabric
- Road surfacing

**5- Cost data:**

- Acquisition cost
- Capital cost
- Taxes
- Inflation
- Management cost
- Maintenance cost
- Operating cost
- Cleaning cost
- Replacement cost
- Demolition cost
- Discount rate
- Insurance

# CHAPTER 4

# METHODS OF LIFE CYCLE COST ANALYSIS

## 4.1 Methods Used in Calculation of Life Cycle Cost Analysis

LCCA methods play a major role in its calculation. It is not easy to reduce all product (building) cost. A building as a body consists of many components, each having further subcomponents each with a different life span. Each component of the system will have its own life cycle while the system overall will command its own. To calculate overall components' LCCA, there are a few methods. By utilizing these methods, a building's whole cost can be projected and a decision reached as to which offers the least cost in the life cycle. After consolidating all the data needed for calculating LCCA, such as present and future costs, discount rate, and study period then the LCCA can now be calculated. There are different methodologies for the calculation of the life cycle cost of an asset such as (Celik, 2006):

- Simple payback
- Discount payback
- Net present value
- Equivalent annual cost
- Internal rate of return
- Net saving

### 4.1.1 Simple payback

The simple payback method computes the period which the initial investment cost is to be obtained by the investor and afterward the income is considered a profit. The system comparison between the alternative assets in terms of payback periods and the one with the shortest payback period is the one to be chosen. The disadvantage of this method does not take the inflation and interest rates of money (Öberg, 2005). The feature of this method is easy and quickly for the calculation. It is usable if the approximation of the investment is profitable (Flanagan et al., 1989; Schade, 2007).

### 4.1.2 Discount payback

The discount payback method is the same as the simple payback period but it takes the inflation and interest rates into consideration. The feature of this method takes the time value of money into account (Schade, 2007). The disadvantage of this method is ignored all cash flow outside the payback period. It is usable for screening devise not as a decision advice (Flanagan et al., 1989).

### 4.1.3 Net present value

The present value is the most important method in Life Cycle Cost Analysis methods and common method as it compares alternative assets with same lifetimes. It depends on converting all the future and annual cost into present value and this of course requires the consideration of inflation and interest rates. The advantage of this method it takes into account all available data. This method is not usable when the alternatives contain different life length (Flanagan et al., 1989; Kishk et al., 2003; Schade, 2007).

### 4.1.4 Equivalent annual cost

The equivalent annual cost method uses the same steps for calculating the net present worth but it takes a step further which is estimating the costs which will be paid on an annual basis. The feature of this method is different alternatives with various lifetime length can be compared. The disadvantage it does not refer the actual cost during each year of the LCCA. It is usable when comparing various alternatives with different life lengths (ISO, 2004; Schade, 2007).

### 4.1.5 Internal rate of return

This method is calculated the rate of return of alternatives with focusing on the discount rates. The most lucrative alternative is the highest rate of return. The IRR is to be compared with the investor’s minimum acceptable rate of return (MARR) so if the internal rate of return is higher than the MARR, then the investment is economic. The feature of this method, the result get presented in percent which gives an obvious interpretation also the disadvantage of this method, the results need a trial and error calculations. (Kishk et al., 2003; ISO,2004).

### 4.1.6 Net saving

This method calculates the net amount in present value which the asset is expected to save during the study period. The alternative which has higher net saving is the most profitable. The advantage of this method is easier to understand the investment appraisal technique. This method is can be only used if the investment generates an income. It can be used to compare investment options but just if the investment generates an income (Sieglinde and Petersen, 1996; Kishk et al., 2003; ISO, 2004).

## 4.2 Discount Rates

The discount rate has to be added to the real costs for the accuracy of the results. It is defined as "Factor reflecting the time value of money that is used to convert cash flows occurring at different times to a common time" (BCIS and the British Standards Institute, 2013, Langdon; 2007). Discount rate consists of the interest rate of long-term investment in bank or government bonds. The interest rate defined as that business would expect as a return for risk and the inflation rate affecting the purchasing power of the currency (New south wales treasury,2004). Discount rate reflects the changes of the asset due to the interest rate earned on the money of the asset along with its value decrease due to inflation. There are two types of the discount method, the first one is real discount rate and nominal discount rate (BCIS and the British Standards Institute, 2013; Heteba, 2013).

### 4.2.1 Real discount rate

Real discount rate takes into account the interest rate of long-term investment in bank or government bonds, the interest rate that business would expect as a return for risk. But it does not include the inflation rate affecting the purchasing power of the currency (Department of Education & Early Development Education Support Services, 1999; Heteba, 2013).

### 4.2.2 Nominal discount rate

Nominal discount rate takes into account the interest rate of long-term investment in bank or government bonds, the interest rate that business would expect as a return for risk, as well as the inflation rate affecting the purchasing power of the currency (Heteba, 2013). Both real and nominal discount rates give the same result as long as each is included in its corresponding present value calculation. As result for this, the exception of the real discount rate to the inflation rate does not mean it is ignoring it. However, it is just excluding it as a matter of simplifying the LCCA calculation (Department of Education & Early Development Education Support Services, 1999). The decision of using real or nominal discount rate is dependent on the decision of usage of constant dollars or current dollars. The real discount rate is used in calculation when constant dollars are used; on the other hand, the nominal discount rate is used in calculation when current dollars are used (Sieglinde and Petersen, 1996).

### 4.3 Life Cycle Cost Analysis Process

According to Barringer (1998) to develop a common methodology for Life Cycle Cost Analysis that can use it in the construction sector, there has to be a framework for the application of LCCA. It is divided into 11 generic steps which can be tailored on the user's project depending on its size, stage and level of detail required. These steps can be altered and iterated according to the objectives and resources available based on the actual situation at that stage (ISO 15663-1, 2000). The typical steps are further elaborated below (Barringer and Weber, 1996).

**First:** Define the problem requiring LCCA, it is the very first step while performing LCC analysis, hence, it is crucial that the problem or business case is correctly defined. This step consists of a determination of the objective of LCC analysis and to define the time period for conducting the study. Problems and scenarios to be analyzed and important financial criteria are also identified in this step.

**Second:** Alternatives and acquisition/sustaining cost, it is the stage where the engineers team conducts study and brainstorms for the alternatives solution in technical aspects that meet the need requirements.

**Third:** Prepare cost breakdown structure, this step identifies the possible cost elements involved and develops cost breakdown structure for further evaluation. The critical cost drivers and solution selection criteria are also identified at this stage. Before starting this process, the common cost for all alternatives should be identified. These are normally excluded in the consideration. According to Ahmed (1995), a cost breakdown structure should fulfill below necessities, it should list down the major costs or activities which had been defined clearly. It should be designed with possibility to find out the impact of cost changes in such area by not influencing others. Also, for proper reporting and controlling purposes, it should be compatible with the requirements concerning data.

**Fourth:** Choose analytical cost model, further from earlier step, an appropriate cost model should be chosen according to the project complexity and available resources.

**Fifth:** Gather cost estimates and cost models, it is the stage that involves data acquisition and collection regarding operating and maintenance data and other associated costs. The outcome obtained from this step facilitates complete evaluation considering both the financial and technical aspects.

**Sixth:** Make cost profiles for each year of study, based on the data and information collected from earlier steps, a cost profile for each alternative will be produced for each year of study throughout the defined life cycle.

**Seventh:** Make break-even charts for alternatives, break even charts are prepared for critical issues and simplify the details into time and money.

**Eighth:** Pareto charts of vital few cost contributors, verify and identify the key cost contributors. These cost contributors have ranked accordingly for further investigation.

**Ninth:** Sensitivity analysis of high costs and reasons, this step facilitates study and identification of how the cost contributors vary and affect the total cost. If a little change in the cost contributor results in huge change in the total ownership cost, it has to be taken note and focus to reduce the risk of over budgeting.

**Tenth:** Study risks of high-cost items and occurrences, an LCCA analysis that does not include risk analysis is incomplete at best and can be incorrect and misleading at worst (Craig, 1998). The uncertainty and risk associated with high-cost items have to be identified and handled. The feedback should then be provided to the team. Monte Carlo simulation is widely used for handling the uncertainties and provides more accurate analysis.

**Eleventh:** Select preferred course of action using LCCA, it is the final step for Life Cycle Cost Analysis that the most suitable alternatives are chosen. The complete cycles allow the engineering team to present facts and figures obtained from the LCCA for better visualization and consideration by the management team. Early introduction in the feasibility study phases has a higher degree of influence power to the design of the system and minimize the risk of having high operating and maintenance cost in the later stage of the development. The outcome of the LCCA in earlier phase can also be used as the basis for LCCA for next phase.

### 4.4 Uncertainty of the Results of the LCCA

Life Cycle Cost Analysis deals with future costs and depends on estimation, accordingly it faces a huge amount of uncertainty in data and results. Therefore, in order for the LCCA study to have sense and to be beneficial, the final result has to be indicative (Tupamaki, 2008). Construction projects lifespan ranges from 20 to 50 years, as a result, many changes will probably happen such as building products prices and service lives. This means that the estimation of detailed and accurate future costs is impossible (Fawcett et al., 2012). In order to overcome the LCCA uncertainty problem, the life cycle cost of the product/asset has to be a range and not a single value.

In the recent years, the LCCA study used the deterministic approach. The deterministic approach incorporates precise data input and yields a single point result for all variables in the product/asset through its study period. Afterward, the probabilistic approach has taken its way into the emergence and since then it is under research, also encompasses a range of values for LCCA (Fawcett et al, 2012). The range of results are calculated using the 3-point estimate method (lowest conceivable value, most likely value and highest conceivable value) in order for the results to be more near to fact (Fawcett et al, 2012).

### 4.5 Limitation of Life Cycle Cost Analysis

According to Barringer & Weber (1996), below examples are identified as the common limitation of LCC analysis:

- The application of LCCA and its method is subjective based on individual perceptions, knowledge and experience. There is no absolutely right or wrong conclusion derived from LCC analysis.

- LCCA requires large amount of data input from various areas to achieve maximum accuracy. However, it is practically challenging, i.e. expensive and difficult, to obtain the required information from the database and operating condition as input to the calculation.

- Limited time and resources are the common problem faced while acquiring information and performing LCCA. During the project execution, the evaluation process is always being shortened and sped up due to the short time limit allocated for the team. It is important to understand completely the limitations of LCCA and necessarily focus on assumptions to get best results (Kayrbekova, 2011). Simplified LCCA can be performed to compare the characteristics of the differences in various alternatives (Kayrbekova, 2011). There is a need to deal with impalpable data because, in some cases, they have a decisive role to play (Flanagan et al., 1989). On the other hand, lack of significant input data and lack of appropriate, relevant and reliable historical information and data are the other constraints (Bull, 1993). In addition, costs of data collection are huge (Fabrycky and Blanchard, 1991). In addition, the time required for data collection and the analysis process may leave enough time for the basic dialogue with the decision-maker and the re-run of alternative options.

It is hard to estimate many factors such as life cycles, future operating, maintenance costs, and discount and inflation rates. Discount rate which affects the result significantly is the critical variable. Inflation may be considered as a general increase of prices of goods and services over time in the economy as whole, without a corresponding increase in value (Kirk and Dell'Isola, 1995). Choosing a discount rate which is too high will bias decisions in favour of short-term low capital cost options, while a discount rate which is too low will give an undue bias to future cost savings. Since the accuracy of choosing a certain discount rate is uncertain, the result of an LCCA calculation can always be questioned.

Moreover, lack of experience in using the calculation models is another constraint. Besides, complex models include many parameters is the other constraints to make use of LCCA difficult. The lack of universal methods, standard formats and useful software are also the reason for limited use of LCCA (Cole and Sterner, 2000). Lack of industry standards is the other constraint. Also, it can be said that there is a lack of understanding on the part of the client (Bull, 1993). On the other hand, the clients do not usually want to pay an extra cost for LCCA calculation (Chinyio et al., 1998).

# CHAPTER 5
# DATA ANALYSIS AND DISCUSSION

## 5.1 General View on Data Analysis

This chapter presents data analysis and results of the questionnaire survey. The parts of the questionnaire will particularly be analyzed from the demographic information of participants including experience, academic qualification and classify the company, cost models, LCCA methods and costs included in estimating of LCCA. Constraints which prevent the use of LCCA. The analysis of data which is obtained from the questionnaire demonstrated the degree of LCCA awareness among engineers.

