

Computerized Life Cycle Cost Analysis

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ABSTRACT

In North Cyprus most of the buildings are being constructed without an economic analysis of costs for the whole life of the buildings. This causes the wasting of resources and unnecessary costs to the project during construction, maintenance and operation.

Economic evaluation has a big significance for construction projects, in order to select the optimum design alternatives. Life cycle costing (LCC) is a method being widely used for such an evaluation of construction projects.

Most owners have little experience or knowledge about economic analysis of design alternatives for selecting the best design alternatives.

This study involves; highlighting the techniques of life cycle costing method and investigation of life cycle costing of the selected project “Student Activity Center building at the Eastern Mediterranean University in North Cyprus” in view of developing a computer system in MS Visual Basic for analyzing of life cycle costing of such building. The Results of manual calculation and results of developed computer system were compared and both results were found to be similar, a difference of approximately 0.0015 percentages was obtained and the developed program finished the operation in only 27 minutes. However, the duration of the same calculations by hand of four estimators on average was approximately 8 hours. That means, the program is almost 17 times more time-efficient than manual life cycle cost calculations. This indicates that, develop computer system is working and

reliable and application of LCC techniques to the Student Activity Center project is beneficial for the owner as well as to the user.

Keywords: Economic analysis, Life cycle costing.

ÖZ

Kuzey Kıbrıs'ta inşaatların çoğu, yapının bütün yaşam süreci boyunca sahip olacağı maliyetin ekonomik analizi yapılmadan inşa edilir. Bu durum, projenin yapım, bakım ve işlevi boyunca, kaynakların boşa harcanmasına ve gereksiz maliyetlere yol açar.

En uygun dizayn alternatiflerini seçmek için ekonomik değerlendirmenin inşaat projelerinde çok büyük önemi vardır. Yaşam süreci maliyet hesaplanması inşaat projelerinin değerlendirilmesinde kullanılan en yaygın yöntemdir.

Çoğu mal sahibinin en iyi dizayn alternatiflerini seçmek için, dizayn alternatiflerinin ekonomik analizi ile ilgili çok az deneyimi ve bilgisi vardır.

Bu çalışma, yaşam süreci maliyet hesaplama yöntemi tekniklerinin önemini vurgular ve Kuzey Kıbrıs'ta bulunan Doğu Akdeniz Üniversitesi'nin Öğrenci Aktivite Merkez binasının yaşam süreci maliyet analizi için MS Visual Basic programında bilgisayar sistemi geliştirilerek, yaşam süreci maliyet hesaplamasını araştırır. Elle yapılan hesaplamalardan elde edilen sonuçlar ve geliştirilen bilgisayar sisteminin sonuçları karşılaştırıldı ve her iki sonuç benzer bulundu. Yaklaşık olarak % 0.0015 fark elde edildi ve geliştirilen program, işlemi sadece 27 dakika içerisinde bitirdi. Fakat 4 değerlendirici tarafından elle yapılan aynı hesaplamaların süresi ortalama olarak yaklaşık 8 saattir. Bu demektir ki, bu program süre açısından elle yapılan yaşam süreci maliyet hesaplamalarından 17 kat daha fazla etkilidir. Bu da şunu gösteriyor ki, geliştirilen bilgisayar sistemi çalışıyor ve güvenilirdir ve Aktivite Merkezi projesi

için uygulanan yaşam süreci maliyet hesaplama teknikleri mal sahibi ve kullanıcılar için faydalıdır.

Anahtar kelimeler: Ekonomik analiz, Yaşam süreci maliyet esaplması.

*To my father and to my mother
To my husband Ahmed and my lovely daughter Iman*

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LIST OF ABBREVIATIONS

CI	Confidence Index
FAST	Function Analysis System Technique
GEC	General Electric Company
GUI	Graphical User Interface
IDE	Integrated Development Environment
LCC	Life Cycle Costing
LCCA	Life Cycle Cost Analysis
NIST	The National Institute Of Standards And Technology
SMART	Simple Multi-Attribute Rating Technique
VB	Visual Basic
VE	Value Engineering
VM	Value Management

Chapter 1

INTRODUCTION

1.1 Background

In construction management, the project with the lowest initial cost is not always the most economical or the best project. From the economical aspect of the project management, there are many other costs that appear during the life time of a project such as the operation, maintenance, or replacement or off the end of the project life like demolition or salvage costs, which are all effective in the project manager decision. A project manager should use an approach that takes into account all of these costs in the procedure of studying a project.

Life cycle costing analysis (LCCA) can be applied to any investment decision; that's to say re higher initial costs are traded for minimized cost requirements in the future. It is mostly effective in the evaluation of building design alternatives which fulfill the required level of building performance, however it has different initial investment costs, different maintenance and operating and repair costs, and even different lives. In alternative economic methods that focus only on the first cost in the related operating costs in the short-term, while the life cycle cost provides a much better valuation of the cost-effectiveness of the project over the long-term (Fuller, 2010), and it can be applied at any level of the design process and it can be used to assess the cost of a full range of projects, from a whole site complex to a specific building system element (Alaska Department of education and early development, 1999).

When choosing a whole building approach, LCCA is very useful for comparing different project alternatives that meet the same performance requirements, but differ with respect to the costs during all stage of the project. On the other hand some problems have been observed by using LCCA technique such as time consuming, calculation errors, difficulties, and sometimes inaccurate results because of the hand calculations mistakes. In order to overcome these problems, this research suggests developing computer software for LCCA for construction projects. The features of using this program are: the simplicity, which it can be used by any user this program accomplish by utilizing a step-by-step method in which the user starts with the basics and moves on to more detailed information, and the results were analyzed in a relatively quick time and reduce the human mistake by the calculations.

Visual Basic 2010 was selected as application software for the program developed in this research. The reasons of selecting Visual Basic 2010 as the application software are as follows:

- A widely used popular program and,
- Not complicated and can easily be used.

The evaluation of the developed program showed that, using the program helps to avoid possible mistakes in manual calculations and reduces the duration of the LCCA by 17 times.

1.2 Scope and Objectives

The purpose of this thesis is to highlight the use of computer tools to train users in selecting the best design alternative, not only based on choosing the lowest initial costs, but also considering all the life cycle costs.

Main objectives of this research are summarized as follows:

1. To highlight the life cycle cost calculations.
2. To show the importance of LCCA techniques and its benefits in project appraisal.
3. To develop a LCC calculation program to facilitate quick and accurate LCCA.
4. To show that savings time can be obtained by using develop program software compared to hand calculations.

1.3 Works Undertaken

In order to achieve the objectives of this thesis, the following works were undertaken:

- A comprehensive literature survey about life cycle costing in construction, its methods and applications were carried out and the types of costs in construction were explained.
- Identification of some techniques and methods about life cycle costing in construction such as weighted evaluation technique.
- The study of value management (VM) principles.
- Collection of data and information about the case study Student Activity Center by direct interviews with the director of Technical Affairs Department, and the section chief of installations, technical services office in the Technical Affairs Department of Eastern Mediterranean University.
- By using Visual Basic 2010, a computer program was developed to make LCCA. The program calculates present worth, future worth and total life cycle cost of any project design. This developed computer system can easily be used by any user, (even those, who are not professional in the field of

construction) and the results can be analyzed in a relatively short time with preventing the human mistake by the calculations.

- Finally, verification of developed computer program was carried out. The program was tested on a selected building project. The LCCA was performed by the program and the same LCCA was made manually by four postgraduate students in the Civil Engineering Department of EMU. The results of manual calculations and developed computer system were compared. This indicated that, the developed computer system is reliable, and can be used effectively.

1.4 Achievements

The achievements in this study can be summarized as follows:

1. The accuracy and precision of the program is much higher than hand calculations.
2. The evaluation of the developed program showed that using the program help to avoid possible mistakes in manual calculations and reduces the duration of the LCCA some 17 times.
3. The results of manual calculations and results obtained by using developed system were compared, a difference of approximately 0.0015 percentages was obtained.
4. The evaluation indicated that the developed system is properly working and reliable.

1.5 Guide to Thesis

This thesis is composed by seven chapters. The first chapter includes general introduction and discusses the background to the problem. It highlights the objectives and achievements of the investigation.

Second chapter involves definitions of time value of money, type of interest formulas, basic equivalent economic approach, and inflation and cost growth.

Third chapter discusses the construction cost estimation, unit price analysis, cost components (Direct Costs & Indirect Costs) and the traditional methods and developed models used in construction cost estimation.

Fourth chapter highlights definitions of life cycle costing, its techniques, cost type, and life cycle costing advantages & disadvantages as well as risk assessment.

Fifth chapter is dealing with the literature survey of value management (VM), its background, principles, key elements and framework, the definition of 'value' and its relation with cost, worth or utility, and comparison of VM with some similarities in order to prevent confusion between those philosophies. The last part of the chapter covers Function Analysis System Technique (Fast).

Sixth chapter focuses on the use of developed computer software using Microsoft Visual Basic 2010. It includes computer and manual calculations of life cycle cost analysis of case study (Student Activity Center in Eastern Mediterranean University, North Cyprus). The results of the developed computer software were compared with the results obtained from hand calculations.

Seventh chapter contains conclusions and recommendations for future studies.

Chapter 2

TIME VALUE OF MONEY

2.1 Introduction

“One of the most basic concepts of business and economics management decision making is that the value of the amount of money to be received in the future depends on the time of receipt or disbursement of the cash. That is to say that money in hand today is value more than money that is expected to be earned in the future. This concept to be valid needs a positive rate of interest that can invest the funds. The time value of money impact a wide spectrum of business decisions, and identify how to integrate time value considerations methodically into a decision is fundamental to an understanding of finance” (Bierman, 2011)

2.2 Time Value of Money

Time value of money means that a Dollar today is worth more than a Dollar tomorrow. A sum of money may be invested to earn (interest) for its owner. For that amount of money in hand today is worth more than the same amount at a later time (Kishk et al., 2003). In determining the total cost of ownership, should be considered in the amounts of money invested or received at different times. Cash flow diagrams are used in sorting out and keeping track of both outlays of money and money received. Interest formulas which are simple mathematical equations are used to compute the amount to which a single investment or a series of equal investments will grow. However, interest tables may also be used for the same purpose which may require a minimum of computation (Ashworth, 2004).

2.3 Cash-Flow Concepts

Cash flow is one of the most important financial for monetary (Dollar) values- inputs (costs) and outputs (benefits) resulting from a project investment. Every person or company has cash outcome (disbursements) and cash income (receipts) which occur over a particular time span. These receipts and disbursements in a given time interval are referred to as cash flow; it is usually measured through specified periods of time, such as 1 month or 1 year.

At any point in time, the net cash flow would be represented as:

$$\text{Net cash flow} = \text{receipts} - \text{disbursements} \quad (2.1)$$

Cost and time are the two major items for the achievement of a construction project; therefore, cash flow analysis is significant for visualizing of cost-time integration of the project.

2.3.1 Cash Flow Diagram

The cash flow diagram is one of the major tools in an economic analysis, especially when cash flow is a complex series. Cash flow diagrams help in the visualization of cash flows these companies or owners have some expenditures (or outlays) and incomes (or receipts) (Kirk & Dell'Isola, 1995).

A horizontal line is used as the time axis. The time scale is usually divided into equal periods such as days, months, or years. Cash flows are represented by vertical arrows and the direction of the arrows on the cash flow diagram is very significant. A vertical arrow pointing down indicates a negative cash flow. On the other hand, an arrow pointing up indicates a positive cash flow. General cash flow diagram is illustrated in Figure 1.

Cash flow A is an income at the end of year 1. Cash flow B is expenditure at the end of year 2 (Kirk & Dell'Isola, 1995).

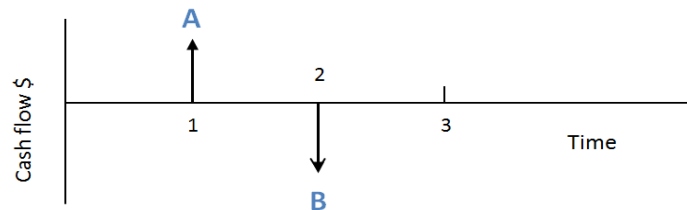


Figure 1: General cash flow diagram
Source: (Kirk & Dell'Isola, 1995)

2.4 Interest Formulas

“Interest formulas are simple mathematical equations that measure the effect of time on money” (Kishk et al., 2003).

To quantify the impact of the interest rate in relating Dollars spent today and Dollars spent in the future, six commonly used interest tables are presented. Some of these formulas address situations involving a single present sum of money or the present amount of a single future sum of money, given the interest rate and the length of time of the cash flow. Others address situations dealing with constant annual payments, such as those involved in paying off a mortgage loan. The six interest formulas are shown in Table 1 (Kirk & Dell'Isola, 1995)

Table 1: Interest formulas

Factor	Expression	Find	Given
A) Single payment			
1) Compound amount	$F = P[1 + i]^n$	(F/P, i%, n)	F P
2) Present worth	$P = F\left[\frac{1}{(1+i)^n}\right]$	(P/F, i%, n)	P F
B) Uniform series			
1) Compound amount	$F = A\left[\frac{(1+i)^n - 1}{i}\right]$	(F/A, i%, n)	F A
2) Sinking fund	$A = F\left[\frac{i}{(1+i)^n - 1}\right]$	(A/F, i%, n)	F A
3) Present worth	$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$	(P/A, i%, n)	P A
4) Capital Recovery	$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$	(A/P, i%, n)	A P

Source: (Pilcher, 1992)

The symbols used in the equations are defined as follows;

P the principal; a sum of money invested in the initial year or a present sum of money.

i the interest rate per unit of time expressed as a decimal.

n time; the number of units of time over which interest accumulates.