## 5.2 Analysis of Personal Data of Participants in the Questionnaire

Table 5.1 and Figure 5.1 show the job position for the participants in the questionnaire. The highest value is 32% of the sample are the project manager and 23% of the participants are the civil engineer. The 12% of the sample are a mechanical engineer and 9% of the sample are an electrical engineer. The percentage of site engineer is 21% and 3% of the sample are architecture. LCCA is especially applied for complex and sophisticated projects with a higher initial cost such as social facility projects. The participating implement LCCA to building projects which are more simple projects than complex ones. Therefore, it may be claimed that the most of the participating might not adequately apply LCCA to their projects.

Table 5.2 and Figure 5.2 show the experience of participants in the questionnaire. The 27% of the sample have experience "0-3 years" and 18% of the participants have experience "4-7 years". Also, 19% of the sample have experience "8-11 years". The percentage of the participants have experience "12-15 years" are 18% and 3% of the sample have experience "16-19 years". Finally, 18% of the participants have experience "20 years and more". These rates indicate that participation of engineers are almost highly experienced in profession life.

Table 5.3 and Figure 5.3 show the academic qualification of participants in the questionnaire. The 87% of the sample have "Bachelor" and the 11% of the participants have "Master". The 2% of the sample have "Ph.D."

Table 5.4 and Figure 5.4 show the organization of participants in the questionnaire. The 27% of the sample are consulting and 67% of the participants are a contractor. Also, 6% of the sample are a government agency. At the end of data analysis, there is not any important relationship between classifying the companies of participants and their knowledge about LCCA.

**Table 5.1:** Frequency and percentage of job participants

| Job | Frequency | Percent |
|---|---|---|
| Project Manager | 38 | 32 |
| Civil Engineer | 28 | 23 |
| Mechanical Engineer | 15 | 12 |
| Electrical Engineer | 11 | 9 |
| Site Engineer | 25 | 21 |
| Architecture | 3 | 3 |
| Total | 120 | 100.0 |

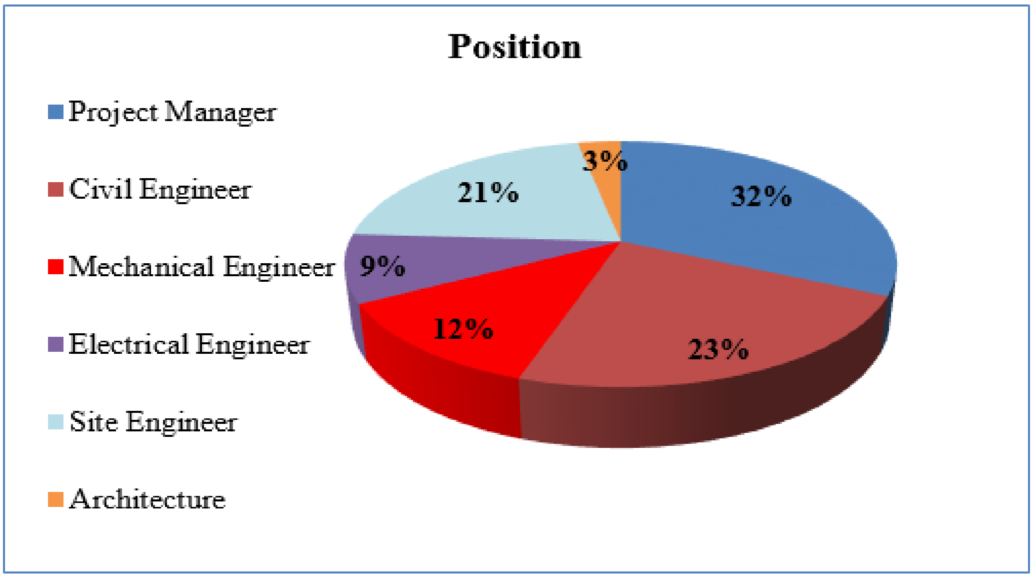


**Figure 5.1:** Percentage of job participants

**Table 5.2:** Frequency and percentage of management experience

| Experience | Frequency | Percent |
|---|---|---|
| 0-3 | 33 | 27 |
| 4-7 | 18 | 15 |
| 8-11 | 23 | 19 |
| 12-15 | 21 | 18 |
| 16-19 | 4 | 3 |
| 20 and more | 21 | 18 |
| Total | 120 | 100.0 |

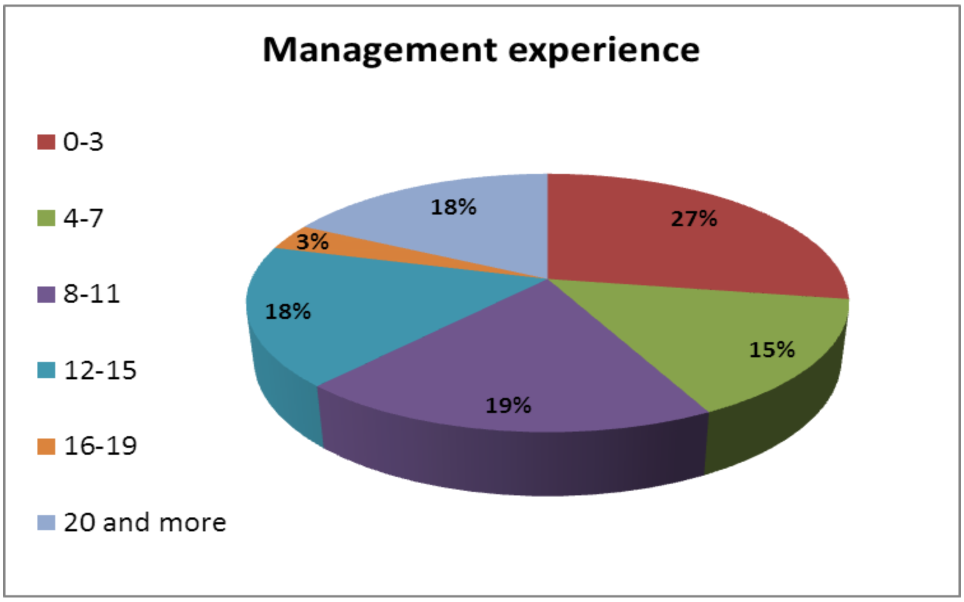


**Figure 5.2:** Percentage of management experience

**Table 5.3:** Frequency and percentage of academic qualification

| Qualification | Frequency | Percent |
|---|---|---|
| Bachelor | 104 | 87 |
| Master | 13 | 11 |
| PhD | 3 | 2 |
| Total | 120 | 100.0 |

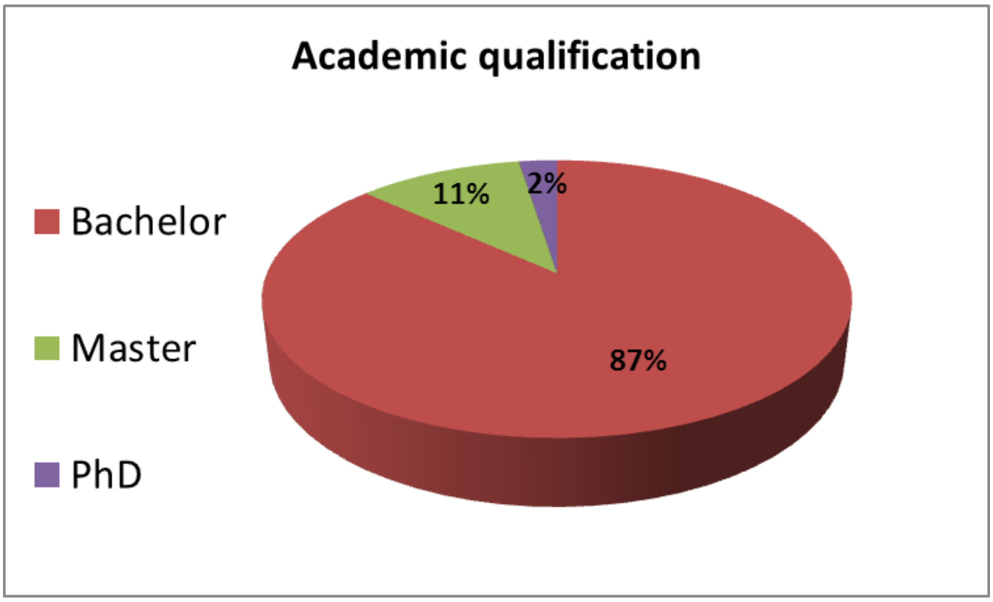


**Figure 5.3:** Percentage of academic qualifications

**Table 5.4:** Frequency and percentage of organization of participants

| Organization | Frequency | Percent |
|---|---|---|
| Consulting | 32 | 27 |
| Contractor | 81 | 67 |
| Government agency | 7 | 6 |
| Total | 120 | 100.0 |

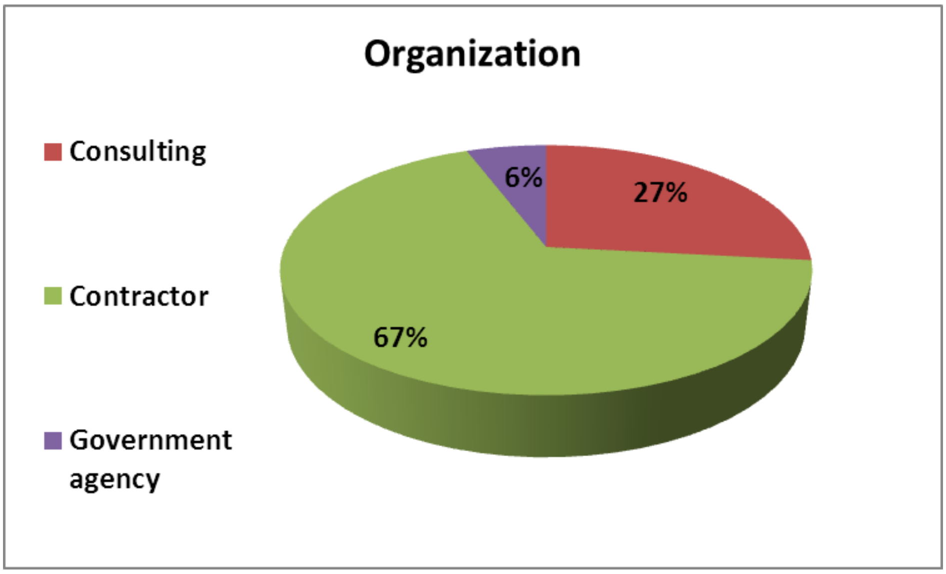


**Figure 5.4:** Percentage of organization of participants

### 5.3 Analysis of the Questions Related to Methods of the LCCA

This section is for analysis of the knowledge of the engineers about the methods of life cycle cost analysis. It indicates the mean and standard deviation values to show the degree of confidence of the engineer's answers.

### 5.3.1 Simple pay back method

The analysis of the question number four (Q4) "What is your knowledge about simple pay back? " is as follows: Table 5.5 and Figure 5.5 show the percent of "never hear" is 36.7%, the percent of “hear” is 23.3%, the percent of "know" 18.3%, the percent of "sometimes use" 18.3% and the percent of "often use" 3.3%. The mean of the question number four equals 2.28 and standard deviation equals 1.231. From the mean result, most of the engineers "hear" about the simple pay back method.

**Table 5.5:** Frequency and percentage of Q4 related to simple pay back

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 44 | 36.7 |
| Hear | 28 | 23.3 |
| know | 22 | 18.3 |
| Sometimes use | 22 | 18.3 |
| Often use | 4 | 3.3 |
| Total | 120 | 100.0 |

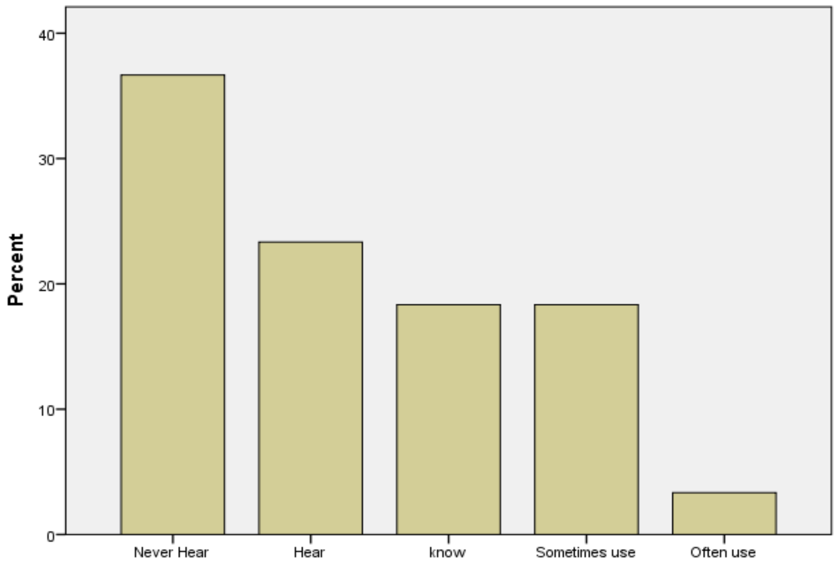


**Figure 5.5:** Percentage of Q4 related to simple pay back

### 5.3.2 Discount payback method

The analysis of the question number five (Q5) "What is your knowledge about discount payback method? " is as follows: Table 5.6 and Figure 5.6 show the percent of "never hear" is 36.7%, the percent of "hear" is 27.5%, the percent of "know" 19.2%, the percent of "sometimes use" 15% and the percent of “often use” 1.7%. The mean of the question number five equals 2.18 and standard deviation equals 1.135. From the mean result, most of the engineers "hear" about the discount payback method.

**Table 5.6:** Frequency and percentage of Q5 related to discount payback

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 44 | 36.7 |
| Hear | 33 | 27.5 |
| know | 23 | 19.2 |
| Sometimes use | 18 | 15.0 |
| Often use | 2 | 1.7 |
| Total | 120 | 100.0 |

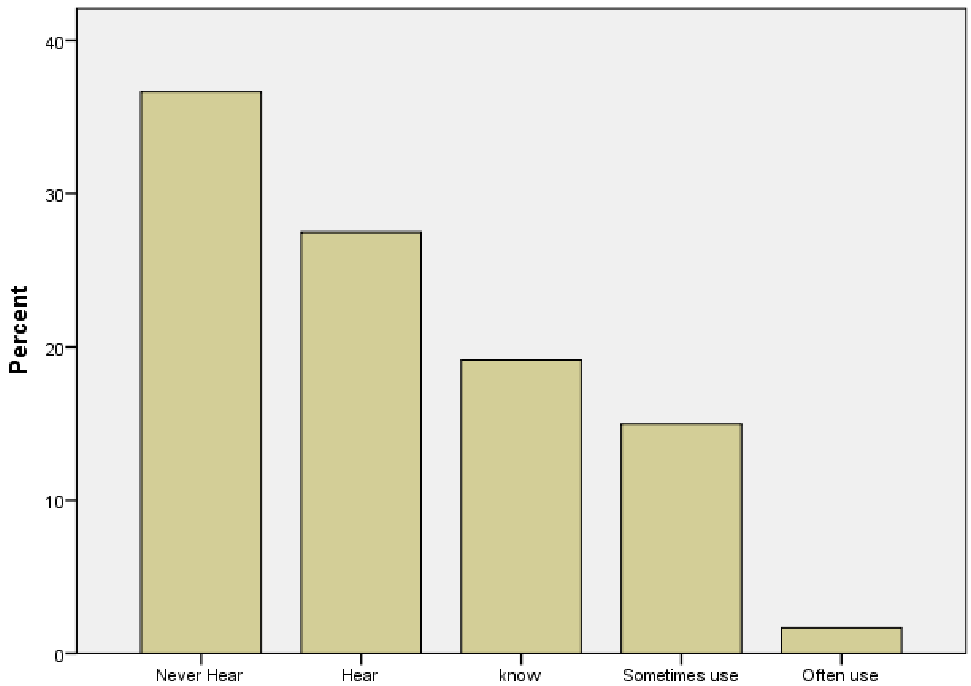


**Figure 5.6:** Percentage of Q5 related to discount payback

### 5.3.3 Net present method

The analysis of the question number six (Q6) "What is your knowledge about net present value? " is as follows: Table 5.7 and Figure 5.7 show the percent of "never hear" is 32.5%, the percent of "hear" is 28.3%, the percent of "know" 24.2%, the percent of "sometimes use" 13.3% and the percent of "often use" 1.7%. The mean of the question number six equals 2.23 and standard deviation equals 1.098. From the mean result, most of the engineers "hear" about the net present value method.

**Table 5.7:** Frequency and percentage of Q6 related to net present value

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 39 | 32.5 |
| Hear | 34 | 28.3 |
| know | 29 | 24.2 |
| Sometimes use | 16 | 13.3 |
| Often use | 2 | 1.7 |
| Total | 120 | 100.0 |

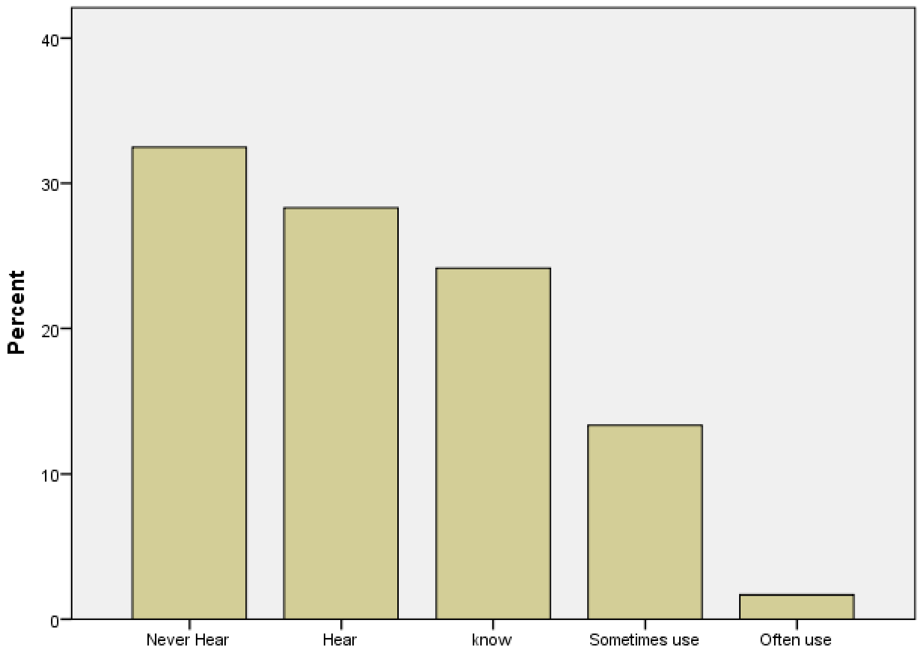


**Figure 5.7:** Percentage of Q6 related to net present value

### 5.3.4 Equivalent annual cost method

The analysis of question number seven (Q7) "What is your knowledge about equivalent annual cost? " is as follows: Table 5.8 and figure 5.8 show the percent of "never hear" is 36.7%, the percent of "hear" is 16.7%, the percent of "know" 24.2%, the percent of "sometimes use" 15.8% and the percent of "often use" 6.7%. The mean of question number seven equals 2.39 and standard deviation equals 1.305. From the mean result, most of the engineers "hear" about the equivalent annual cost method.

**Table 5.8:** Frequency and percentage of Q7 related to equivalent annual cost

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 44 | 36.7 |
| Hear | 20 | 16.7 |
| know | 29 | 24.2 |
| Sometimes use | 19 | 15.8 |
| Often use | 8 | 6.7 |
| Total | 120 | 100.0 |

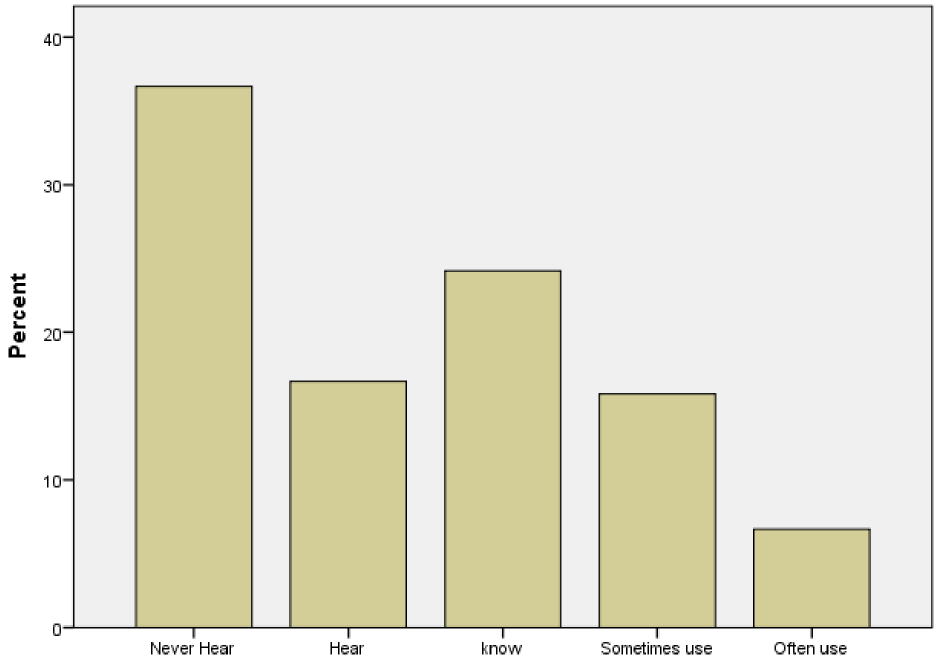


**Figure 5.8:** Percentage of Q7 related to equivalent annual cost

### 5.3.5 Internal rate of return method

The analysis of question number eight (Q8) "What is your knowledge about internal rate of return? " is as follows: Table 5.9 and Figure 5.9 show the percent of "never hear" is 36.7%, the percent of "hear" is 13.3%, the percent of "know" 33.3%, the percent of "sometimes use" 10% and the percent of "often use" 6.7%. The mean of question number eight equals 2.37 and standard deviation equals 1.256. From the mean result, most of the engineers "hear" about the internal rate of return method.

**Table 5.9:** Frequency and percentage of Q8 related to internal rate of return

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 44 | 36.7 |
| Hear | 16 | 13.3 |
| know | 40 | 33.3 |
| Sometimes use | 12 | 10.0 |
| Often use | 8 | 6.7 |
| Total | 120 | 100.0 |

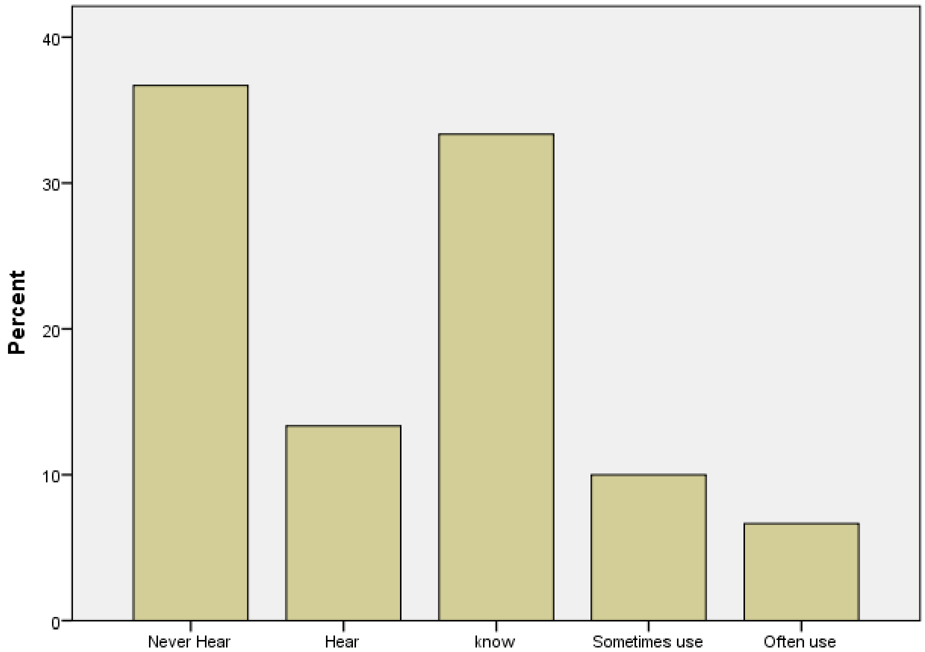


**Figure 5.9:** Percentage of Q8 related to internal rate of return

### 5.3.6 Net saving method

The analysis of question number nine (Q9) "What is your knowledge about net saving? " is as follows: Table 5.10 and Figure 5.10 show the percent of "never hear" is 40%, the percent of "hear" is 23.3%, the percent of "know" 13.3%, the percent of "sometimes use" 13.3% and the percent of "often use" 10%. The mean of question number nine equals 2.30 and standard deviation equals 1.376. From the mean result, most of the engineers "hear" about the net saving method.