F a compound amount; a sum of money at the end of (n) units of time at interest (i).

A uniform series end-of-period payment or receipt that extends of n periods.

2.4.1 Single Compound Amount (SCA)

The single-payment, compound-amount factor is used to compute a future payment (F) for an amount borrowed at the present (P) for n years at an interest of i . The future sum is calculated by applying the following formula (Ayyub, 2003) :

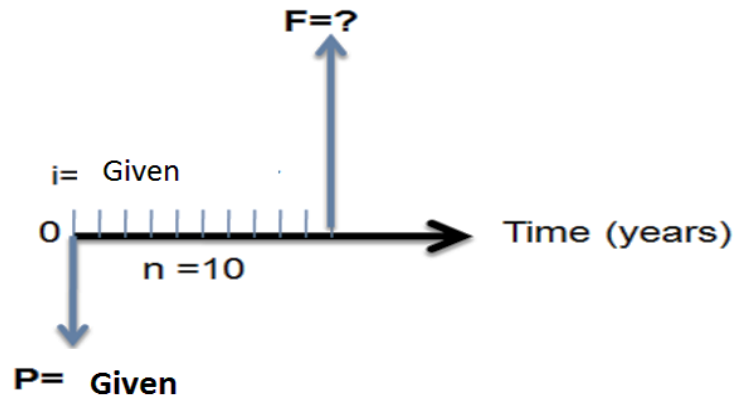


Figure 2: Cash flow diagram of the single compound amount
Source: (Ayyub, 2003)

$$SCA = [1 + i]^n \quad (2.2)$$

$$F = P \times SCA \quad (2.3)$$

2.4.2 Single Present Worth (PW)

This factor may be used to determine the present amount of a future amount discounted at interest rate i for n periods, as follows:

$$PW = \left[\frac{1}{(1+i)^n} \right] \quad (2.4)$$

$$P = F \times PW \quad (2.5)$$

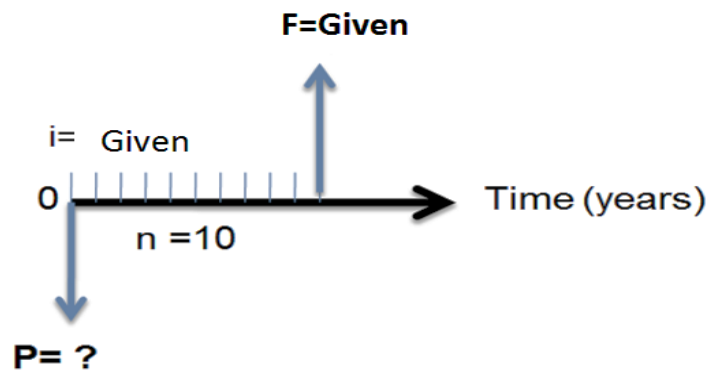


Figure 3: Cash flow diagram of the single present worth formula
 Source: (Kirk & Dell'Isola, 1995)

2.4.3 Uniform Compound Amount (UCA)

The UCA factor may be used where n periodic installments, invested at i percent interest rate, amount to a future sum of money which is to be determined, it can be expressed as in Figure 4.

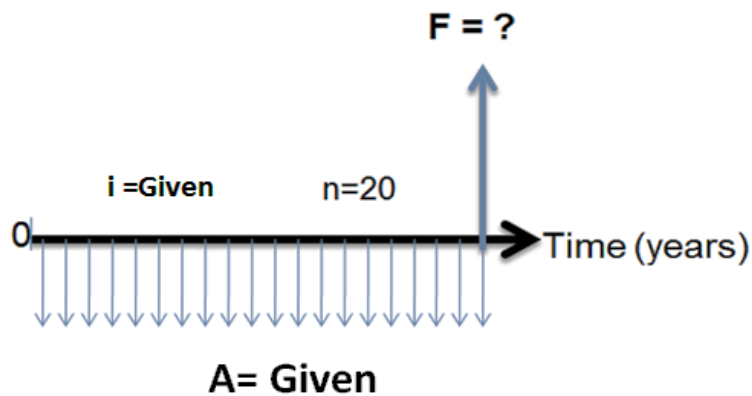


Figure 4: Cash flow diagram of the uniform compound amount formula
 Source: (Kirk & Dell'Isola, 1995)

$$UCA = \left[\frac{(1+i)^n - 1}{i} \right] \quad (2.6)$$

$$F = A \times UCA \quad (2.7)$$

2.4.4 Uniform Sinking Fund (USF)

For an annual interest rate i over n years, the equal end-of-year amount to accomplish a financial goal of having a future amount of F at the end of the n year can be computed from Equation 2.8, as follows, the cash flow diagram of this case is shown in Figure 5 (Ayyub, 2003):

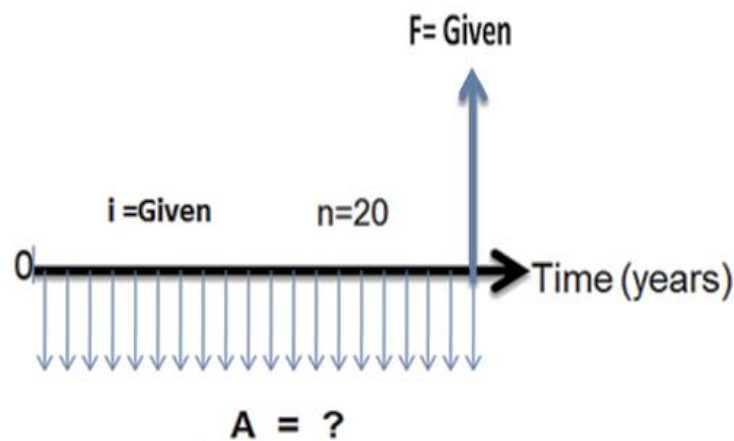


Figure 5: Cash flow diagram of the uniform sinking fund formula
Source: (Ayyub, 2003)

$$USF = \left[\frac{i}{(1+i)^n - 1} \right] \quad (2.8)$$

The formula to get A is:

$$A = F \times USF \quad (2.9)$$

The USF is very commonly used to save money on a periodic basis to pay for some future anticipated cost such as college expenses (Kirk & Dell'Isola, 1995).

2.4.5 Uniform Present Worth (UPW)

The UPW factor may be used where a present amount at i percent interest is returned in n equal periodic installments.

Formula 2.10 can be used to obtain the uniform present worth (Panneerselvam, 2001).

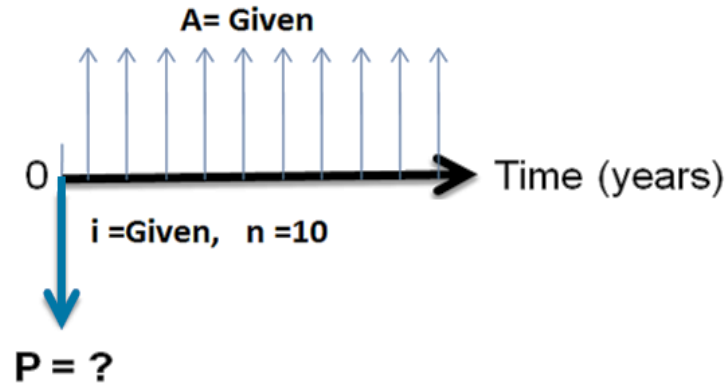


Figure 6: Cash flow diagram of the uniform present worth formula
Source: (Kirk & Dell'Isola, 1995)

$$UPW = \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] \quad (2.10)$$

$$P = A \times UPW \quad (2.11)$$

2.4.6 Capital Recovery

The objective of this mode of investment is to find the annual equivalent amount A which is to be recovered at the end of every interest period for n interest period for a loan P which is sanctioned now at an interest rate of i compounded at the end of every interest period, as shown in Figure 7 (Panneerselvam, 2001):

$$CR = \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad (2.12)$$

The formula to compute P is as follows:

$$A = P \times CR \quad (2.13)$$

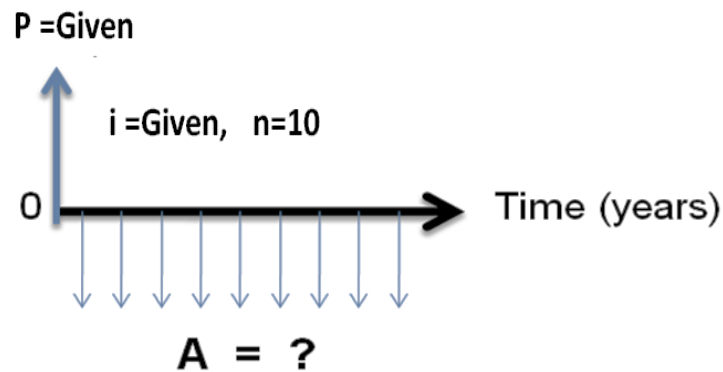


Figure 7: Cash flow diagram of the capital recovery formula
Source: (Panneerselvam, 2001)

2.5 Inflation

Inflation is a general rise in the price of goods and services over time, due to the increase in cost without a corresponding increase or decrease in value. Inflation can be defined as, “a continuing growth in the general price levels, caused usually by an increase in the volume of money and credit relative to available goods”.

It is a weakening in the general purchasing power of a currency. Inflation is one of the important considerations in life cycle costing because of the effect it has on costs.

The following are some of the characteristics of inflation:

1. Inflation refers to the way that the price of goods and services tend to change over time.
2. Inflation causes money to lose its purchasing power because the same amount buys less.
3. The nominal rate of return (ROR) on an asset or investment is the amount you get back. The real rate of return is the return after inflation has been taken into account.

4. Cash deposits such as savings accounts, although secure, do not keep pace with inflation.
5. Interest rates are used to control inflation. By raising interest rates, governments can dampen consumer spending which results in reducing economic activity.
6. Low inflation is supposed to be a good thing because it leads to price stability.
7. The opposite threat of deflation is considered to be just as much a threat as inflation.
8. Zero inflation is rarely desirable. The level of interest rates needed to achieve this would discourage economic activity (Ashworth, 2004).

Even with relatively low levels of inflation (say, less than 7%); prices will be substantially affected over long periods of time. An item costing \$100.00 today would cost \$197 after ten years at a rate of 7% per annum.

$$\text{Today } \$100 = 100 / 0.5083 = \$196.73 \cong \$197$$

Where 0.5083 is the interest factor, which can be found from the interest factor tables.

2.6 Discount Rate (Interest Rate)

The Discount Rate “is used to recognize the time value of money”; today’s expenditure is more important than tomorrow’s. This is, of course, no justification for ignoring life cycle costs and making project decisions on first cost only. Discounted cash flow calculations are needed when the expenditure profile of one option differs significantly from that of another (Bull, 2003).

The choice of discount rate will have a major impact on present value calculation as shown in Figure 8.

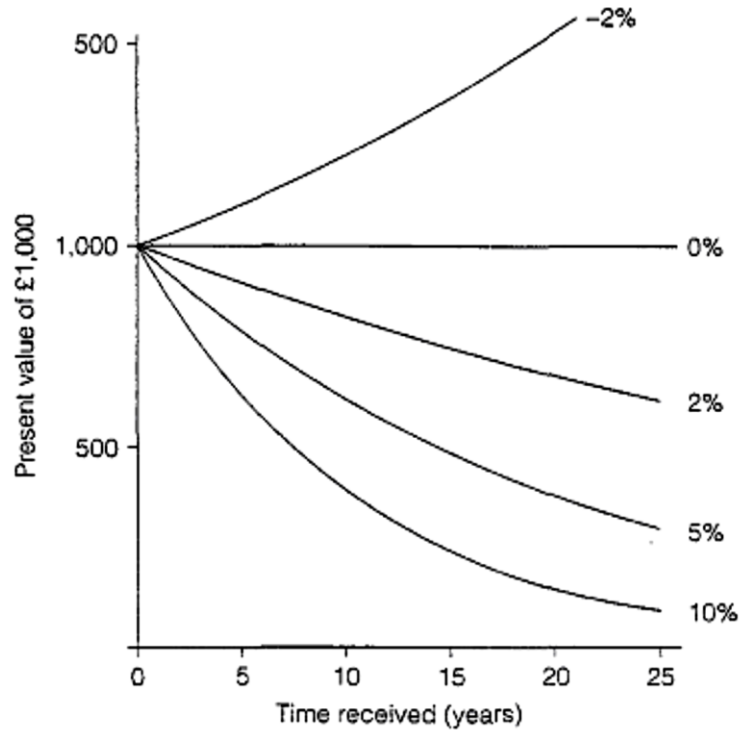


Figure 8: Present value of £1000 at various discount rates
Source: (Flanagan & Norman, 1981).

The objective of discount rate is to produce a present value it follows that this present value will relate to current prices. It is to be expected, however, that costs will increase over time. When discounting future cash flows, therefore, account must be taken of the effects of inflation. However it can be debated that it is one of the critical variables in the analysis, in that the decision whether to continue with a particular investment project will be crucially affected by the choice of discount rate (Flanagan & Norman, 1981).

2.7 Nominal and Effective Interest Rates

It is generally assumed that interest is compounded per annum. However, interest may be compounded more frequently. When this occurs, there is an effective interest

earned or paid in a year or some other time period and a nominal interest quoted based on an annual period (Park, 2004).

For instant, a savings bank may offer 7% interest compounded quarterly, which is not the same as 7% per year. A nominal rate of 7% compounded quarterly is the same as 1.75% every 3 months or an effective rate of 7.2% per year (Blank & Tarquin, 2005 a).

The nominal interest rate for a time period ignores the effect of any sub-period compounding. The effective interest rate for a time period includes the effect of any sub-period compounding. Unless specified otherwise, a quoted nominal rate is assumed to apply to a time period of one year.

$$i_p = \left(1 + \frac{r_p}{m}\right)^m - 1 \quad (2.14)$$

Where,

i_p = nominal interest rate for a time period:

m = number of compounding subperiods per time period;

r_p = effective interest rate for a time period (Revelle et al., 2003).

For instance a dot-com company plans to place money in a new venture capital fund that currently returns 18% per year, compounded daily. What is the effective rate?

$$\text{Effective } i\% \text{ per year} = \left(1 + \frac{0.18}{365}\right)^{365} - 1 = 19.716\%$$

2.8 Net Present Value

The net present value (NPV) “is the difference between the present value of all cash inflows and outflows of a project”. The NPV technique not only allows the selection

of a single project based on the NPV but also a selection of the most economical choice of the project from a list of more than one alternative projects (Accounting For Management, 2011).

Net present value can be calculated using the Equation 2.15.

$$\begin{aligned}
 NPV &= \frac{A_0}{(1+i)^0} + \frac{A_1}{(1+i)^1} + \frac{A_2}{(1+i)^2} \dots \dots \dots + \frac{A_n}{(1+i)^n} \\
 &= \sum_{n=0}^N \frac{A_n}{(1+i)^n}, \quad = \sum_{n=0}^N An(P/F, i, n) \quad (2.15)
 \end{aligned}$$

Where:

NPV is a stream of cash flows over the life of the project,

A_n is net cash flow at the end of period “n”,

i is the discount rate,

n is service life of the project (Danile & William, 2002) .

A positive NPV means it promises a return greater than the required rate of return, so the project makes a profit. Therefore, if the NPV of a prospective project is positive, it should be accepted. A negative NPV means it promises a return less than the required rate of return, the project should probably be rejected, as the following decision rules:

If NPV greater than 0, accept the investment.

If NPV equal 0, remain indifferent.

If NPV less than 0, reject the investment (Park, 2004) .

2.9 Present Worth Analysis

The present worth (PW) can be defined as one of the discounted cash flow techniques, which represents the time value of money (Panneerselvam, 2001).

To estimate a present worth of income -producing property like an apartment house, the future income and cost need to be identified, then we can use a proper interest rate to calculate the present worth of the property. This should give a good evaluation of the price at which the property could be bought or sold. PW can be calculated using the Equation 2.16 and 2.17 (Newnan et al., 2004):

$$PW = \sum_{t=0}^n FW(P/F, i\%, n) \quad (2.16)$$

$$PW = \sum_{t=0}^n AW(P/A, i\%, n) \quad (2.17)$$

Where,

FW= Future worth (value or amount of money at some future time),

AW= Annual worth.

Before starting an evaluation, it is very essential to recognize the nature or type of alternatives. Determine whether the alternatives are equal life or unequal life (Blank & Tarquin, 2005 a).

2.10 Analysis Period

The analysis period is the number of years over which the total cost of ownership will be determined for the various design alternatives.

The more commonly used criteria for establishing the analysis period are;

1. **Component Life:** If some alternatives being considered all have the similar economic life, then that life, or a multiple of it, may be used as the analysis period.

2. **Common Multiple of Component Life:** If the design alternatives have different economic lives, it may be possible to choose, as the analysis period, a common multiple of these lives. For example, if the economic life of two competing alternatives is 6 years and 8 years, then, a common multiple of 24 years may be selected as the analysis period. The use of this criterion simplifies calculations of involving unequal life and eliminates residual values.

3. **Facility Life:** This is the technological or useful life of the facility as a whole.

4. **Investment or Mission Life:** This is the expected number of years, until the owner's investment objective is achieved. For example, the economic life of an investor who wishes to build and sell a building is short, while for the other owner wishing to keep the building for other purposes is longer.

5. **Arbitrary Life:** Arbitrary analysis period may also be selected, which does not include such important considerations such as component life, facility life or mission life. This analysis life might be established by organizational policy as a limit of the planning period (Neap, 1999).

2.11 Annual Worth Analysis

It is the best way to use, when compared to present worth, future worth and rate of return. Since its value "is the equivalent uniform annual worth of all valued incomes and outcomes during the life cycle of the project or alternative". Moreover annual

worth is easy to understand by any person recognizes the annual amounts, for several engineering economic studies, The AW value, which has the same economic interpretation as a used thus far, is equivalent to the PW and FW values for n years. All three can be easily determined from each other by the relation in Equation 2.18.

$$AW = PW(A/P, i, n) = FW(A/F, i, n) \quad (2.18)$$

Where,

n = the number of years for equal-service comparison.

Annual worth is also known by other titles. Some are equivalent annual worth (EAW), EUAC (equivalent uniform annual cost), annual equivalent (AE), and equivalent annual cost (EAC). The resulting equivalent annual worth amount is the same for all name variations.

Not only is annual worth an excellent method for performing engineering economy studies, but it is also applicable in any situation where PW, FW and Benefit/Cost analysis can be utilized (Ayyub, 2003).

2.12 Future Worth Analysis

Future value means the Dollar amount you will receive in the future. “The future worth of an alternative may be determined directly from the cash flows by determining the future worth value, or by multiplying the PW value by the F/P factor shown in Equation 2.19. Therefore, it is an extension of present worth analysis. The *n* value in the F/P factor depends upon which time period has been used to determine PW”. Analysis of one alternative or the comparison of two or more alternatives, using FW values is especially suitable to large capital investment decisions when a main objective is to maximize the future worth of a company’s stakeholders.

$$FW = \sum_{t=0}^n PW(F/P, i, n) \quad (2.19)$$

Alternatives such as electric generation facilities, hotels, toll roads and the like can be analyzed using the FW value of investment obligations made during the construction (Blank & Tarquin, 2005 a).

2.13 Calculation of Capital Recovery and (AW) Values

Many of the expenses of a company must meet - rent, wages, and taxes - occur on a regular periodic basis. So it is good to present investment options in terms of their equivalent uniform annual cost. Simple calculations are done, that's to say PW is converted to EAW by multiplying by the suitable conversion factor - however care is needed in deciding what period of time to consider (Jones, 2008).

Capital recovery (CR): "The equivalent annual cost of owning the asset plus the return on the initial investment".

For instance, having a machine that is purchased for a specified cost P and expected to be sold after n years for salvage cost S. What is the equivalent annual worth cost of the machine? (It is a useful result when comparing between buying the machine outright and renting it for a period). The equivalent cost is conventionally referred to as capital recovery, and can be calculated from Equation 2.20 (Jones, 2008).

$$CR = -[P(A/P, i, n) - S(A/F, i, n)] \quad (2.20)$$

Relationship between Capital Recovery and AW:

$$AW = -CR - A \quad (2.21)$$

Where:

CR =the *capital recovery factor*. (Capital Recovery only includes the initial cost and salvage value).

A = equivalent annual cost or worth of all costs with the exception of the initial cost and all annual receipts with the exception of the residual value.

Both CR and A have minus signs because they represent costs. The total annual amount A is determined from uniform recurring costs (and possibly receipts) and nonrecurring amounts. The P/A and P/F factors may be necessary to first obtain a present worth amount, then the A/P factor converts this amount to the A value in Equation 2.21. If the alternative is a revenue project, there will be positive cash flow estimates present in the calculation of the A value (Blank & Tarquin, 2005 a).

2.14 Internal Rate of Return

The discount rate often used in capital budgeting that makes the net present value of all cash flows from a specific project equal to zero. Internal Rate of Return (IRR) is also called the Rate of Return (ROR).

2.14.1 Calculation of Rate of Return

To calculate rate of return on an investment, the various must be convert consequences on the investment into a cash flow. Then the cash flow will be solved for the unknown value of the Internal Rate of Return (IRR). Five forms of the cash flow equation are as follows:

$$PW \text{ of benefits} - PW \text{ of costs} = 0 \quad (2.22)$$

$$\frac{PW \text{ of benefits}}{PW \text{ of costs}} = 1 \quad (2.23)$$

$$\text{Net present worth} = 0 \quad (2.24)$$

$$EUAB - EUAC = 0 \quad (2.25)$$

$$PW \text{ of costs} = PW \text{ of benefits} \quad (2.26)$$

The five equations represent the same concept in different forms. They can relate costs and benefits with the IRR as the only unknown (Ayyub, 2003).

For instance, \$8200 investment returned \$2000 per year over a 5-year useful life.

What was the rate of return on the investment?

Using equation 2-23:

$$\frac{PW \text{ of benefits}}{PW \text{ of costs}} = 1 \quad \frac{2000(P/A, i, 5)}{8200} = 1$$

$$(P/A, i, 5) = \frac{8200}{2000} = 4.1$$

Then look at the compound interest table of the value of i where $(P/A, i, 5)=4.1$, if no tabulated value of i gives this value, then the values will be found on either side of the desired value (4.1) and interpolate to find the Internal Rate of Return (IRR).

From interest tables:

i	($P/A, i, 5$)
6%	4.212
7%	4.100
8%	3.993

In this example, no interpolation is needed because the internal rate of return is exactly 7%.

Chapter 3

COST ESTIMATION

3.1 Introduction

Cost estimate is one of the most significant phases in project management. It establishes the standards of the project cost at several stages of its development. Depending on the available data, estimating the cost at a particular stage of evolution of the project represents the probability given by the engineer or cost estimator. Cost engineering definition according to the American Association of Cost Engineers, is an area of engineering practice where engineering judgment and skills are employed in the application of scientific principles and techniques to the problem of cost estimation, cost control and profitability (Hendrickson, 1998; Sengupta & Guha, 2002).

Cost estimates are usually expressed in units of currency (Dollars, Euros, Yen, etc.) to facilitate comparisons both within and across project. “In some cases the estimator may use units of measure to estimate cost, such as staff hours or staff days, along with their cost estimates to facilitate appropriate management control. Cost estimating generally includes considering suitable risk response planning, such as emergency plans” (PMBOK Guide, 2000).

3.2 Approach to Cost Estimation

Usually cost estimation is applied according to one or some combination of the following basic approaches:

3.2.1 Production Function

In construction, Production function means the relationship between the output of a process and the necessary resources. It may be expressed by the correlation between the volume of construction and a factor of production such as labour or capital. Moreover, production function relates the amount or volume of output to the different inputs of labour, material and equipment.

3.2.2 Unit Costs for Bill of Quantities

This is the most important and widely used means for achieving the cost estimates of civil engineering. The unit cost is the summation of the cost of materials, labour, equipment, overhead and profit. The total cost is the summation of the products of the quantities multiplied by the corresponding unit costs. The unit cost is simple and effective. It is assigned to each and then the total cost is determined by adding together the costs incurred in each task, this process is represented by the bill of quantities. The practicing cost engineer must be conversant with the method of determining the unit cost (Sengupta & Guha, 2002).

3.2.3 Allocation of Joint Costs

It could be used to develop a cost function of an operation. The principal idea is that each expenditure item can be assigned to certain characteristics of the operation. Ideally, the allocation of joint costs should be causally related to the category of basic costs in an allocation process.

In construction projects, the accounts for main costs may be classified according to the following items:

- Labor
- Material
- Construction equipment
- Construction supervision
- General office overhead (Hendrickson, 1998).

3.3 Types of Construction Cost Estimates

Construction cost constitutes only a portion, though a substantial portion, of the total project cost. However, it is the part of the cost under the control of the construction project manager. The required levels of accuracy of construction cost estimates vary at different stages of project development (Sengupta & Guha, 2002).

There are many types of estimating techniques; these can be categorized into two main groups as follows.

3.3.1 Approximate Estimates

“An approximate estimate is an approximate or rough estimate prepared to get an approximate cost in a short time. For certain purposes the use of such method is justified”.

3.3.2 Detailed Estimate

It is the best model and the most reliable of the estimates, detailed estimates are the most accurate. But keep in mind that as the accuracy increases, so does the time, effort, and skill required to complete the estimate (Jackson, 2010). A detailed estimate of the cost of a project is prepared by recognizing the quantities and costs of everything that a contractor is required to provide and do for satisfactory completion of the work.

A detailed estimate may be prepared in the following two methods as following:

3.3.2.1 Unit Quantity Method

Here, the work is divided into multiple operations or elements as are required. First a unit of measurements is decided, and then the total quantity of work under each item is taken out in the selected unit of measurement. The total cost per unit quantity of each item is analyzed and worked out. After that the total cost for the item is found by multiplying the cost per unit quantity by the number of units.

For example, to estimate the cost of a construction work, several steps are needed, to start with, the quantity of brickwork in the building can be in cubic meters. The total cost (which includes cost of materials, labour, plant, subcontractors, overheads and profit) per cubic meter of brickwork can be found and then this unit cost multiplied by the number of cubic meters of brickwork in the building which will give the estimated cost of brickwork”.