**Table 5.10:** Frequency and percentage of Q9 related to net saving

| Valid | Frequency | Percent |
|---|---|---|
| Never Hear | 48 | 40.0 |
| Hear | 28 | 23.3 |
| know | 16 | 13.3 |
| Sometimes use | 16 | 13.3 |
| Often use | 12 | 10.0 |
| Total | 120 | 100.0 |

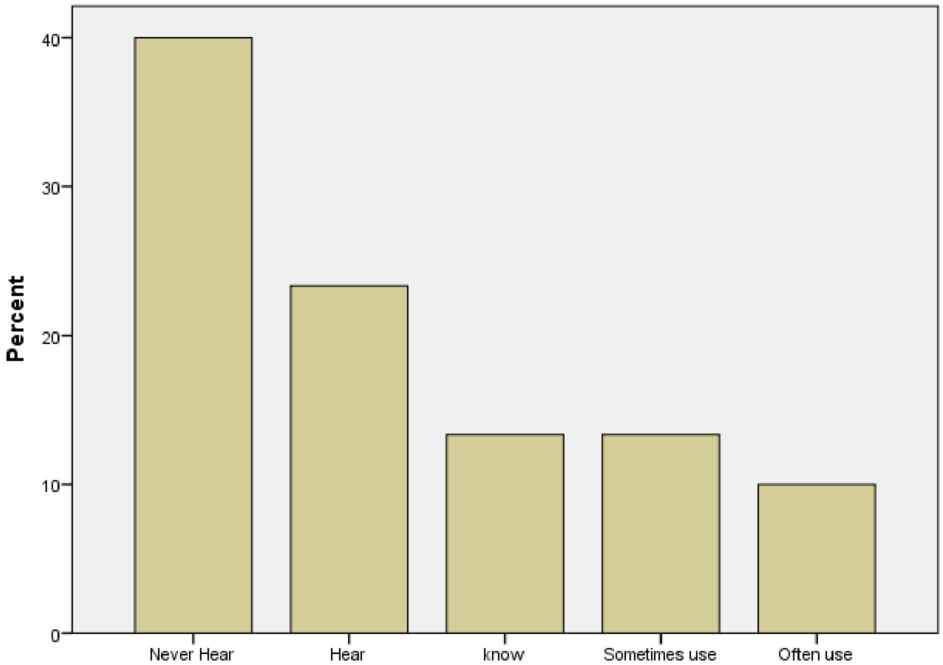


**Figure 5.10:** Percentage of Q9 related to net saving

### 5.3.7 Means and standard deviation for the methods of LCCA

Table 5.17 show the average of "the methods of LCCA". According to weighted mean of the user values a (Likert) scale, which ranges from (1-5) and it clear that all statements were mean of between 2.39 to 2.18, which means that they are in a category between (1.81-2.6) as the weighted Mean, which means the respondents chose "hear".

**Table 5.11:** Means and standard deviation for the methods

| NO | Item | N | Mean | Std. Deviation | Rank |
|---|---|---|---|---|---|
| 4 | What is your knowledge about simple pay back? | 120 | 2.28 | 1.231 | 4 |
| 5 | What is your knowledge about discount payback method? | 120 | 2.18 | 1.135 | 6 |
| 6 | What is your knowledge about net present value? | 120 | 2.23 | 1.098 | 5 |
| 7 | What is your knowledge about equivalent annual cost? | 120 | 2.39 | 1.305 | 1 |
| 8 | What is your knowledge about internal rate of return? | 120 | 2.37 | 1.256 | 2 |
| 9 | What is your knowledge about net saving? | 120 | 2.30 | 1.376 | 3 |
| | **All items of the field** | **120** | **2.29** | **1.233** | |

Figure 5.11 shows the questions with the maximum mean are questions 7 equal 2.39, while question 5 has the minimum mean equal 2.18.

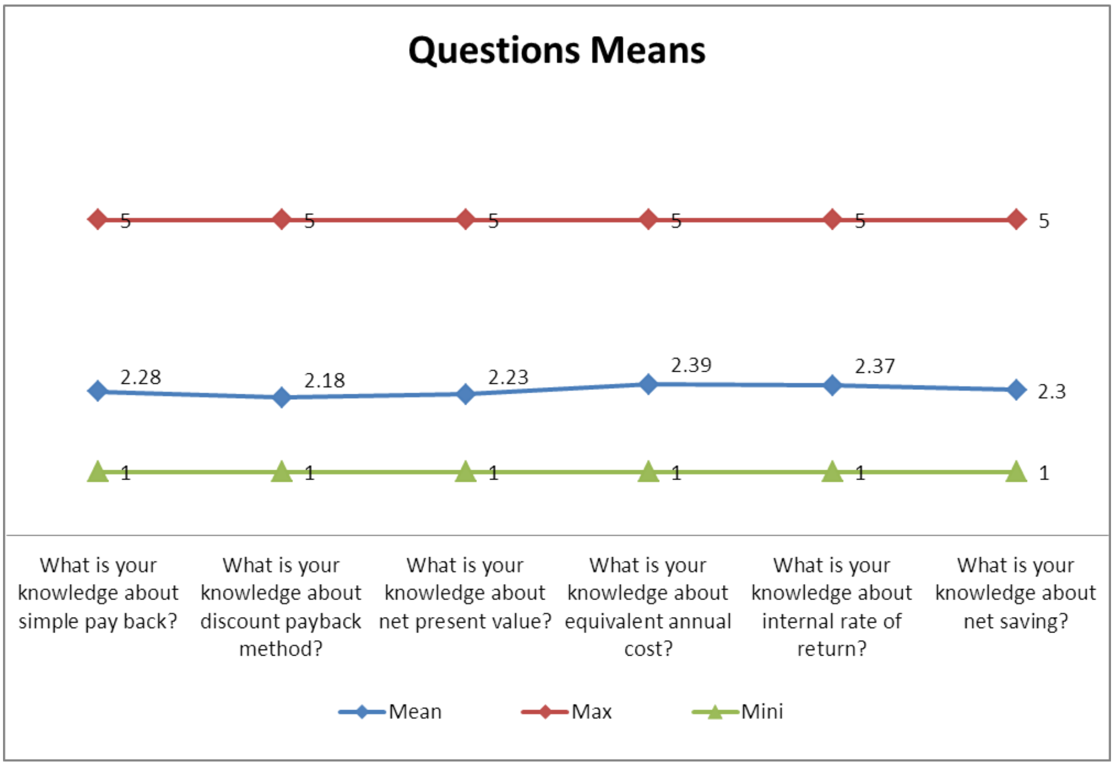


**Figure 5.11:** Mean of questions related to the methods

### 5.4 Analysis of the Questions Related to Cost Parameters of the LCCA

This section indicates the parameters that are usually included in LCCA calculation in order of engineer's usage frequency. It indicates the mean and standard deviation to shows the degree of confidence of the engineer's answers.

#### 5.4.1 Initial investment cost

The analysis of question number ten (Q10) "Do you take into account building initial investment cost? " is as follows: Table 5.12 and Figure 5.12 show the percent of "partially disuse" is 7.5%, the percent of "uncertain" is 10%, the percent of "partially use" is 26.3% and the percent of "certainly use" is 54.2%. The mean of question number ten equals 4.29 and standard deviation equals 0.929. From the mean result, most of the engineers "certainly use" for the initial investment cost.

**Table 5.12:** Frequency and percentage of Q10 for the initial investment costs

| Valid | Frequency | Percent |
|---|---|---|
| Partially disuse | 9 | 7.5 |
| uncertain | 12 | 10.0 |
| Partially use | 34 | 28.3 |
| Certainly Use | 65 | 54.2 |
| Total | 120 | 100.0 |

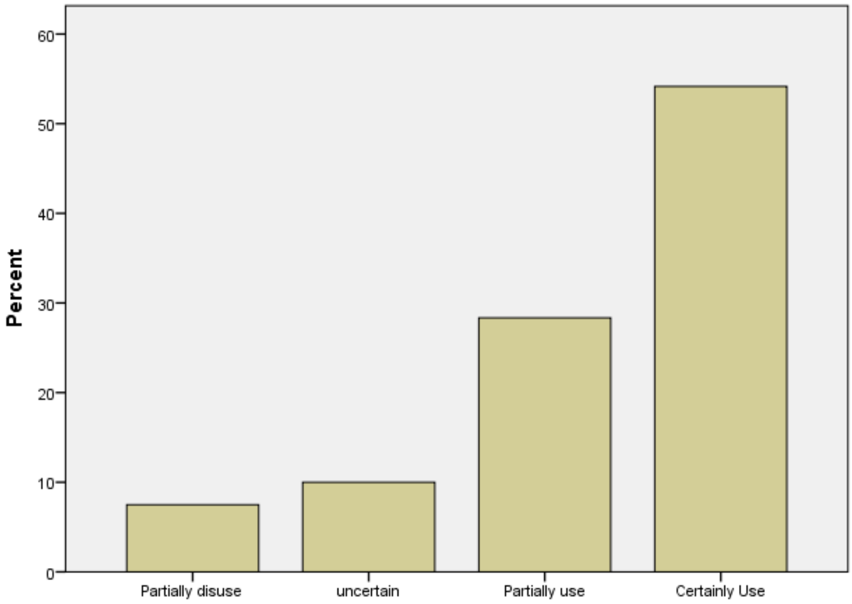


**Figure 5.12:** Percentage of Q10 related to initial investment costs

### 5.4.2 Operation costs

The analysis of question number eleven (Q11) "Do you take into account building operation costs? " is as follows: Table 5.13 and Figure 5.13 show the percent of "certainly disuse" is 0.8%, the percent of "partially disuse" is 1.7%, the percent of "uncertain" is 9.2%, the percent of "partially use" is 35% and the percent of "certainly use" is 64%. The mean of question number eleven equals 4.38 and standard deviation equals 0.791. From the mean result, most of the engineers "certainly use" for the operation costs.

**Table 5.13:** Frequency and percentage of Q11 for the operation costs

| Valid | Frequency | Percent |
|---|---|---|
| Certainly disuse | 1 | 0.8 |
| Partially disuse | 2 | 1.7 |
| uncertain | 11 | 9.2 |
| Partially use | 42 | 35.0 |
| Certainly Use | 64 | 53.3 |
| Total | 120 | 100.0 |

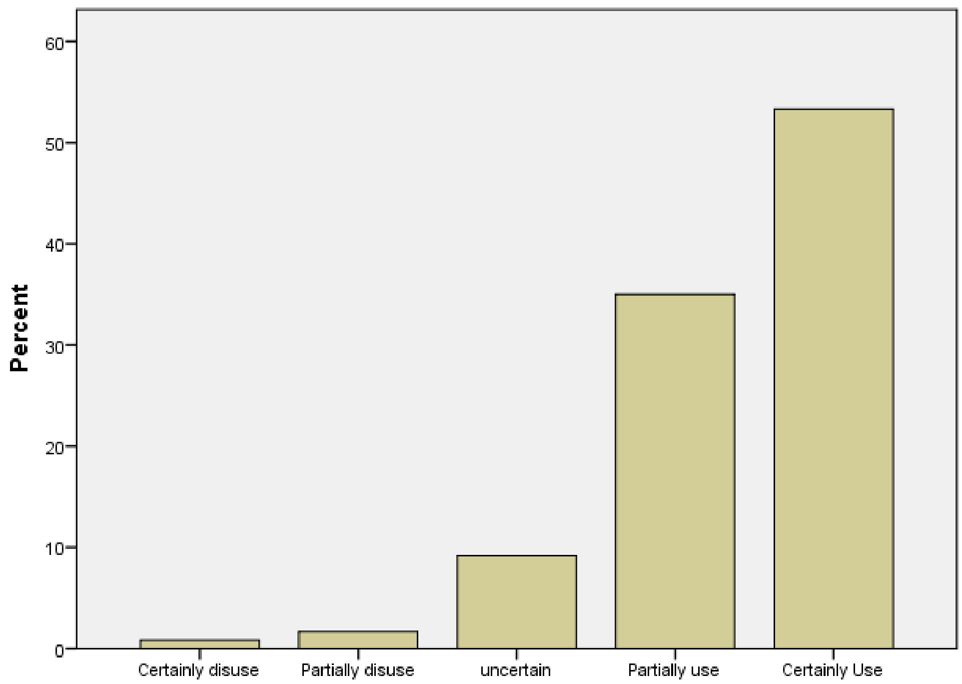


**Figure 5.13:** Percentage of Q11 related to operation costs

### 5.4.3 Maintenance and replacement costs

The analysis of question number twelve (Q12) "Do you take into account building maintenance and replacement costs? " is as follows: Table 5.14 and Figure 5.14 show the percent of "partially disuse" is 10.8%, the percent of "uncertain" is 30.8%, the percent of "partially use" is 21.7% and the percent of "certainly use" is 36.7%. The mean of question number twelve equals 3.84 and standard deviation equals 1.045. From the mean result, most of the engineers "partially use" for the maintenance and replacement costs.