3.3.2.2 Total Quantity Method

In the total quantity method, an item of work is divided into the following five portions:

- Material
- Labour
- Plant
- Overheads
- Profit

The costs of all five sub-heads are summed up to give the estimated cost of the item of work. For example, the cost of brickwork in a building would be determined as shown in Table 2 (Danile & William, 2002).

Table 2: Total quantity for brickworks

I	i-Cost of Materials at the source	Cost in \$
	Bricks	Cost in \$
	Cement	Cost in \$
	Water	Cost in \$
	ii-Cost of handling and transporting above materials	Cost in \$
I	Cost of labour, both skilled and unskilled	Cost in \$
III	Cost of plant	Cost in \$
IV	overheads	Cost in \$
V	profit	Cost in \$
	Total cost of brickwork	Cost in \$

Source: (Danile & William, 2002)

3.4 Cost Components

The main components of cost are;

i.Direct Costs

ii.Indirect Costs

iii.Mark-up

3.4.1 Direct Cost

Direct costs are the costs attributed to the production activities of a project. They are estimated based on detailed analysis of the contractor, the site conditions, resource productivity data, and the methods of construction being used for every activity. The direct costs are the summation of the cost of the labour, equipment, crews, materials, and subcontractors used in all activities in the project (Bledsoe, 1992). Direct costs make up the bulk of any construction estimate. These are the obvious direct costs associated with any project.

3.4.1.1 Materials

When we speak of material costs, we refer to the costs at the site to the contractor and to owner. Storage, freight, transportation and inspection are different parts of the cost of material.

This estimation is most important in cost estimation. “It involves the cost of raw materials, supplies, and other equipment needed to complete project tasks. The real costs incurred for materials depend on the nature of the project; for instance, material costs for software development projects can be quite small, while in construction projects they are very large” (Venkataraman & Pinto, 2008).

3.4.1.2 Labour

This is an important factor that is required to be estimated. “It involves hiring costs and wages for the various human resources related with the project. Given that a project requires a variety of personnel with varying skill levels, labor cost estimation is not an easy task”. The estimator must be in knowledge of the various operations to be performed, tools to be used, machines employed and the departments in which the product is to be manufactured. He must also be conversant with the salaries or hourly rates, pension and health benefits, and other overhead (Kesavan et al., 2009; Venkataraman & Pinto, 2008).

3.4.1.3 Equipment Costs

An estimate will support in determining amount and type of equipment needed to complete the work.

The cost estimation for equipment will also differ if the equipment is usually hired by the contractor or may be owned by the contractor directly (Fellows, Langford, Newcombe, & Urry, 2002).

3.4.2 Indirect Costs

These costs are of two categories:

3.4.2.1 Project Overhead (or job overhead), such as the following:

- Project staff (project manager, project supervisor, project engineer, receptionist or secretary, worker, etc.).
- Temporary roads and parking and other temporary structures.
- Office equipments (photocopying machine, fax machine, computers, etc.).
- Temporary utility lines and utilities consumed during construction (electricity, water, drinking water and ice, telephones, cell phones, gas, portable toilets, etc.).
- Other indirect project-related expenditures, such as power generators and projectors used to provide light during night working hours.

3.4.2.2 General Overhead, such as the following:

- Main office expenses (rent, lease, maintenance, utilities, etc.).
- Main office equipments and automobiles.
- Main office services, such as lawyers and accountants (not working exclusively for a specific project).
- Other main office expenses, such as advertising and charity contributions (Mubarak, 2005).

3.4.3 Markup

This bid component represents the contractor's added fees (percentage of direct plus indirect costs) that covers two aspects:

3.4.3.1 Profit

Generally estimated by the contractor before he/she takes on the project, depending on the business objectives of the contractor organization. This item can be decided

based on the level of competition and the contractor's need for winning this particular project.

3.4.3.2 Risk Contingency

Used to provide protection against the uncertain conditions that are expected to affect the project, such as weather, labor problems, and soil conditions.

3.4.4 Estimating Time

“The estimate of a work and the previous experience enable one to estimate quite closely the length of time required to complete an item of work or the work as a whole”. Based on the estimation of materials, labour, and plant, the implementation time can be estimated (Construction Cost Estimating Software, 2001).

3.5 The Characteristics of a Good Estimator

The estimator is probably one of the most important people in construction management. This person preparing estimate should be highly qualified and experienced. The following specific skills and characteristics are common among estimators:

- A fund of information collected or gained through experience in construction work, relating to materials required, hourly output of workers and plant, overhead expenses and costs of all kinds.
- Is knowledgeable about construction techniques.
- An understanding of a good method of preparing an estimate.
- Must be familiar with computer applications.
- A systematic and orderly mind.
- A thorough understanding of architectural drawings.
- Ability to collect, classify and evaluate data that would be useful in estimating.

- Ability to do careful and accurate calculations (Jackson, 2010).

3.6 Historical Cost Data

Historical cost data will be useful for cost estimation only if they are collected and organized in a way that is compatible with future applications. Historical cost data must be used carefully. Changes in relative prices may have substantial influences on construction costs which have increased in relative price.

The format of cost data, such as unit costs for various items, should be organized according to the current standard of usage in the organization (Hendrickson, 1998).

Chapter 4

LIFE CYCLE COST ANALYSIS

4.1 Introduction

Buildings are considered as investments for future. The buildings around the world prove that return on such investments will last for hundreds of years and this will not be achieved without continuing maintenance and operating of the facility. Failure to make effective building expenditures during the life cycle of the building can lead to early deterioration or loss of services, damage to facilities and exposure of occupants to unsafe condition.

According to the design selection of good construction materials that can lower or eliminate replacement or repair during future maintenance and operation will help in lowering overall costs. Owners of buildings and designers often recognize that there are possibilities of trade-offs between initial costs and recurring costs. They are also aware that the decision about the building design, construction, maintenance and operation can be made in principle so that the building performs well over a specified period of time with minimum total costs (National Research Council, 1991).

Many building users during the 1930s began to notice that the operation (or supplier) costs of building (i.e. energy, maintenance, management, and others) began to have a significant impact on the budget of the occupier. It was found that the “least-cost” option of choice was not always the best solution over the long-term of the building.

It is apparent that some other methods of financial analysis that take into account the running costs of the building must be used to give credibility to the decisions when a number of choices are under consideration for decisions (Bull, 2003).

“The National Institute of Standards and Technology (NIST) Handbook 135 (1995) defines Life Cycle Cost (LCC) as the total discounted Dollar cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time” (Alaska Department of education and early development, 1999).

LCCA is an important design procedure for controlling the initial and the future costs of building ownership and can also be applied at any level of the design process.

4.2 Building Life Cycle Cost

In the past, decisions in the building industrial sector during the design phase were made basically by comparing initial capital costs. The main reason for using this approach was its simplicity. Various studies conducted over the years indicate that a building’s long-term costs can far outweigh initial capital costs. Thus, estimating the life cycle cost of a building at the initial design stage is very important, because past experiences indicate that the earliest decisions tend to establish boundaries to a certain degree for the later ones. According to Khanduri, Bedard, and Alkass (Smith, 1934) around 75–95% of the total life cycle costs of a typical building are locked in by the time its working drawings are prepared. Furthermore, if an estimate of the total life cycle cost is available at an early design stage of a building project, then it is relatively easy to take appropriate cost reduction measures. However, once the project goes into construction, chances to influence the total project cost are reduced quite significantly.

Building life cycle cost is defined by:

$$LCC_b = CC + OC + RMC + DC \quad (4.1)$$

Where:

LCC_b = is life cycle cost of a building.

CC = is capital cost, which is composed of land and construction costs.

OC = is operation costs associated with items such as energy, insurance, and wages.

RMC = is repair and maintenance costs.

DC = is demolition cost (Dhillon, 2010).

4.3 More About Life Cycle Cost

Life cycle costing is the process of making an economic valuation of design alternatives, considering all the significant costs of ownership over an economic life expressed in equivalent currency (i.e. in Dollars) (Kirk & Dell'Isola, 1995); in other words, it is a technique for economic evaluation of alternatives.

A LCCA study is not primarily about costs but about personnel, finance, resources, material items (hardware, software) and time. A life cycle cost analysis is a major element in the project decision-making process that allows a project manager to determine the cost consequences of all the technical, schedule and procurement options (Bull, 2003).

It is easily understood that the total cost of a product through its life cycle includes not only “acquisition costs” (It is not only the raw material cost for manufacturing of the item. It also includes the drawing and design cost as well as development cost), like site cost, capital cost, professional cost but also many of the other cost categories

such as “costs of ownership”, like operation costs, maintenance costs, energy costs, etc. as shown in Figure 9, may be the cost of ownership to be higher than the cost of acquisition. It is believed that a typical range of the ownership costs is 60% to 80% of the total LCC. If we do not care about the ownership costs at purchasing of the product, it is likely that we get surprised by the growing ownership costs after the purchase. It is therefore important to try to reduce the LCC at an early stage of the product life cycle (Mukhopadhyaya, 2009; Dangel, 1969).

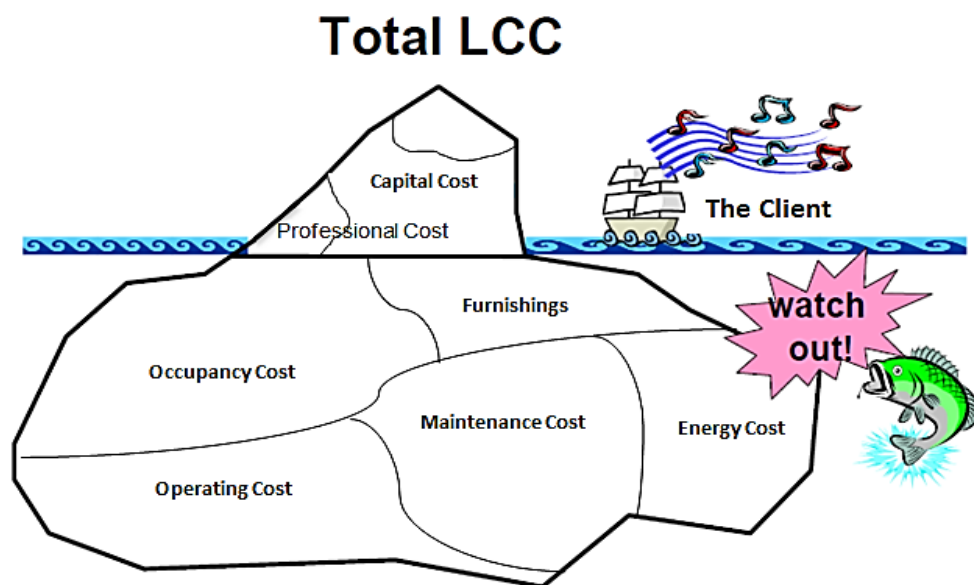


Figure 9: Total Life Cycle Cost
Source: (Flanagan & Norman, 1981)

4.4 Life Cycle Costing Advantages and Disadvantages and Related Important Points

Over the years, various advantages and disadvantages of life cycle costing have been identified by various professionals. Some of the important advantages of life cycle costing are shown in Figure 10. In contrast, some of the main disadvantages of life cycle costing could be:

- It is time wasting;
- It is costly;
- It has doubtful data accuracy.

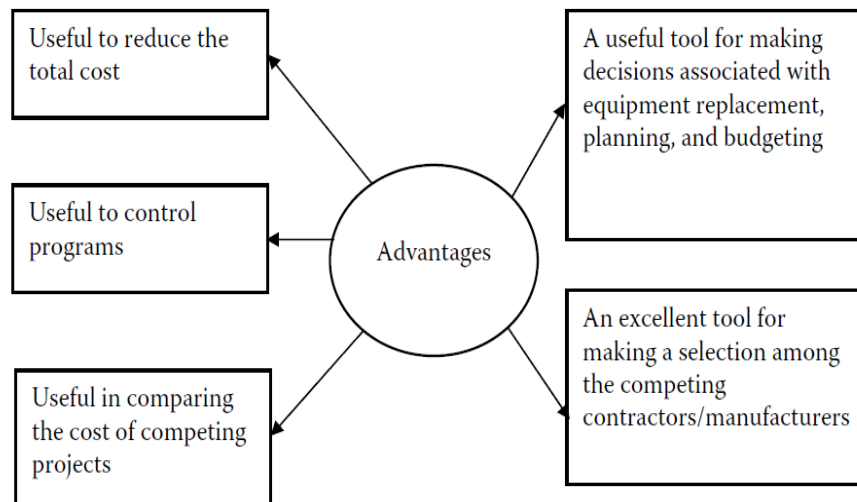


Figure 10: Life Cycle Costing advantages
Source: (Dhillon, 2010)

Many important points are associated with life cycle costing, some of which include:

- The main goal of life cycle costing is to get the maximum income (profit) from limited resources.
- The management plays a key role in making life cycle costing a worth for the effort.
- In general risk management is the heart of life cycle costing.
- The availability of good data is very important for good life cycle cost estimates.
- The life cycle cost model must contain all program-related costs.
- There is a sure need for both the product manufacturer and the user to organize successfully to control life cycle cost.

- There is a definite need to perform trade-offs among life cycle cost, design to cost, and performance throughout the life of the program.
- Some surprises may still occur, even when the estimator is very competent.
- Life cycle costing is gaining importance as a method for performing design optimization, making strategic decisions, conducting detailed trade-off studies, etc.
- A highly knowledgeable and experienced cost analyst may compensate for various database-related difficulties (Dhillon, 2010).

4.5 Life Cycle Costing Logic

Figure 11 illustrates a flow chart for applying LCC to a project. The first requirement is the input data. It would normally consist of data such as (1) program of requirements and operational mode and (2) criteria and standards, quantities, and economic data such as time value of money, interest rates and life cycle period. Next, input data for facility components, such as initial cost, useful life and maintenance and operation costs and site data such as climatic and environment conditions would be collected. With these data, alternatives would be generated. This would be followed by the life cycle cost predictions. These predictions would be tempered by non-economic comparisons before a final recommendation is developed (Dell'Isola, 1997; Kirk & Dell'Isola, 1995).

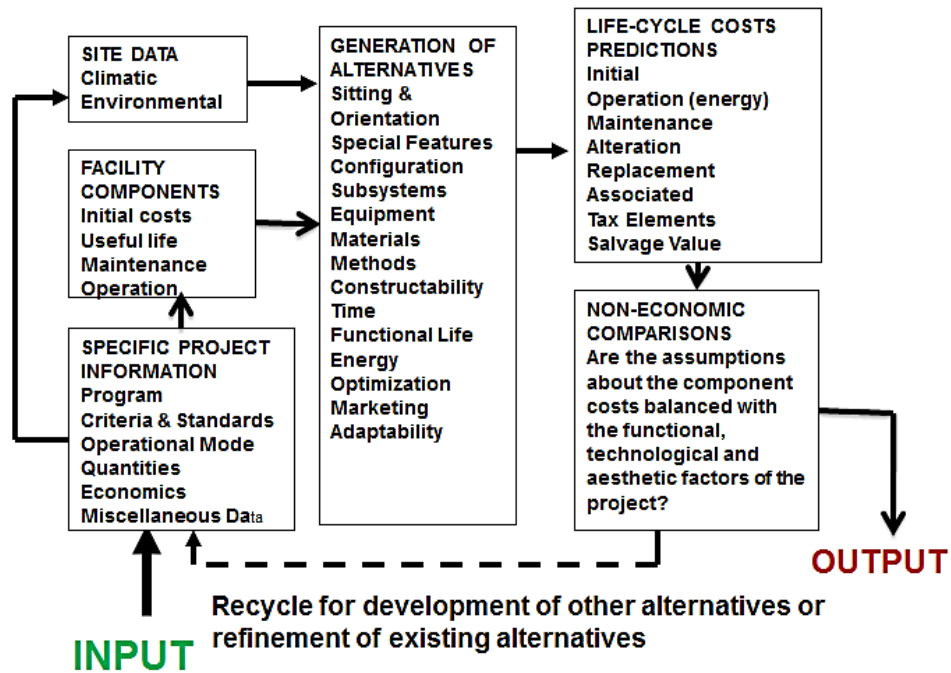


Figure 11: Life Cycle Costing Logic
Source: (Kirk & Dell'Isola, 1995)

4.6 Types of Costs

All significant costs attributable to the alternative should be considered in the analysis. This would include all the construction, construction related, and procurement costs; all the disposal, demolition, and other salvage values at the end; and all the various types of costs incurred between the construction and end of the analysis period (Neap, 1999).

These costs could be of the following types;

- 4.6.1 Initial (Investment) Costs:** include the owner's costs related with the initial development of a facility, such as project costs (site, fees, real estate and so on) and construction costs. Financing costs include the costs of any debt associated with the facility's capital costs.

- 4.6.2 Energy Costs:** Costs related with the ongoing energy consumption of the facility. These include cost of electricity, natural gas, oil, coal and other fuels necessary for operation of the facility and its components.
- 4.6.3 Operation and Maintenance Costs:** All costs associated with the operation, maintenance, repair and services, these include, personnel costs, supplies and contract services, security, routine maintenance and repair, cleaning necessary for ongoing operation.
- 4.6.4 Alteration and Replacement Costs:** These are costs associated with planned additions, alterations, and other improvements to the facility to meet the new functional requirements, and the replacement costs required to restore the facility to its original performance, such as redesign, demolition, relocation all the construction costs to alterations.
- 4.6.5 Tax Costs:** those assignable costs associated with taxes, credits, and depreciation. These costs must be continually reviewed as tax laws change.
- 4.6.6 Associated Costs:** Other identifiable costs associated with a LCCA not previously mentioned. These include functional use costs, denial of use costs, security and insurance.
- **Functional use costs** include that for the staff, materials, etc. required to perform the function of the organization using the facility or installation. For example, suppose a life cycle cost analysis is required for a hospital. What is the function of the hospital? It is to treat patients. Suppose two hospitals are identical in costs and area, but in one hospital a doctor can treat a patient in half the time it would take in the other hospital. Which is more cost-effective? The one that processes more patients. Functional use costs for a

hospital are those of treat patients. The LCC would be tempered for the difference in functional use cost.

- **Denial-of-use costs:** include the extra costs or lost income during the life cycle because occupancy or production is delayed for some reason. For example, suppose that in making an alteration there are two approaches whose construction costs are the same. One alternative would require moving people out of the space for six months; the other alternative could be accomplished during nonworking hours. In the life cycle cost, the cost of not being able to use the space would have to be recognized.

4.6.7 SALVAGE VALUE: is the value (it will be negative if demolition is required and positive if it has residual economic value) of competing alternatives at the end of the life cycle period. This cost can become very important if one alternative requires a major replacement toward the end of its economic life. For example, two automobiles are being analyzed for purchase. The plan is to keep these cars for 4 years. It is estimated that one car will reach the end of 4 years without requiring any major motor repairs, but it will then need a major overhaul. The other car will require a major engine overhaul at the end of the third year. As a result, the salvage value of the car with the recently overhauled engine will be significantly higher. The same concept applies to building equipment (Kirk & Dell'Isola, 1995).

4.7 Unnecessary Costs

Unnecessary cost “is the difference between the cost of an existing option and a better one”, because of the complexity of construction design; it is rare to find an

option which is optimum in every respect. But it is important to seek improvement by considering the costs and benefits of alternative before making a choice.

Unnecessary costs can occur at a number of levels:

- **Cost of unnecessary component.** This is the simplest category of unnecessary cost; the cost of a component that provides no useful function.
- **Cost of unnecessary material.** Unnecessary cost is sometimes due to an expensive material being specified for a particular component where a cheaper one would satisfy all the required functions.
- **Unnecessary cost of poor buildability.** Unnecessary cost can be caused by the labour and plant resources which are required to construct a particular design. If a designer does not consider the construction implications of the design then the result will be an unnecessary cost due to poor buildability.
- **Unnecessary life-cycle cost.** The unnecessary costs which are inherent in a given building design are not limited to capital costs; they can also include costs-in-use. It is necessary to consider the future running costs when considering the implications of different design alternatives.
- **Unnecessary opportunity cost.** Unnecessary opportunity cost refers to the revenue that is foregone by the adoption of a particular solution. The failure to achieve revenue is equally as important as the failure to avoid wasteful expenditure (Connaughton & Green, 1996).

4.8 Economic Index (Risk) Assessment

It is important to make an assessment of the effects of uncertainties (risks) on the results of life cycle cost analyses (LCCAs). The two basic approaches are the

confidence index (probabilistic) approach and the sensitivity analysis approaches which are used for uncertainty (risk) assessment.

4.8.1 Confidence Index Approach

Confidence index approach is an approximate probabilistic approach to uncertainty assessment. It provides a numerical measure of the degree of uncertainty in the LCCA results.

The Confidence Index (CI) approach is based on two assumptions:

1. Uncertainties in all cost data are normally distributed.
2. The high and low estimates correspond to 90% points of the probability distribution. Fortunately, these are reasonable assumptions for construction works.

CI approach should be considered valid if;

- High, low and best estimates are obtained at the same time and from the same source or sources.
- They should represent knowledgeable judgment rather than guesses.
- The differences between the PW of the best estimate for each cost and the PWs of the high and low estimates for that cost are within 25% or so of each other.

The Confidence index is calculated by applying the following formula:

$$\text{Confidence index} = \frac{PW(\text{High}) - PW(\text{Low})}{(PW \text{ diff}(\text{High})^2 + PW \text{ diff}(\text{Low})^2)^{\frac{1}{2}}} \quad (4.2)$$

Confidence assignment:

- If Confidence index is less than 0.15, results are low.
- If Confidence index is greater than 0.15 but less than 0.25, results are Medium.
- If Confidence index is greater than 0.25, results are High, then use Sensitivity analysis (Kirk & Dell'Isola, 1995).

4.8.2 Sensitivity Approach.

It is used to categorize the probability that, of two alternatives, the alternative with the lower computed LCC will in fact have the lower LCC. It is a method for determining how the value of one parameter is affected by variation in the value of a second parameter on which it depends, which are; Present Worth (PW) and Annual Worth (AW), initial cost, annual cost, replacement cost, salvage value, and any combination of those.

This method involves the assignment of several reasonable values to the input parameter; the computation of the output parameter value that corresponds to each input parameter value, and analysis of the pairs of values using tables or graphs, and determining the break-even points, if any.

The break-even point in LCC is the value of the cost element that causes the LCC of the least cost alternative, to equal to the LCC of the next lowest cost alternative.

Sensitivity approach should be used instead of the confidence index approach, when;

- One parameter is predominant and unable to determine high/low estimates or 25% condition is not satisfied.

- One parameter is predominant and 25% condition is not satisfied for that parameter (Kirk & Dell'Isola, 1995).

4.8.2.1 Application of Sensitivity Approach.

The sensitivity approach to uncertainty assessment may be applied in an LCCA as follows:

1. Verify that the uncertainty in one input-data element (the Dollar amount or timing of a cost for one of the two lowest LCC alternatives) is the predominant uncertainty. No formal verification is needed when it is known beforehand that uncertainty in a particular input-data element is predominant.
2. Conduct a sensitivity analysis of the input element whose uncertainty is predominant, using the best estimate and at least two other values for this element; tabulate and plot the results of the analysis.
3. Determine the break-even point.
4. Determine the probabilities;
 - If probability is greater than 0.67, result are conclusive.
 - If probability is less/equal to the 0.5, result are inconclusive.
 - If probability is greater than 0.5 but less than 0.67, additional cost information is required in determining whether the LCCA results should be used to select an alternative for implementation (Kirk & Dell'Isola, 1995).

4.9 Evaluating Life Cycle Costs

In most LCCAs, monetary benefits are considered to be negative costs. Thus, for example, salvage values are credited to the life cycle costs of alternatives at the end of the analysis period. Non-monetary benefits (safety, expansion potential, environmental sustainability, reduction of environmental pollution, etc.) for the

public sector are normally assumed to be the same for all alternatives that satisfy the minimum functional and technical requirements for inclusion in the analysis; they are, therefore, not considered in the usual LCCA.

When non-monetary benefits are considered, the technique of weighted evaluation is helpful in evaluating alternatives (Kirk & Dell'Isola, 1995).

4.9.1 Weighted Evaluation

The economic data of costs have to be tempered with the human factors such as comfort, appearance, performance, safety, and costs (initial, operation and maintenance, replacement, and salvage). A weighted evaluation is used to more formally organize the process. Weighted evaluation ensures perfect decisions. Good decisions are made by placing the proper emphasis on all criteria. Through evaluation it is very important to discuss and weigh the following areas:

- Requirements versus desires,
- Necessary versus unnecessary,
- Design tradeoffs versus required functions (Dell'Isola, 1997).

4.9.1.1 Procedure for Weighted Evaluation

The procedure for weighted evaluation consists of two processes: (1) criteria identification and weighting and (2) alternatives analysis. The criteria weighting process is designed to isolate important criteria and establish their weights of relative importance (Kirk & Dell'Isola, 1995).

Each pair of criteria is compared and the stronger of the two is scored to the how important scale (that is, 4-major preference, 3-medium preference, 2-minor preference, 1-light preference). Raw score as illustrated at the bottom of criteria

scoring matrix, gives the addition of all the scores for each criteria. Figure 12 shows the weighted evaluation for the alternatives.

Next line in the table shows the weighted importance of the criteria from 1 to 10, based on the raw scores. Note that if any criteria has zero raw score then a minimum score of 1 can be assigned for calculations.

The analysis matrix lists the alternatives and each alternative is then rated on the degree to which it provides each benefit, according to the scale (1 to 5) as shown at the bottom of the figure. A benefit score is then found for each alternative-benefit pair by multiplying the alternative rating by the benefit weight. The total benefit score for each alternative is the sum of its individual scores. Alternative with the highest total benefit score is the best recommended alternative.

Weighted Evaluation

Project		Item							
Criteria									
Criteria Scoring Matrix									
A.									
B.									
C.									
D.									
E.									
F.									
G.									
		G	F	E	D	C	B	A	
Alternatives									
Analysis Matrix		Raw Score						Weight of Importance (0-10)	Total
1.									
2.									
3.									
4.									
5.									
6.									
7.									
		Excellent - 5; Very Good - 4; Good - 3; Fair - 2; Poor - 1							

Figure 12: Weighted Evaluation
Source: (Kirk & Dell'Isola, 1995)

Chapter 5

VALUE MANAGEMENT

5.1 Introduction

The construction industry needs to be more competitive, not just in the area of cost but also value. The final product of most construction projects does not offer the client with the best available value of money, particularly in terms of function (what things actually do). In the present economic climate, the construction industry is as competitive as it will ever be in terms of cost. The industry can improve dramatically in the area of functional value (Albert, 1993).