**Table 5.14:** Frequency and percentage of Q12 for maintenance and replacement

| Valid | Frequency | Percent |
|---|---|---|
| Partially disuse | 13 | 10.8 |
| uncertain | 37 | 30.8 |
| Partially use | 26 | 21.7 |
| Certainly Use | 44 | 36.7 |
| Total | 120 | 100.0 |

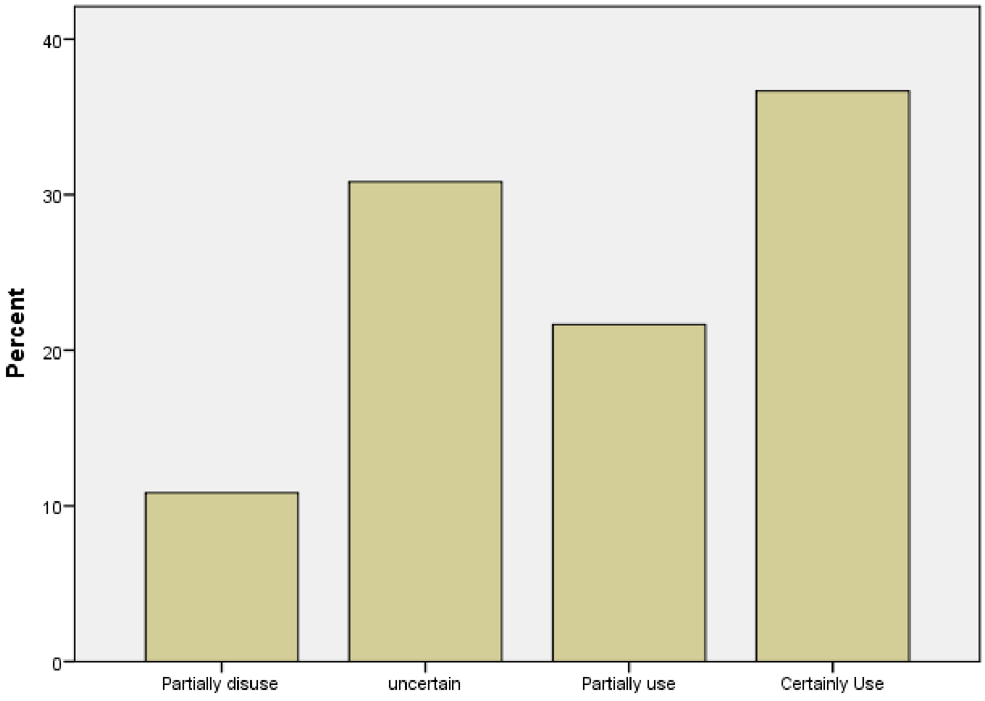


**Figure 5.14:** Percentage of Q12 related to maintenance and replacement

### 5.4.4 Occupancy costs

The analysis of question number thirteen (Q13) "Do you take into account building occupancy costs? " is as follows: Table 5.15 and Figure 5.15 show the percent of "certainly disuse" is 1.7%, the percent of "partially disuse" is 19.2%, the percent of "uncertain" is 25.8%, the percent of "partially use" is 34.2% and the percent of "certainly use" is 19.2%. The mean of question number thirteen equals 3.50 and standard deviation equals 1.061. From the mean result, most of the engineers "partially use" for the occupancy costs.

**Table 5.15:** Frequency and percentage of Q13 for the occupancy costs

| Valid | Frequency | Percent |
|---|---|---|
| Certainly disuse | 2 | 1.7 |
| Partially disuse | 23 | 19.2 |
| uncertain | 31 | 25.8 |
| Partially use | 41 | 34.2 |
| Certainly Use | 23 | 19.2 |
| Total | 120 | 100.0 |

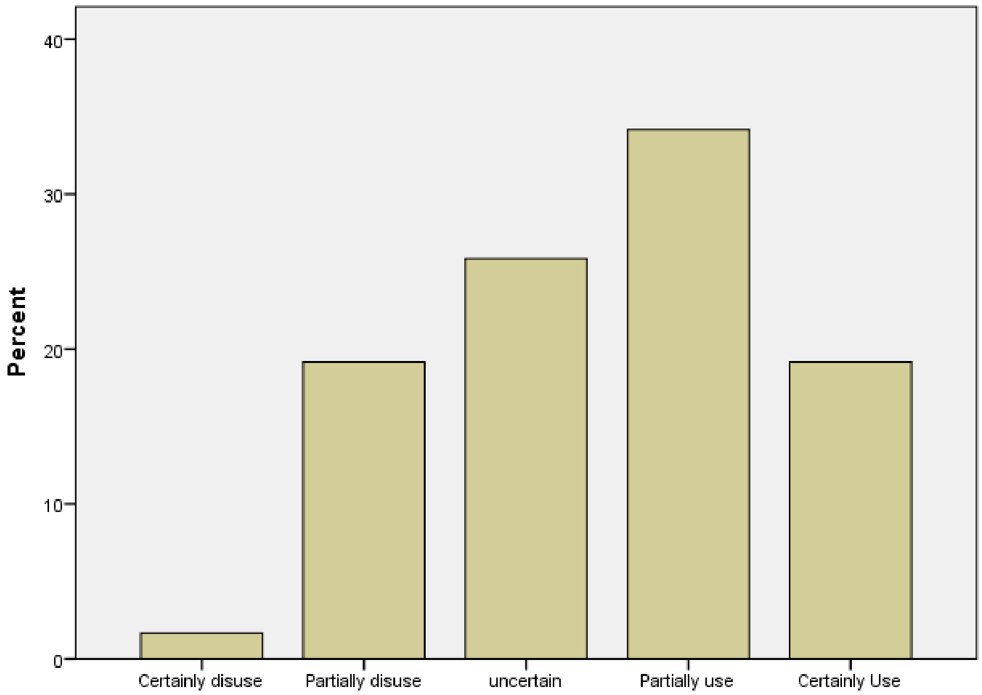


**Figure 5.15:** Percentage of Q13 related to occupancy costs

### 5.4.5 End of investment costs

The analysis of question number fourteen (Q14) "Do you take into account building end of investment costs? " is as follows: Table 5.16 and Figure 5.16 show the percent of "certainly disuse" is 7.5%, the percent of "partially disuse" is 18.3%, the percent of "uncertain" is 16.7%, the percent of "partially use" is 22.5% and the percent of "certainly use" is 35%. The mean of question number fourteen equals 3.59 and standard deviation equals 1.332. From the mean result, most of the engineers "partially use" for the end of investment costs.

**Table 5.16:** Percentage of Q14 related to end of investment cost

| Valid | Frequency | Percent |
|---|---|---|
| Certainly disuse | 9 | 7.5 |
| Partially disuse | 22 | 18.3 |
| uncertain | 20 | 16.7 |
| Partially use | 27 | 22.5 |
| Certainly Use | 42 | 35.0 |
| Total | 120 | 100.0 |

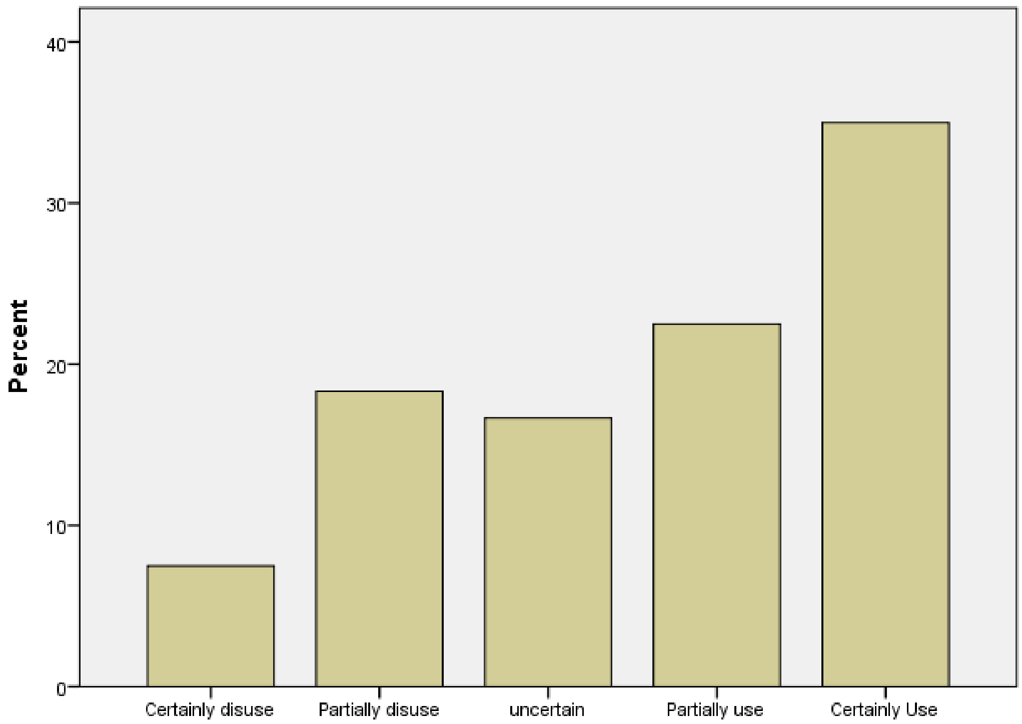


**Figure 5.16:** Percentage of Q14 related to end of investment cost

### 5.4.6 Means and standard deviation for the cost parameters of the LCCA

Table 5.28 show the average of " Cost parameters of the life cycle analysis ". According to weighted mean of the user values a (Likert) scale, which ranges from (1-5) and It clear that statements (10,11) were mean between (4.29 – 4.38), which means they are in a category between (4.21-5) as the weighted mean, which means the respondents chose " Certainly Use".

The statements (12,13,14) were mean of between (3.50 – 3.84), which means they are in a category between (3.41-4.20) as the weighted mean, which means the respondents chose "Partially use".

**Table 5.17:** Means and standard deviation for the cost parameters

| NO | Item | N | Mean | Std. Deviation | Rank |
|---|---|---|---|---|---|
| 10 | Do you take into account building initial investment cost? | 120 | 4.29 | 0.929 | 2 |
| 11 | Do you take into account building operation costs? | 120 | 4.38 | 0.791 | 1 |
| 12 | Do you take into account building maintenance and replacement costs? | 120 | 3.84 | 1.045 | 3 |
| 13 | Do you take into account building occupancy costs? | 120 | 3.50 | 1.061 | 5 |
| 14 | Do you take into account building end of investment costs? | 120 | 3.59 | 1.332 | 4 |
| | **All items of the field** | **120** | **3.92** | **1.031** | |

Figure 5.17 shows the questions with the maximum mean are questions 11 equal 4.38, while question 13 has the minimum mean equal 3.50.

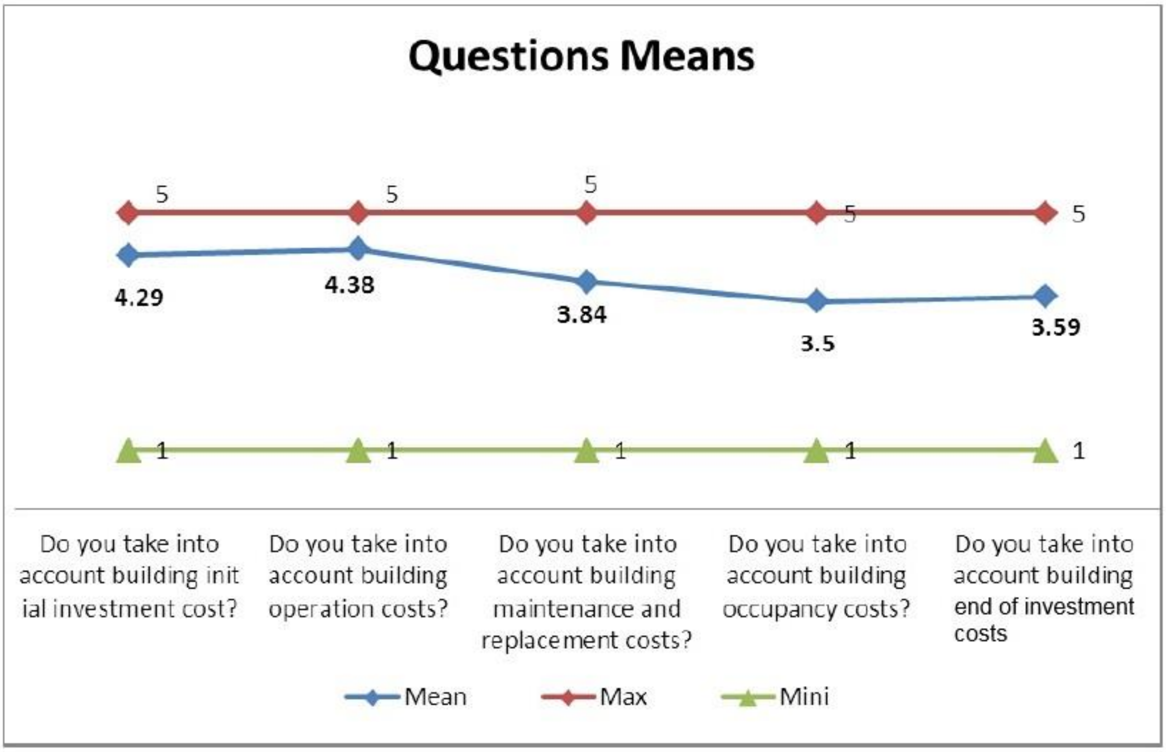


**Figure 5.17:** Mean of questions related to the cost parameters

## 5.5 Analysis the Questions of LCCA in General

This section is for analysis the questions in general about the LCCA for the last part in questionnaire. Also, the question number nineteen is about the hypothesis of research.

The analysis of question number fifteen (Q15) "Have you ever worked in a project which applies life cycle cost analysis? " is as follows: Table 5.18 and Figure 5.18 show the percent of "no" is 75% and the percent of "yes" is 25%. The mean of question number fifteen equals 1.25 and standard deviation equals 0.435. From the mean result, most of the engineers didn't work in project applied LCCA before.

**Table 5.18:** Frequency and percentage of Q15 for work in project applied LCCA

| Valid | Frequency | Percent |
|---|---|---|
| No | 90 | 75.0 |
| Yes | 30 | 25.0 |
| Total | 120 | 100.0 |

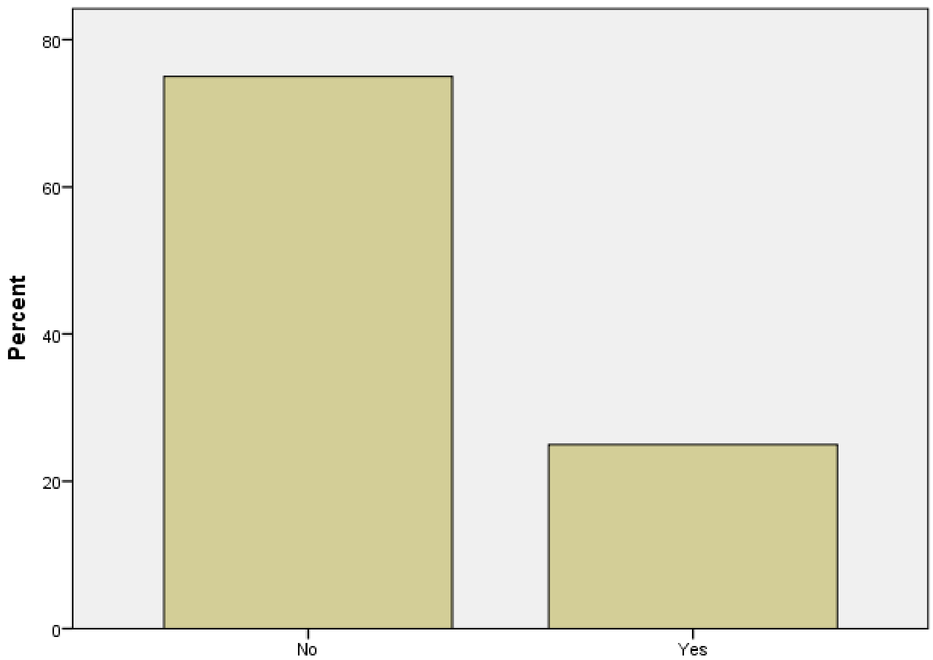


**Figure 5.18:** Percentage of Q15 for work in project applied LCCA

The analysis of question number sixteen (Q16) "Does the type of contract of the project affect the application of life cycle cost analysis? " is as follows: Table 5.19 and Figure 5.19 show the percent of "no" is 46.7% and the percent of "yes" is 53.3%. The mean of question number sixteen equals 1.53 and standard deviation equals 0.501. From the mean result, most of the engineers agree for the type of the contract effect application LCCA.

**Table 5.19:** Percentage of Q16 for the type of contracts

| Valid | Frequency | Percent |
|---|---|---|
| No | 56 | 46.7 |
| Yes | 64 | 53.3 |
| Total | 120 | 100.0 |

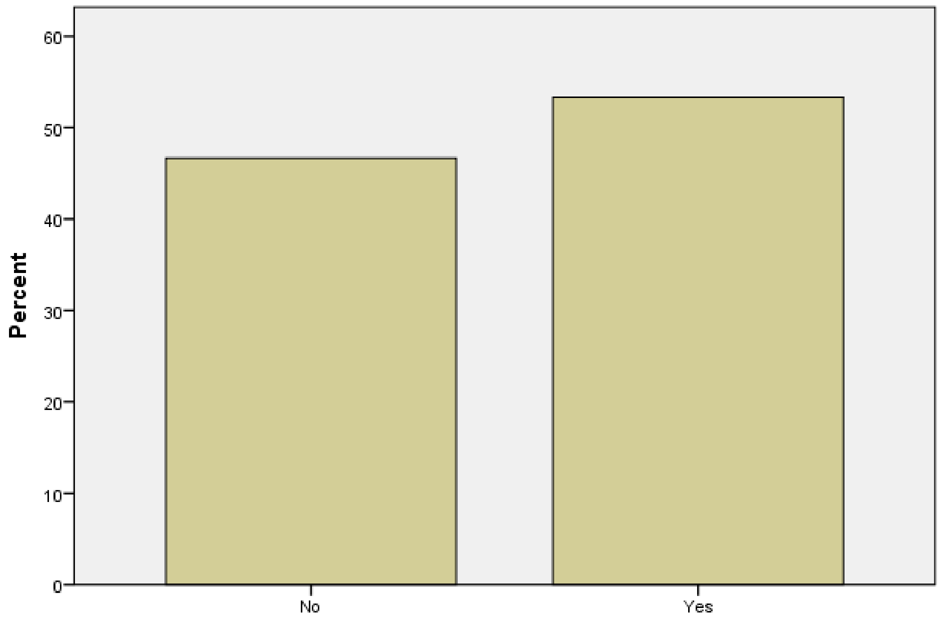

**Figure 5.19:** Percentage of Q16 for the type of contracts

The analysis of question number seventeen (Q17) "which is more preferable for the accuracy of the final result of life cycle cost analysis? " is as follows: Table 5.20 and Figure 5.20 show the percent of "probabilistic result" is 37.5% and the percent of "Deterministic result" is 62.5%. The mean of question number seventeen equals 1.63 and standard deviation equals 0.486. From the mean result, most of the engineers preferable the deterministic result.

**Table 5.20:** Percentage of Q17 for the type of accuracy

| Valid | Frequency | Percent |
|---|---|---|
| Probabilistic result | 45 | 37.5 |
| Deterministic result | 75 | 62.5 |
| Total | 120 | 100.0 |

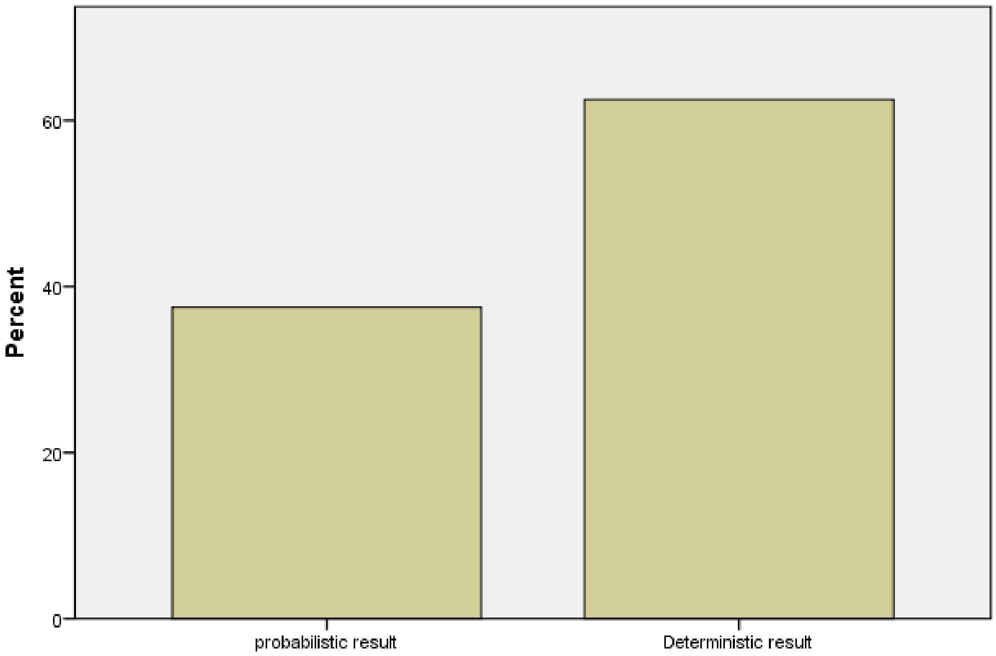


**Figure 5.20:** Percentage of Q17 for the type of accuracy

The analysis of question number eighteen (Q18) "What are the problems faced when conducting life cycle cost analysis? " is as follows: Table 5.21 and Figure 5.21 show the percent of "lack of data" is 38.3%, the percent of "no software model available" is 30% and the percent of "lack of experience" is 31.7%. The mean of question number eighteen equals 1.93 and standard deviation equals 0.837. From the mean result, the most problem faced engineers when applying LCCA is a lack of data.

**Table 5.21:** Frequency and percentage of Q18 for the problem conducting LCCA

| **Valid** | **Frequency** | **Percent** |
|---|---|---|
| Lack of data | 46 | 38.3 |
| No software model available | 36 | 30.0 |
| Lack of experience | 38 | 31.7 |
| Total | 120 | 100.0 |

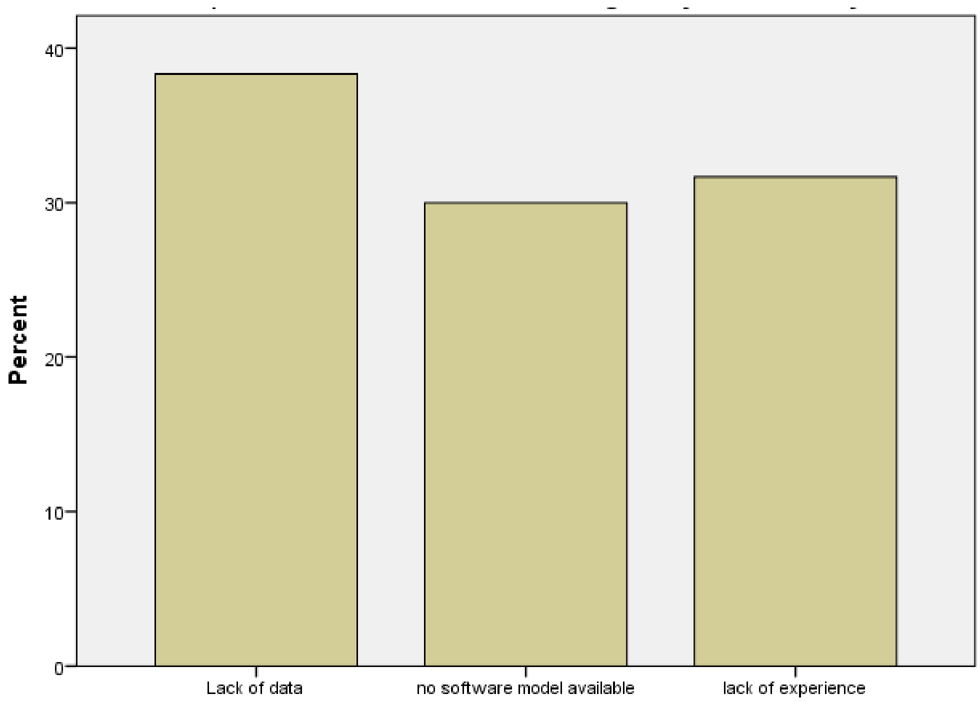


**Figure 5.21:** Percentage of Q18 for the problem faced LCCA

The analysis of question number nineteen (Q19) for the hypothesis of the research "Applying life cycle cost analysis (LCCA) in construction building adds more cost-effective, management and controlling the works of facilities? " is as follows: Table 5.22 and Figure 5.22 show the percent of "never" is 3.3%, the percent of "seldom" is 4.2%, the percent of "sometimes" is 12.5%, the percent of "often" 28.3% and the percent of "usually" 51.7%. The mean of question number nineteen equals 4.21 and standard deviation equals 1.036. From the mean result, most of the participants of engineers agree with hypothesis of the study.