The use of value concept has increased dramatically during the past few years especially in construction industry. The reason for this is the rising construction costs which are even doubled by the follow-on costs and the increasing dissatisfaction of clients of the components of the constructed facility (Neap, 1999).

Value Management in construction concerns with client value system and his/her optimum satisfaction of the constructed facility. It helps client to ensure that his/her investment in construction produces valuable assets (Neap, 1999).

The purpose of applying value management is achieving best value for project or process by identifying those functions required to achieve the value objectives and to provide those functions at lowest cost (total life cost or resource use), consistent with

the required quality and performance; saving time, money and energy; simplifying methods and procedures; removing unnecessary expenditure.

This chapter explains the characteristics of value management within value concept, develops a definition of value of a constructed facility and outlines the steps of value management in construction.

5.2 Background of Value Management

Value management is generally attributed to Lawrence Miles who, in the 1940s described an approach that was established at the General Electric Company (GEC) in America during the Second World War, had developed the shortage of a number of key raw materials and other resources but the alternatives couldnot satisfy the request of the community. Out of necessity the company began to search for new alternative materials and to substitute these wherever possible in their designs and processes.

The technique was continued after the war had ended as a try to minimize all the unnecessary costs from budgets, they found out that this method of function analysis generally produced cheaper products, fortunately without reducing the quality of the product (O'Brien, 1976).

The use of value engineering in the construction industry is supposed to have started in the USA in 1963. The use of the technique in that industry spread rapidly and by 1972 the US General Services Administration required that a clause on value management was to be included in all public sector construction contracts. The estimated cost savings reportedly ran into millions of Dollars (Ashworth, 2004).

5.3 Concept of Value Management

Value is defined by Dell'Isola (1988) as the most cost effective way to reliably accomplish a function that will meet the user needs desires and expectations.

The objective in value is not only to reduce costs but also to balance performance with cost. "Good value" is achieved when balance is obtained between quality and resources.

Mathematically value may express as a ratio of (Function + Quality) to the cost as realized by the owner, based upon his/her satisfaction (need & resources) in any given situation. This ratio is the principle measure of value and it may be expressed as follow:

$$\text{Value} = (\text{Function} + \text{Quality}) / \text{Cost} \quad (5.1)$$

Where,

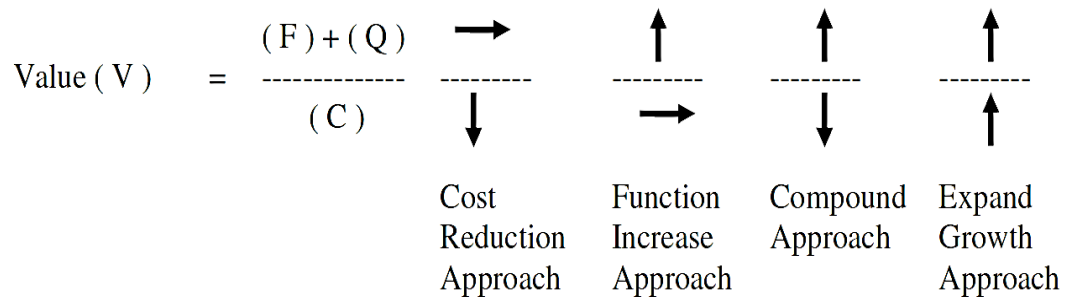
The function is specific work that a design / item must achieve;

Quality is the owner's requirements and expectations of the finished project;

Cost represents the life cycle cost of product / construction project;

Therefore, we can say that value is "the most cost-effective way to reliably accomplish a function that will meet the user's needs, desires and expectations" (Dell'Isola, 1988).

As such, value can be increased while maintaining the quality by the following approaches:



- i. Decreasing the cost with the constant function;
- ii. Increment the function with no change in cost;
- iii. Increment the function with reduction of cost;
- iv. Increment the function significantly with the small addition of cost (Che Mat M. M., 2002).

The term value management can be described in many ways such as:

Kelly and Male (1993) quoted Burt (1975) who stated that maximum value “is obtained from a required level of quality at least cost, the highest level of quality for a given cost or from an optimum compromise between the two”.

Value management is a technique used to define what ‘value’ means to a client and make framework with the project stakeholders to produce a clear statement of the project objectives (Che Mat M. M., 1995).

“A structured technique to define what value means to a client in meeting a perceived need by clearly defining and agreeing project objectives and how they can be achieved” (Connaughton & Green, 1996)

Value management as an oriented effort to achieve optimum value in product, system or service by providing the necessary function at the lowest cost (Kelly & Male,

1991). In other words, value management requires multidisciplinary approach which aims to solve the problems, reduce costs that can be applied during the objective setting, concept, design and construction stages and the ongoing management of buildings (SAVE, 2006). The purpose of value management exercise to achieve optimal value which gives crucial functions at the lowest cost without impact on quality and performance.

5.4 Comparisons of Value Engineering & Value Management

Whilst it is being considered by some commentators that there is no real distinction between value engineering and value management and the practitioner tend to use the name with which they feel most comfortable, the principles and methodology of the two are not exactly the same, although, well documented principles of value engineering provides basis for the methods of value management, shown in Table 3 (Neap, 1999).

Table 3: Comparison between Value Management and Value Engineering

	Value Management	Value Engineering
Definition	Value Management “is an organized work for best value and cost of project without ignoring the optimal performance levels. It is an inspired way of team working to accomplish clients and stakeholder’s needs”	Value Engineering “is a management technique using a systematic approach to achieve the functional balance between cost, and performance of a product” (Dell’Isola, 1988).
Objective	to maximize functional value of a project	To achieve the necessary functions for minimum cost of project
Subjects for discussion	Project proposal, existing design	Existing design
Timing of application	From the concept to occupancy of the project	During design and construction stage

Value improving approach	It integrates client's subjective and objective value criteria	It generally assumes that value can be improved by reducing cost
Best solution	It decides on the best solution based on client's value system	The best solution, usually, is the most economical

Source: (Liu, 2003)

5.5 Value Management Application

Value management is a service which raises the functional value of a project and this service is achieved through the "Job Plan" which it was firstly proposed by Miles in 1961 and it represents the discipline or structure of the system similar to the plan of work which architects use (Kelly & Male, 1993).

There are a number of standardized value management job plans, depending on the country and/or organization; every value manager develops his own variation of the job plan. The job plan should be perceived as a foundation on which every specific value study is developed, depending on the project to be tackled (Thiry, 1997).

The principal phase of a value management application (Job Plan), proposed by Miles are:

Phase 1: Orientation

Phase 2: Information

Phase 3: Speculation (creativity)

Phase 4: Analysis (evaluation / judgment)

Phase 5: Program planning (development)

Phase 6: Program execution (presentation)

Phase 7: Conclusion (feedback)

And each is discussed as follows:

5.5.1 Orientation

It is the introductory phase when it is being decided just what is to be accomplished. It will seek to separate the client's needs from the client's wants and to establish what is to be accomplished and the desirable characteristics of the proposed project. And it is a meeting or meetings chaired by the value engineer for the project and attended by the design team and those who have an interest or possess some ownership of the problem being addressed to enable everyone who is involved in the project to understand the problems and constraints (Ashworth, 2004).

5.5.2 Information

In this phase as much as possible of the information relating to the project is collected together. The aim of this is to find the functions of the whole or parts of the project. Information must be taken from the best possible sources to obtain the suitable quality of decision making and no assumption is advised (Kelly & Male, 1993).

In brief this phase secures all costs, quantities, drawings, specifications, manufacturing and construction approaches, samples and prototypes. Specific information like, client needs, client wants, project constraints, budgetary limits and time for design and construction is gathered (Kelly et al., 2004).

5.5.3 Speculation (creativity & idea generation)

This phase is most important in whole stages of value management as it seeks to provide alternatives technical solutions to the functions identified. Here, the team, still in the workshop environment generate random idea, without evaluation.

The aim of this phase is to create every possible solution to the identified problem and record all proposals (Kelly et al, 2004).

5.5.4 Analysis (evaluation / judgment)

This phase a crude filter for reducing the ideas that have been created to a manageable set of propositions. The role of value management team at this phase is to discuss the selected ideas and weigh both advantages and disadvantages and what has been suggested and eliminate the various options using appropriate evaluative techniques like idea comparison and cost comparison, many of which depend upon some form of weighted assessment to eliminate the various options. If any one of the ideas did not fulfill the criteria, the team will go back to the previous stage (Ashworth, 2004).

5.5.5 Development

“The objective of this phase is to select and prepare the “optimal” alternative(s) to enhance value. The alternative proposal is estimated preferably its life cycle cost that includes not only initial cost but operation and maintenance during its economic life span. Besides writing the final recommendations for the chosen alternatives, this procedure will also involves a full technical, economic evaluation with considering the probability of successful application” (Macedo, Dobrow, & O'Rourke, 1978).

5.5.6 Presentation

The refined ideas supported by drawings, calculations and costs are presented by the value management team to the body which commissioned the value management exercises (Ayorlo, 1995).

5.5.7 Conclusion (feedback)

The final phase involves presenting the findings to the client. Throughout the whole process the client will have been kept informed about progress and possible solutions.

The final result should not therefore present the client with any unwanted surprises (Ashworth, 2004).

5.6 Value Management Techniques

This section explains major techniques used in value management, namely function analysis method, life cycle costing and function analysis system technique.

5.6.1. Function Analysis Method

The analysis of function has been considered important for at least two thousand years. The analytical description of function is more recent and it has two apparently unrelated sources. One can be followed to the operational technique of objectives hierarchies and the second to functional analysis diagramming developed within the framework of value management (Kelly & Male, 1993).

Functional Analysis (FA) is a specific technique or methodology used to establish objectives and to eliminate uncertainty. It focuses the mind on the price task in hand, and sets targets for the creative problem solving techniques to follow. Functional analysis is at the heart of value management and is fundamental aspect which distinguishes it from other decision-making process (Ayorlo, 1995).

In functional analysis method, component is defined as a single manufactured item, for instance a brick, a hinge, a gear wheel, a length of pipe, a switch, or as a unit comprised of a number of components, such as a window, a door, a roof truss, a

wash basin, a kitchen unit. An element is defined as a unit of construction that fulfills a specific function or functions such as a window, an external wall, a floor. Functional analysis is a powerful technique in the identification of the key functional requirements of a project. However, the techniques for diagramming or other forms of representation lie within the skills and experience of the value manager (Neap, 1999).

5.6.1.1. Characteristics of functional analysis

1. **Verb/Noun Definition:** Most texts recommend that the function of an item or a system be expressed in as brief a phrase as possible, ideally one containing just a verb followed by a noun.

For example, the functions of a foundation of a structure are to support columns, to transfer loads to increase stability (Kelly & Male, 1993).

The typical active verb and measurable noun relationships are:

Door: control (verb) access (noun)

Vehicle: Transport (verb) People (noun)

Washing machine: Remove (verb) Dirt (noun)

Bulb: Provide (verb) Light (noun)

Pen: Enable (verb) Writing (noun)

Steering wheel: Control (verb) Direction (noun) (Leeuw, 2001).

2. **Functional Definition/Technical Solution:** A technical solution to a problem is represented by an element or component. For instance, where light is required in a room, a technical solution is to install an electric light bulb. To search for alternatives to a technical solution functional definition should be realized. Therefore, for the above example;

Functional definition: Light is required in a room.

Technical solutions: Install an electric light, install a sheet of transparent material, install a gas light, etc.

3. Basic /Secondary Functions: Basic functions describe the primary utilitarian characteristic of a product or design to satisfy a user's need. Secondary functions are those which are a characteristic of the technical solution chosen for the primary/secondary functions should be seek in order to fully understand a problem (Kelly & Male, 1993).

For instance, the basic function of a match is to generate flame. The phosphorus tip is classified as a basic function. No flame can be generated without the tip (Dell'Isola, 1997).

4. Cost/Worth "Cost is the price paid or to be paid", worth is defined "the least cost to perform a required function".

The main assumption in functional analysis with respect to cost/worth appreciation is that secondary functions have zero worth, as by definition, the project does not fail if a secondary function is omitted. The task, therefore, is to correctly identify the basic functions.

For example, consider a door within a fire-check partition in a plant room area and also consider a door within a fire-check partition between an office and the foyer of a quality hotel. Door within a plant room area;

Basic functions: maintain access, prevent the spread of fire

Technical solutions: a fire-check door which is open for access and automatically closed in the case of fire to prevent fire spread.

Maintain access function is worth the amount required to form a hole in the partition and prevent the spread of fire function is worth the amount paid for the least expensive fire-check door and automatic door closer. Design solutions should be checked against the worth. Alternative technical solutions which could cost less than the worth could be found through the creativity process.

Door between an office and the foyer;

Basic functions: establish access, restrict access, prevent the spread of fire, contribute to aesthetic environment, and insulate office from foyer.

Technical solutions: a fire-check door which has an acceptable aesthetic standard.

Establish access, prevent the spread of fire and insulate office from foyer could be provided by the least expensive fire-check door, and the cost of the door is their worth. The worth of the function, restrict access, is zero because the door could be placed behind the reception counter. Again other alternative solutions could be created for costs less than the worth established (Neap, 1999).