**Table 5.22:** Frequency and percentage of Q19 for the main hypothesis

| Valid | Frequency | Percent |
|---|---|---|
| Never | 4 | 3.3 |
| Seldom | 5 | 4.2 |
| Sometimes | 15 | 12.5 |
| Often | 34 | 28.3 |
| Usually | 62 | 51.7 |
| Total | 120 | 100.0 |

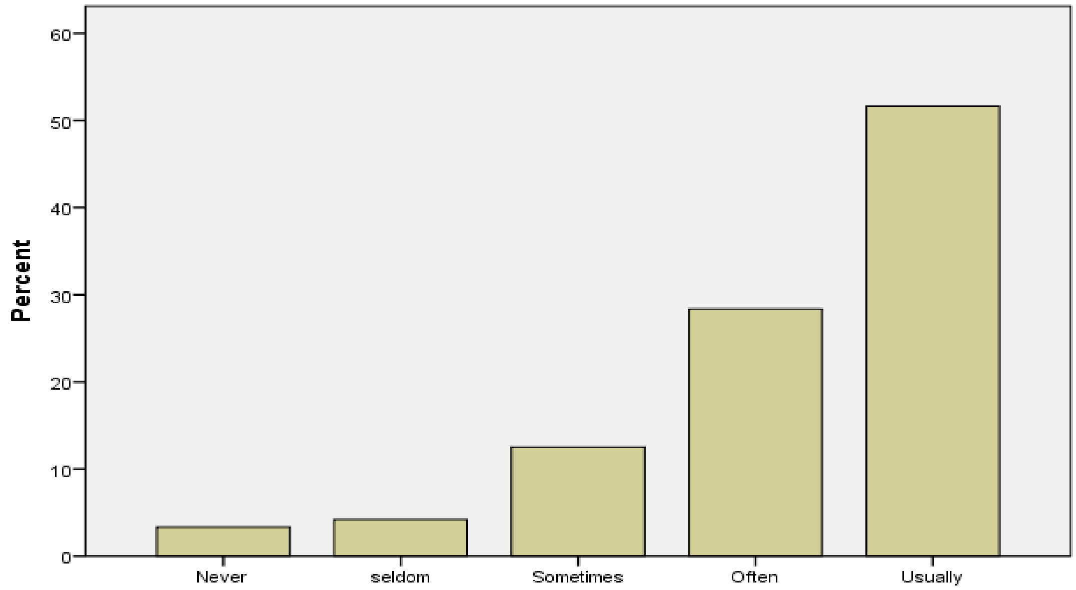


**Figure 5.22:** Percentage of Q19 for the main hypothesis

The analysis of question number twenty (Q20) "Do you think your colleagues know about importance of life cycle cost analysis? " is as follows: Table 5.23 and Figure 5.23 show the percent of "never" is 12.5%, the percent of "seldom" is 11.7%, the percent of "sometimes" is 37.5%, the percent of "often" 22.5% and the percent of "usually" 15.8%. The mean of question number twenty equals 3.18 and standard deviation equals 1.207. From the mean result, most of the participants of engineers they think their colleagues maybe know about LCCA.

**Table 5.23:** Frequency and percentage of Q20 for the importance of the LCCA

| Valid | Frequency | Percent |
|---|---|---|
| Never | 15 | 12.5 |
| Seldom | 14 | 11.7 |
| Sometimes | 45 | 37.5 |
| Often | 27 | 22.5 |
| Usually | 19 | 15.8 |
| Total | 120 | 100.0 |

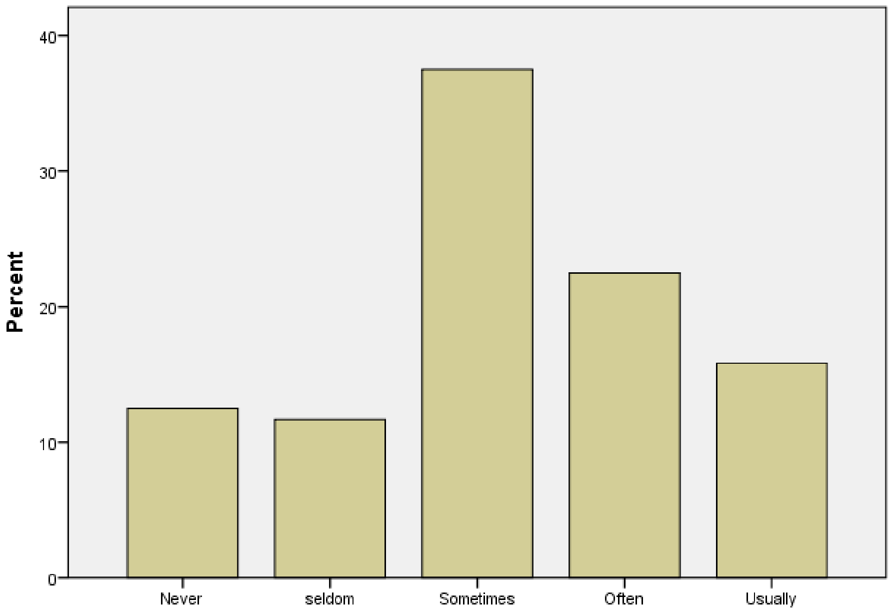


**Figure 5.23:** Percentage of Q20 for the importance of the LCCA

The analysis of question number twenty-one (Q21) " Do you believe how a different systems solution will affect and minimize the costs?" is as follows: Table 5.24 and Figure 5.24 show the percent of "never" is 10.8%, the percent of "seldom" is 6.7%, the percent of "sometimes" is 26.7%, the percent of "often" 29.2% and the percent of "usually" 26.7%. The mean of question number twenty-one equals 3.54 and standard deviation equals 1.256. From the mean result, most of the participants of engineers they agree and believe in different systems solution to minimize the costs.

**Table 5.24:** Frequency and percentage of Q21 for a different system solution

| Valid | Frequency | Percent |
|---|---|---|
| Never | 13 | 10.8 |
| Seldom | 8 | 6.7 |
| Sometimes | 32 | 26.7 |
| Often | 35 | 29.2 |
| Usually | 32 | 26.7 |
| Total | 120 | 100.0 |

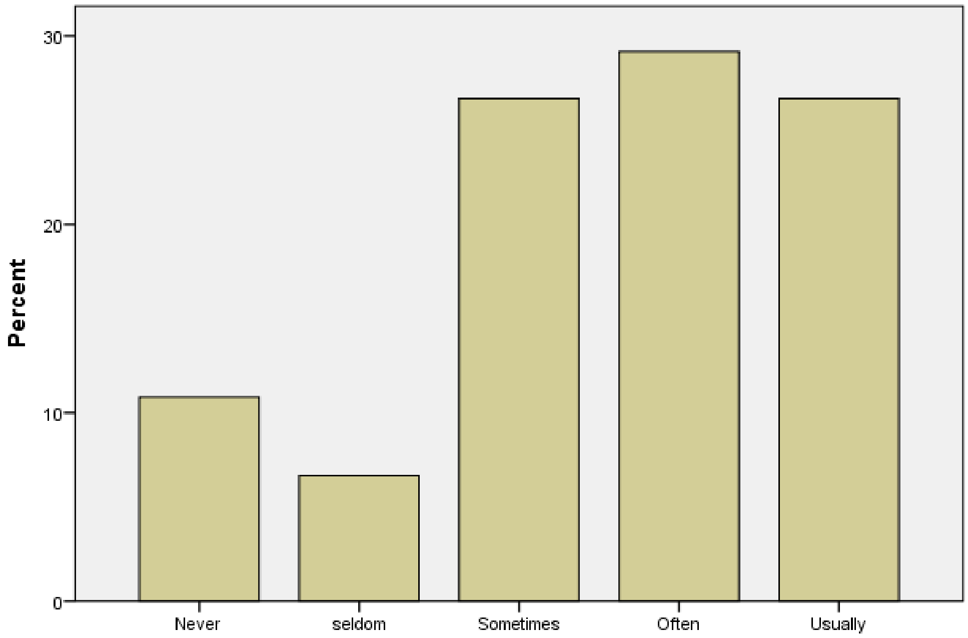


**Figure 5.24:** Percentage of Q21 for a different system solution

The analysis of question number twenty-two (Q22) "Did you evaluate which technical solution will yield the lowest cost?" is as follows: Table 5.25 and Figure 5.25 show the percent of "never" is 15%, the percent of "seldom" is 17.5%, the percent of "sometimes" is 30.8%, the percent of "often" 17.5% and the percent of "usually" 19.2%. The mean of question number twenty-two equals 3.08 and standard deviation equals 1.313. From the mean result, most of the participants of engineers evaluate a technical solution for the lowest cost and that can make them able to understand easily the LCCA and use it in the future.

**Table 5.25:** Frequency and percentage of Q22 for a technical solution

| Valid | Frequency | Percent |
|---|---|---|
| Never | 18 | 15.0 |
| Seldom | 21 | 17.5 |
| Sometimes | 37 | 30.8 |
| Often | 21 | 17.5 |
| Usually | 23 | 19.2 |
| Total | 120 | 100.0 |

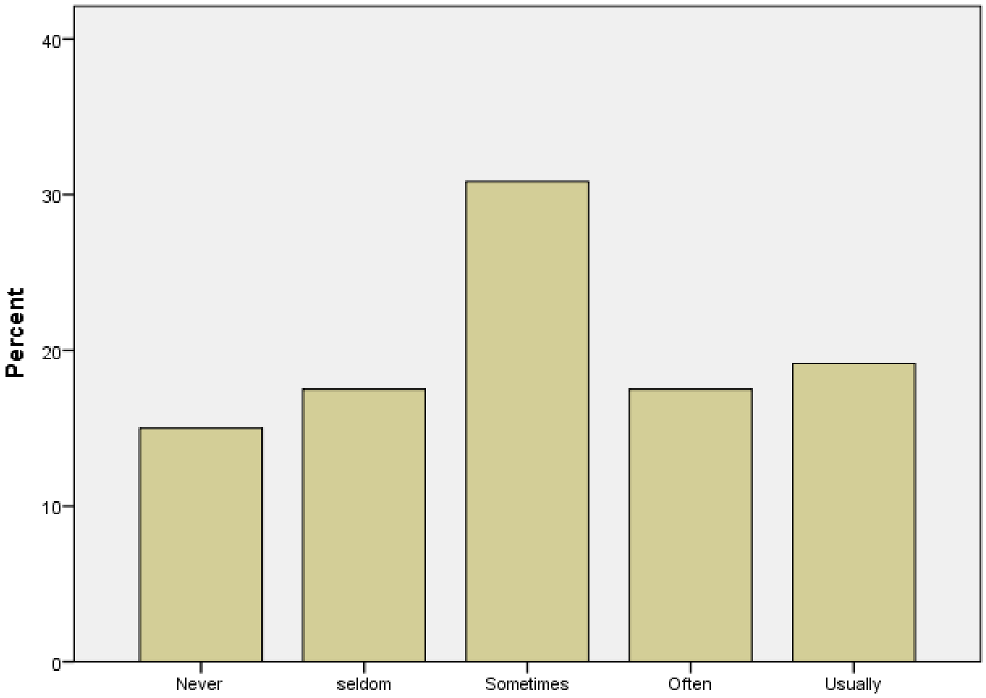


**Figure 5.25:** Percentage of Q22 for a technical solution

The analysis of question number twenty-three (Q23) " Do you add risk in the calculation of life cycle cost analysis?" is as follows: Table 5.26 and Figure 5.26 show the percent of "never" is 11.7%, the percent of "seldom" is 14.2%, the percent of "sometimes" is 9.2%, the percent of "often" 33.3% and the percent of "usually" 31.7%. The mean of question number twenty-three equals 3.59 and standard deviation equals 1.369. From the mean result, most of the participants of engineers they add risk in the calculations

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**Table 5.26:** Frequency and percentage of Q23 for a risk in a calculation

| Valid | Frequency | Percent |
|---|---|---|
| Never | 14 | 11.7 |
| Seldom | 17 | 14.2 |
| Sometimes | 11 | 9.2 |
| Often | 40 | 33.3 |
| Usually | 38 | 31.7 |
| Total | 120 | 100.0 |

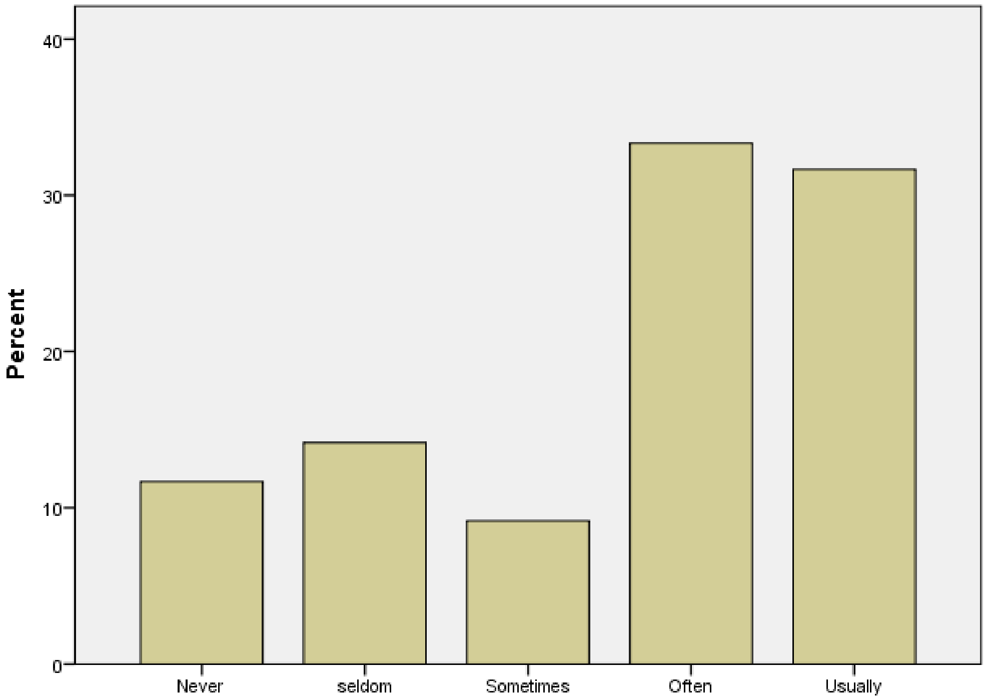


**Figure 5.26:** Percentage of Q23 for a risk in a calculation

Finally, the analysis of the last question number twenty-four (Q24) " Is the life cycle cost analysis calculation done by you?" is as follows: Table 5.47 and Figure 5.27 show the percent of "never" is 47.5%, the percent of "seldom" is 15%, the percent of "sometimes" is 15%, the percent of "often" 10.8% and the percent of "usually" 11.7%. The mean of question number twenty-four equals 2.24 and standard deviation equals 1.438. From the mean result, most of the participants of engineers they did not do the calculations of LCCA.

**Table 5.27:** Frequency and percentage of Q24 for LCCA calculation

| Valid | Frequency | Percent |
|---|---|---|
| Never | 57 | 47.5 |
| seldom | 18 | 15.0 |
| Sometimes | 18 | 15.0 |
| Often | 13 | 10.8 |
| Usually | 14 | 11.7 |
| Total | 120 | 100.0 |

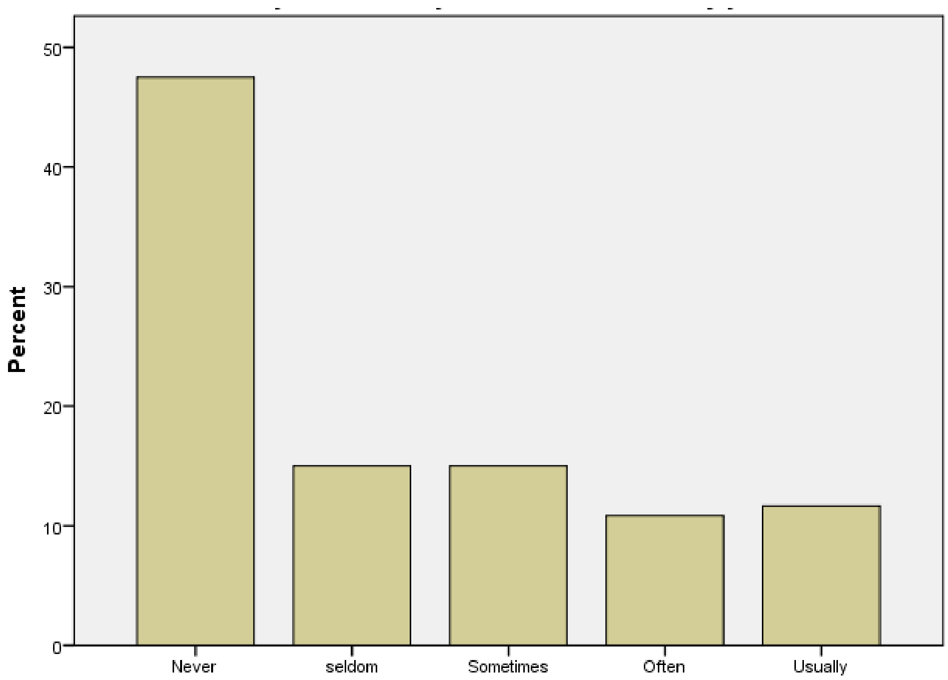


**Figure 5.27:** Percentage of Q24 for LCCA calculation

## 5.6 Summary

The outline of the LCCA methods and parameters included LCCA calculation for identify which are being used by engineers practicing in Saudi Arabia. For the all methods of LCCA, the engineers heard about these methods but for equivalent annual cost method and internal rate of return are usually included in LCCA calculation. The parameters that are usually included in LCCA calculation are operation costs and initial investment cost then maintenance and replacement costs. The study focus on define awareness of LCCA among engineers in order to establish the importance of LCCA. The use of LCCA and different system solutions for lowest cost is usually important for the engineers. The constraints prevent the engineers to use LCCA are the lack of data and lack of experience.

# CHAPTER 6

# CONLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

The LCCA in the building sector is new subject of a field of scientific research in the Saudi Arabia and there a few studies related to LCCA of in the building sector in Saudi Arabia. This study was done on the 120 engineers from different companies who work in the building sector in Saudi Arabia. The main of the study to spread and measuring awareness among the engineers on the importance of LCCA. In general, applying the Life Cycle Cost Analysis concept in different countries of the world and especially in Saudi Arabia is almost hard. Because it is a new subject for engineers who work in Saudi Arabia and this is what reached through questionnaires. There are several important conclusions from the research presented in this thesis. Firstly, the awareness and knowledge of the engineers for the methods of the LCCA and what are the most employed methods in the building sector in Saudi Arabia. The results showed that the engineers heard about all methods of the LCCA. The equivalent annual cost method and internal rate of return are usually included in the LCCA calculation of data analysis.

Secondly, the cost parameters included in LCCA calculation for identifying which are being used by engineers practicing in Saudi Arabia. The parameters that are usually included in LCCA calculation are operation costs and initial investment cost and then the maintenance and replacement costs. The 75% of the participants of engineers did not work in a project which applied LCCA in the building sector. The 53.3% of the participants agree about the type of contract of the project affect the application of LCCA and the participants of engineers preferable the deterministic result for the accuracy of the final result of the LCCA. The lack of data and the lack of experience are the problems faced the engineers when conducting LCCA. In order to increase the use of LCCA, these two constraints should be addressed.

The main hypothesis of the study, results show more than 51.7% of participants agree with this hypothesis. The study indicates the engineers' respondents to the survey if their colleagues know about the importance of Life Cycle Cost Analysis, results show most of the participants of engineers they think their colleagues maybe know about the important of LCCA. The study show how the use of LCCA and different system solutions for lowest cost is usually important for the engineers. The study indicates the percentage of engineers add risk in the calculation of LCCA, the results show most of the participants add or care for the risk in calculations. The study shows the percentage of the engineers they calculated the LCCA Calculations in their career and from the result the most of engineers did not do the calculations of LCCA and they do not have the experience to do it.

### 6.2 Recommendations

Through the conclusions of the study, he following recommendations are as follow:

1- Organization seminars and conferences on the topic of Life Cycle Cost Analysis by Saudi Council of Engineers.
2- The studies on this topic in the Arabic language is very rare. Therefore, the further studies on the Life Cycle Cost Analysis in the Arabic language is necessary.
3- Educate the engineers from all fields on the importance of the Life Cycle Cost Analysis and its impact on the economy of the construction sector. Also, its impact on the economy of the Saudi Arabia.
4- Raising awareness about the methods of engineering economy and especially in the Life Cycle Cost Analysis methods.
5- Instruct the engineers to understand more about the cost parameters of the Life Cycle Cost Analysis and Instruct them to attention more about all the parameters.
6- Raising awareness between the project managers and the owners of companies about the Life Cycle Cost Analysis and the impact of it on the financial income of companies in the future.
7- Also, raising awareness of the engineers about the types of contracts to make engineers able to take decisions about save money in different ways.
8- Clarify the difference between the deterministic result and the probabilistic result because it is important for the calculations. Also, the Life Cycle Cost Analysis dependent on the probabilistic result and the results of the survey show the participants chose the deterministic results.
9- Find solutions for the problems when conducting the Life Cycle Cost Analysis. For example, purchase the programs that applied Life Cycle Cost Analysis calculations in details. Also, contact with engineers from different countries they have a high experience in applying the Life Cycle Cost Analysis in construction sector.

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# APPENDICES

## APPENDIX 1

Questionnaire of Life Cycle Cost Analysis (LCCA)

**Please select the right information about you:

Name: ……………………………………………………….

Company name: ………….……………………………

Your position: …………………………………………

Telephone: ………………..………………………..

email: ……………………….……………………….

1-Number of constructions your management experience is based on?

☐ 0-3 ☐ 4-7 ☐ 8-11 ☐ 12-15 ☐16-19 ☐ 20 and more

2- What is your academic qualification?

☐ Bachelor ☐ Master ☐ PhD

3-How do you classify your company?

☐ Consulting ☐ Contractor ☐ Government agency

**please select the suitable choice about the methods of life cycle cost analysis

| | Never Hear | Hear | know | Sometimes use | Often use |
|---|---|---|---|---|---|
| 4-What is your knowledge about simple pay back? | | | | | |
| 5-What is your knowledge about discount payback method? | | | | | |
| 6-What is your knowledge about net present value? | | | | | |
| 7-What is your knowledge about equivalent annual cost? | | | | | |
| 8-What is your knowledge about internal rate of return? | | | | | |
| 9-What is your knowledge about net saving? | | | | | |

**please select the suitable choice about cost according to their importance of life cycle cost analysis:

| | Certainly Use | Partially use | uncertain | Partially disuse | Certainly disuse |
|---|---|---|---|---|---|
| 10- Do you take into account building initial investment cost? | | | | | |
| 11- Do you take into account building operation costs? | | | | | |
| 12- Do you take into account building maintenance and replacement costs? | | | | | |
| 13- Do you take into account building occupancy costs? | | | | | |
| 14- Do you take into account building end of investment costs? | | | | | |

**Please select the suitable answer about questions of life cycle cost analysis in general

15- Have you ever worked in a project which applies life cycle cost analysis?

□ Yes □ No

16- Does the type of contract of the project affect the application of life cycle cost analysis?

□ Yes □ No

17 – which is more preferable for the accuracy of the final result of life cycle cost? analysis

□ Deterministic result □ probabilistic result

18- what are the problems faced when conducting life cycle cost analysis?

□ Lack of data □ no software model available □ lack of experience

**Please select the suitable answer about questions of life cycle cost analysis in general

| | Usually | Often | Sometimes | seldom | Never |
|---|---|---|---|---|---|
| 19- Applying life cycle cost analysis (LCCA) in construction building adds more cost-effective, management and controlling the works of facilities | | | | | |
| 20- Do you think your colleagues know about importance of life cycle cost analysis? | | | | | |
| 21- Do you believe how a different systems solution will affect and minimize the costs? | | | | | |
| 22- Did you evaluate which technical solution will yield the lowest cost? | | | | | |
| 23- Do you add risk in the calculation of life cycle cost analysis? | | | | | |
| 24- Is the life cycle cost analysis calculation done by you? | | | | | |