5.6.1.2. Function Analysis System Technique (FAST)

Charles Blythway in 1968 developed function analysis into a complete technique for logically linking functions; this technique became to be known as Function Analysis System Technique (FAST) (Dallas, 2006). The technique is described as having a

4. Support the process of generating creative alternative solutions (Crow, 2002).

5.6.2. Life Cycle Costing

A method used to evaluate the total cost of ownership over an economic life expressed in equivalent currency (i.e. in Dollars). In other words it is a technique for economic evaluation of alternatives. It is a cost focused engineering economic analysis whose objective is to systematically determine the costs attributable to each of one or more alternative courses of actions over a specified period of time.

5.6.2.1 Value Management Using Life Cycle Costing

The value management using the life cycle cost analysis study concerns with the establishment of the goal of ensuring that the correct economic and performance criteria are followed, all feasible alternatives are studied along with their associated costs and performances, and the results of the study, including alternative selection, truly reflect both the economic reality of the design situation and the wishes and policies of the organization for which the study is conducted (Naim, 2006).

General steps of value management using life cycle cost analysis study can be listed as follows;

I. Identifying economic criteria

In this step the economic criteria used is explained as, the economic approach, project life cycle, discount (interest) rate, present time, Inflation, cost growth and cash flow.

II. Generating design alternatives

Using creativity techniques, like brainstorming, alternatives are generated for the project.

III. Life cycle cost analysis

Present worth method is used making life cycle cost analysis.

IV. Weighted evaluation

To include non-monetary benefits which might be of interest to the decision makers, the alternatives therefore are assessed by the weighted evaluation technique. The procedure for weighted evaluation consists of criteria identification and weighing and evaluating the alternatives to the criteria selected.

V. Risk assessment

Economic risk assessment could be made by using different approaches. Confidence index and sensitivity analysis approaches can be used for risk assessment. That has been mentioned in chapter IV.

VI. Ranking and selection

The final step consisted of ranking the four alternatives on the basis of the previous calculations. It also gives the benefit-to-cost ratio for each alternative. Benefit-to-cost ratio is calculated by dividing the benefit score by the life cycle cost (Neap, 1999).

5.6.3. Simple Multi-Attribute Rating Technique (SMART)

Simple multi-attribute technique is a soft-system approach of weighted evaluation technique used in value engineering. SMART method to value management is based on client's value system and completely consistent with the design workshops to ensure user contribution in the design of buildings. Main contribution of SMART to value management is the method in which it provides a framework for facilitating thought and communication. This is particularly important when responsibility is shared within a group of different value systems (Neap, 1999).

Stages of SMART methodology in value management can be summarized as follows:

5.6.3.1 Information

At this stage, decision makers are identified, and they are represented at senior level in the meetings.

5.6.3.2 Objectives

Each shareholder is invited to discuss his/her initial understanding of the problem and the related design objectives. Differences are discussed until an agreed list of key objectives can be produced.

5.6.3.3 Value Tree

The aims listed in stage 2 are structured into a value tree. It is often necessary to limit the number of attributes to a manageable level. This can usually be achieved by removing those which do not directly the choice of outline design.

5.6.3.4 Assignment of Importance Weight

The importance weights are evaluated for each branch of the value tree. It is calculated by multiplying the final weights through the tree, and the weights are checked for consistency.

5.6.3.5 Utility Assignment

Each outline option is then assessed against each attribute on a scale of 0 to 100. A decision matrix is then used to get a collected utility assessment for each design option.

5.6.3.6 Sensitivity Analysis

The results of the utility assessment phase are tested to changes in the chosen importance weights and utility scores by the use of a sensitivity analysis.

5.6.3.7 Cost/Value Reconciliation and Selection

The estimated capital cost of each proposal is compared with the combined usefulness evaluations, and the decision is made as to which design option represents the highest value for money.

5.6.3.8 Marginal Improvements

A brainstorming session is then held to generate ideas of how the cost of the chosen option could be reduced without compromising the design utility rating (Neap, 1999).

Chapter 6

DEVELOPING A COMPUTER SYSTEM IN VISUAL BASIC 2010 FOR LCCA

6.1 Introduction

Most of the construction clients have little experience or knowledge about economic analysis of a project. Therefore many projects are constructed without considering economic analysis of costs for the whole life of building. This causes waste and unnecessary costs to the construction of the buildings, and the owners might become unsatisfied with the project.

LCCA is a useful technique for comparing different project alternatives that meet the same performance requirements, but differ with respect to the costs during all stages of the project. On the other hand, some problems have been observed by using LCCA techniques such as time consuming, percentage of errors, difficulties and sometimes inaccurate results due to mistakes in hand calculations. In order to overcome these problems, this research suggests to develop a computer software for LCCA for construction projects. Therefore, computer system was developed by using MS Visual Basic 2010 to facilitate this function for users. This system was designed to be simple and the results of the analysis to be obtained in a relatively short time.

This chapter focuses on the life cycle cost analysis for projects with different types of costs and discount rates using present worth method. Also, this chapter highlights the use of computer tools to train users in selecting the best design alternative, not only based on choosing the lowest initial costs, but also considering all the life cycle costs. The manual and computer calculations will be explained in details in this chapter.

6.2 Microsoft Visual Basic 2010

“It is a powerful Integrated Development Environment (IDE) from Microsoft which can be utilized to develop control and graphical user interface (GUI) applications along with Windows Forms applications, web sites, web applications, and services for all platforms supported by Microsoft Windows”. Visual Studio provides many application templates to help user to create programs, and several programming languages such as Visual Basic, Visual C#, Visual C++, Visual F#, Windows applications, Web applications, Office applications and SharePoint applications (Microsoft Corporation, 2012).

Visual Basic 2010 is part of the Visual Studio 2010 family. It is Microsoft’s latest incarnation of the extremely popular Visual Basic language, and it is basically different from its prior. Visual Basic (VB) is a high-level programming language that can read inputs, calculate results, display outputs to the user, and perform other operations typical of high-level programming languages (Foxall, 2010; Stephens, 2011)

MS VB 2010 “is an important improvement and enhancement of the popular Visual Basic programming language and compiler, it is a technology that enjoys an installed

base of millions of programmers around the world. VB is not an independent producer but a key component of MS Visual Studio 2010 and an inclusive development system that helps to achieve powerful applications of Windows, the web, handheld devices, and a host of other environments” (Halvorson, 2010).

The language feature for Microsoft Visual Basic is easily to be learned and used by beginner programmers. The language designed not only for beginner programmers to create simple graphical user interface (GUI) applications, but also achieve complex applications. Visual Basic has new features that shorten syntax and enable the user to write code faster. The positive issue with Visual Basic is that, it is a popular language due to ease of learning and widely availability (Casuncad, 2011) and it is also powerful enough to satisfy the needs of experienced programmers.

The Microsoft Visual Basic 2010 interface contains many of the traditional elements of Microsoft Office applications. However, the Visual Basic 2010 interface contains elements that facilitate project management and enhances a user’s ability to develop projects.

6.3 Life Cycle Cost Template

Life cycle cost process is heavily information dependent. Therefore, well-maintained and organized data is essential to support the timely control of project. With the large amount of information related to resources and operations, it is sometimes difficult to obtain and organize such information either because of the limited time or the inefficient methods of data collection and organization. Thus, to improve the quality, integrity, and timeliness of construction data is a well recognized need. Thus, a

template based on Microsoft Visual Basic 2010 for the calculation of life cycle cost has been developed.

The following template has been developed to help users in determining the Life Cycle Costs for economic investments. The advantages of this program are being freeware application together with user-friendly interface and rich multifunctional environment for coding and designing the program. In this program, it is assumed that a positive cost means expense and a negative cost means profit.

The program starts with “Template of Life Cycle Cost Analysis” window as shown in Figure 14. In this window, the user will select the type of project, either a new project (create a new project and start working with LCCA) or an existing project (editing or continue working on an available (or existing) project).

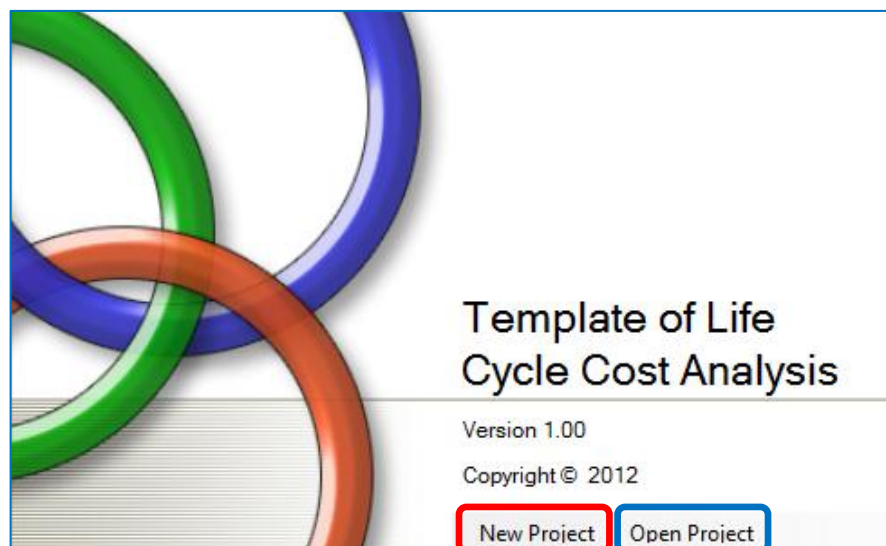
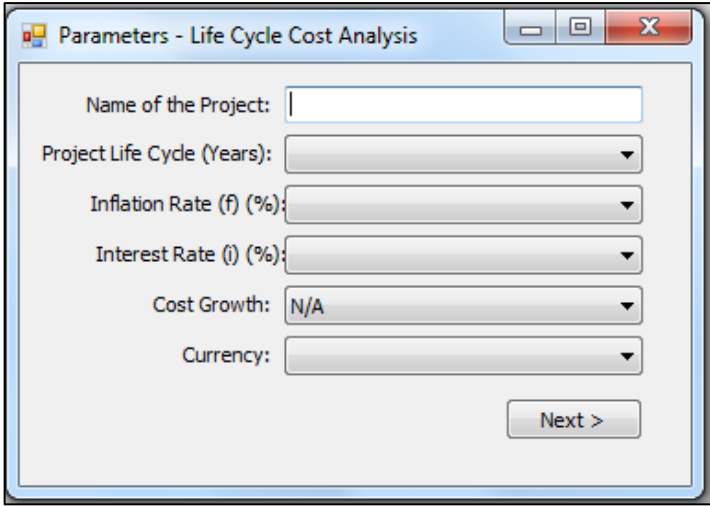


Figure 14: Template of Life Cycle Cost Analysis

After choosing the project type, a new window called the “Parameters - Life Cycle Cost Analysis” will be opened, as shown in Figure 15. Some general information about the selected project should be filled in this window, these information include:

1. **Name of the Project:** The program will create a folder with this name to save the files.
2. **Project Life Cycle (Year):** Service life of the project expressed in year.
3. **Inflation rate (f) (%):** Expressed in percentage which is the rate of increase in the prices of goods and services usually considered annually.
4. **Interest rate (i) (%):** interest rate or rate of return per time period; given as percent per year.
5. **Cost Growth:** is an increase or decrease in the price of an individual item with or without a corresponding increase or decrease in value. In this program, the cost growth is neglected and assumed to be zero.
6. **Currency:** the user can choose a suitable currency based on implementation of the project such as (TL, \$, £, € and other). The last one means that the user can use any currency.



The image shows a software dialog box titled "Parameters - Life Cycle Cost Analysis". It contains the following fields and controls:

- Name of the Project:** A text input field.
- Project Life Cycle (Years):** A dropdown menu.
- Inflation Rate (f) (%):** A dropdown menu.
- Interest Rate (i) (%):** A dropdown menu.
- Cost Growth:** A dropdown menu with "N/A" selected.
- Currency:** A dropdown menu.
- Next >** A button at the bottom right.

Figure 15: Parameters - Life Cycle Cost Analysis

After entering the basic information of the project, the user should click on “Next”. Then a new window, “Life Cycle Cost Analysis” will be opened, this window contains inflated interest rate value (i_f) which can be used to adjust the interest rate

to account for inflation, also it contains all the costs associated with life cycle cost like initial cost, replacement cost, maintenance cost, operations cost and salvage cost, as shown in Figure 16.

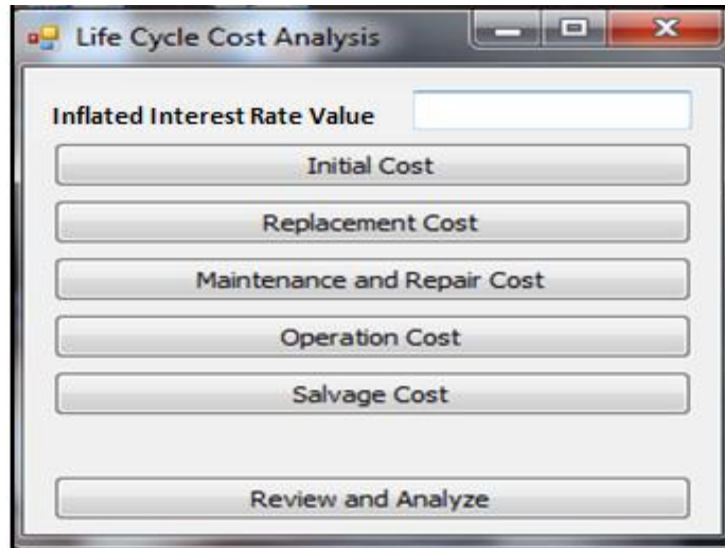


Figure 16: Life Cycle Cost Analysis

The costs and explanation about how to calculate them are as follow:

- **Initial cost:** is the capital cost that includes all equipment and installation costs as well as cost of land if applicable, and is represented as (P).

When the user clicks on “Initial Cost” on “Life Cycle Cost Analysis” window, a new window will appear which is called “Initial Cost”. In order to calculate this cost, the user has to enter the entire information given in the bill of quantities such as description for each item, unit type, quantity and unit cost. This table has an extra column for any notes, as shown in Figure 17.

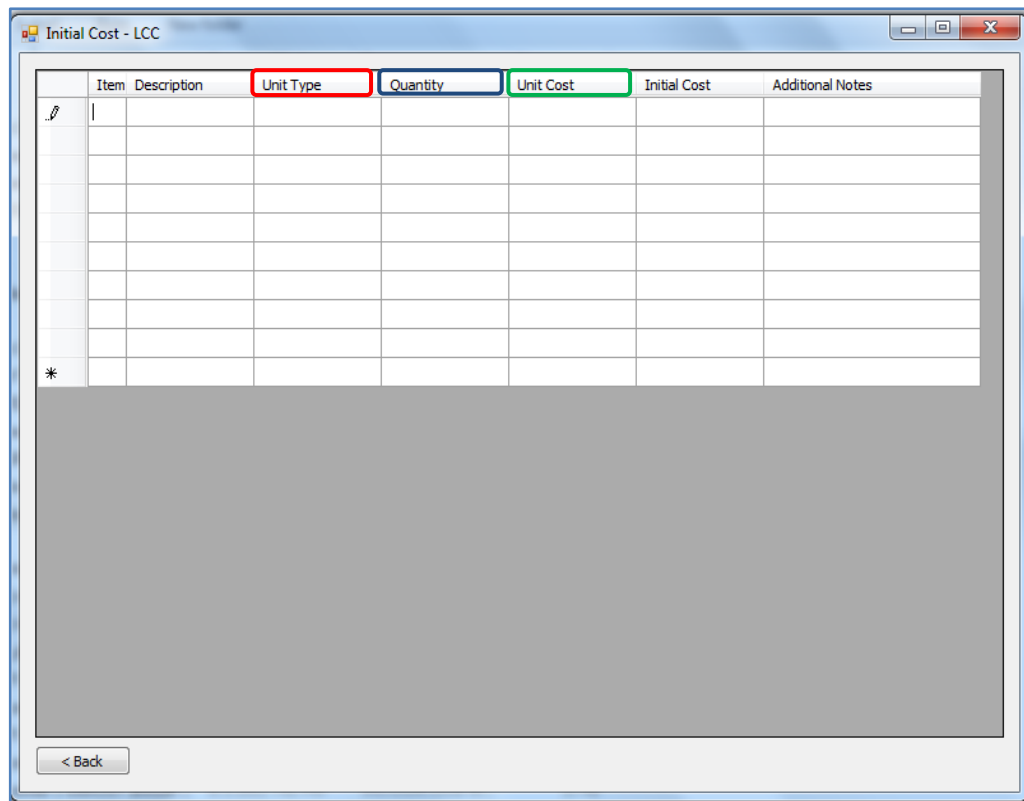


Figure 17: Initial Cost

- **Replacement cost:** is generally created by the replacement of a building system or component that has reached the end of its useful life.

After entering all the information related to initial cost, the user must return to “Life Cycle Cost Analysis” window and click on “Replacement Cost”, which will open a new window called “Replacement Cost”. In this window, if the item has replacement, the user should put a tick in front of this item and write every how many years the replacement will occur for the item and the amount of replacement cost as a percentage of the initial cost of the item, as shown in Figure18.

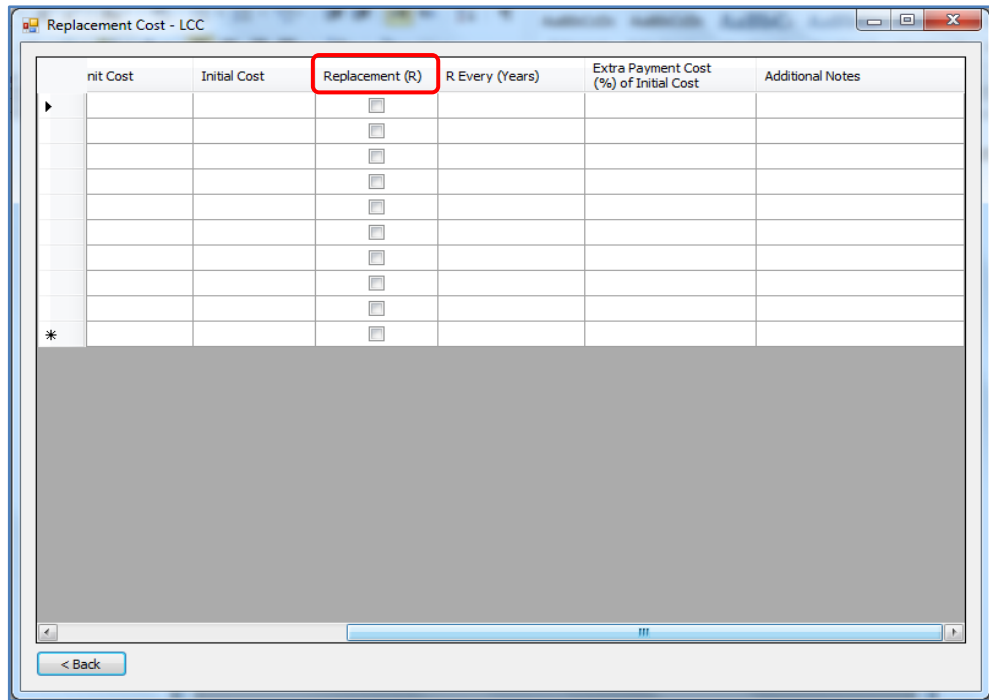


Figure 18: Replacement Cost

- **Maintenance and repair costs:** are commonly generated by the maintenance, repair and service; which include supplies and security, routine maintenance and repair.

After entering all the information of replacement costs, the user must return to “Life Cycle Cost Analysis” window and click on “Maintenance and Repair” Cost to open “Maintenance and Repair Cost” window. In this window, if the item has maintenance or annual maintenance, the user should put a tick in front of this item and write every how many years the maintenance will occur for the item and how much percent of the initial cost for the item, as shown in Figure 19.

As an advantage of this program, if there is a replacement cost and a maintenance cost in the same year for the same item, the program will eliminate the cost of maintenance and calculate the cost of replacement for that specific item. Also for

will occur for the item and its value as a percentage of the initial cost of the item, as shown in Figure 21.

To calculate the salvage cost for entire project, not only each item alone but also for all items of the project, the user should put tick in front of salvage cost for entire project and demolition cost at the top left of the window. A new sub window will open and the user must put a value for salvage cost or demolition cost expressing it as a percentage of the initial cost for the whole project. The salvage cost will be minus even if the user has not indicated it. The demolition cost will be summed up with salvage value, as shown in Figure 22.

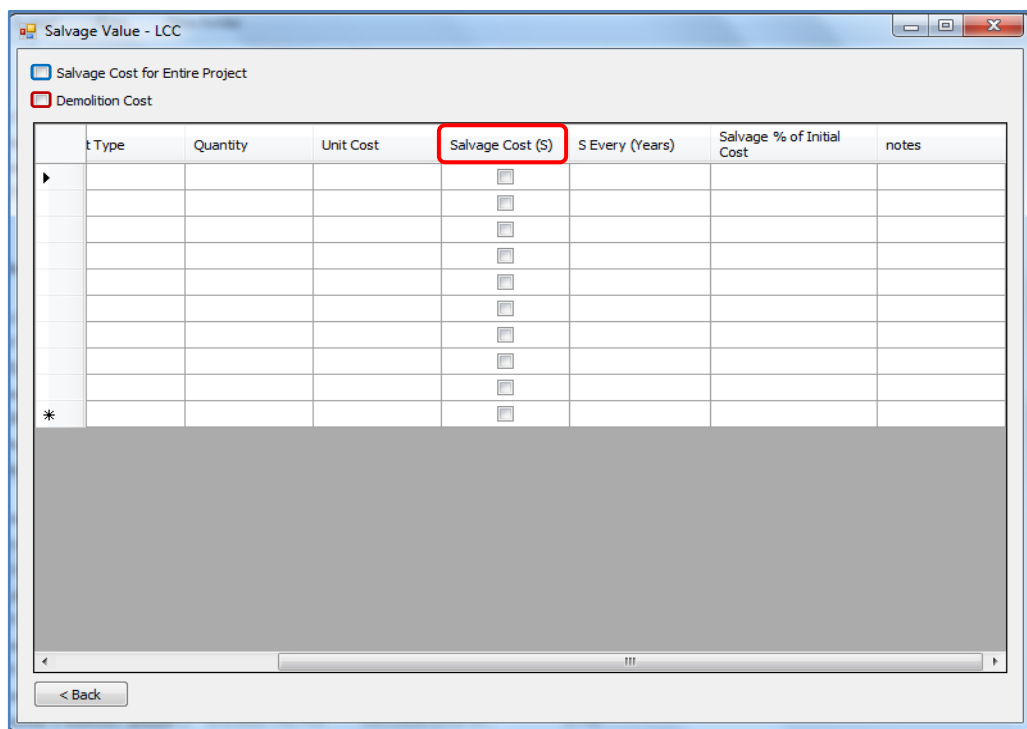


Figure 21: Salvage Cost for each item

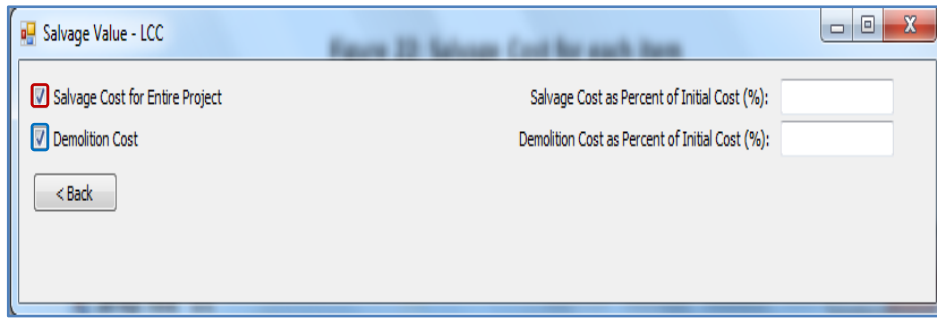


Figure 22: Salvage Cost for the entire project

After entering all the information of all the costs related to any specific project, the user must return to “Life Cycle Cost Analysis” window and click on “Review and Analyze”. In “Review and Analyze” window (Figure 23), the user can see the total cost of each item such as initial cost, replacement cost, maintenance cost, etc.

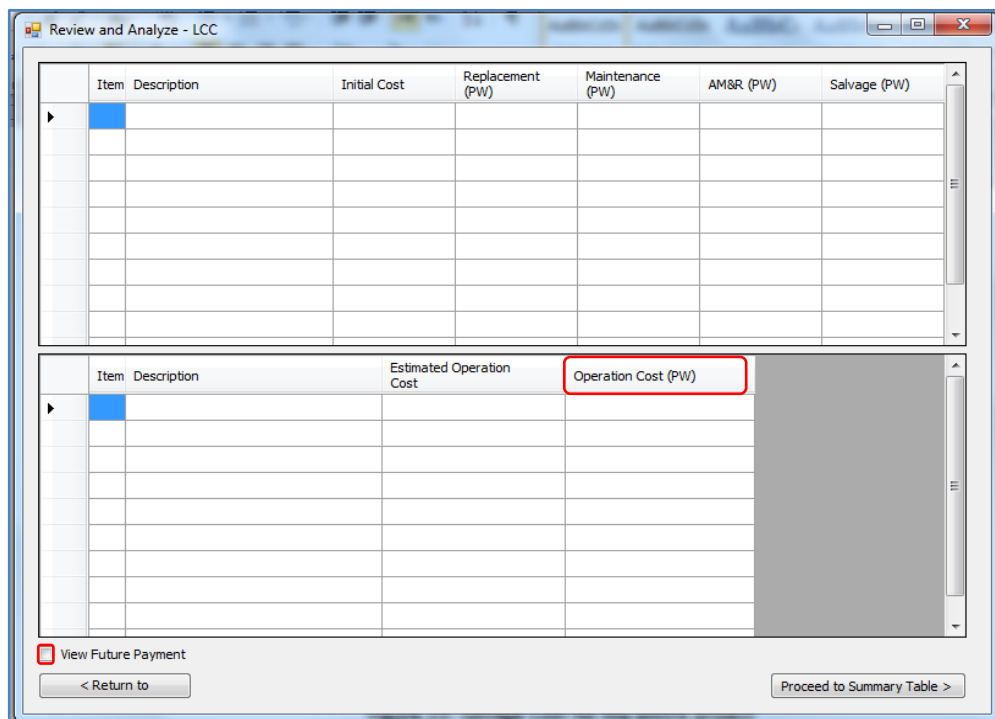


Figure 23: Review and Analyze (Present Worth)

To calculate the future payment for the project, the program is capable to calculate the results not only as present worth, but also as in future worth method, where the user should put tick in front of “View Future Payment” at the bottom-left of the

window. In this case, new columns will appear in the same window and the user will see all the results both in present worth (PW) and future worth (FW), as shown in the Figure 24.

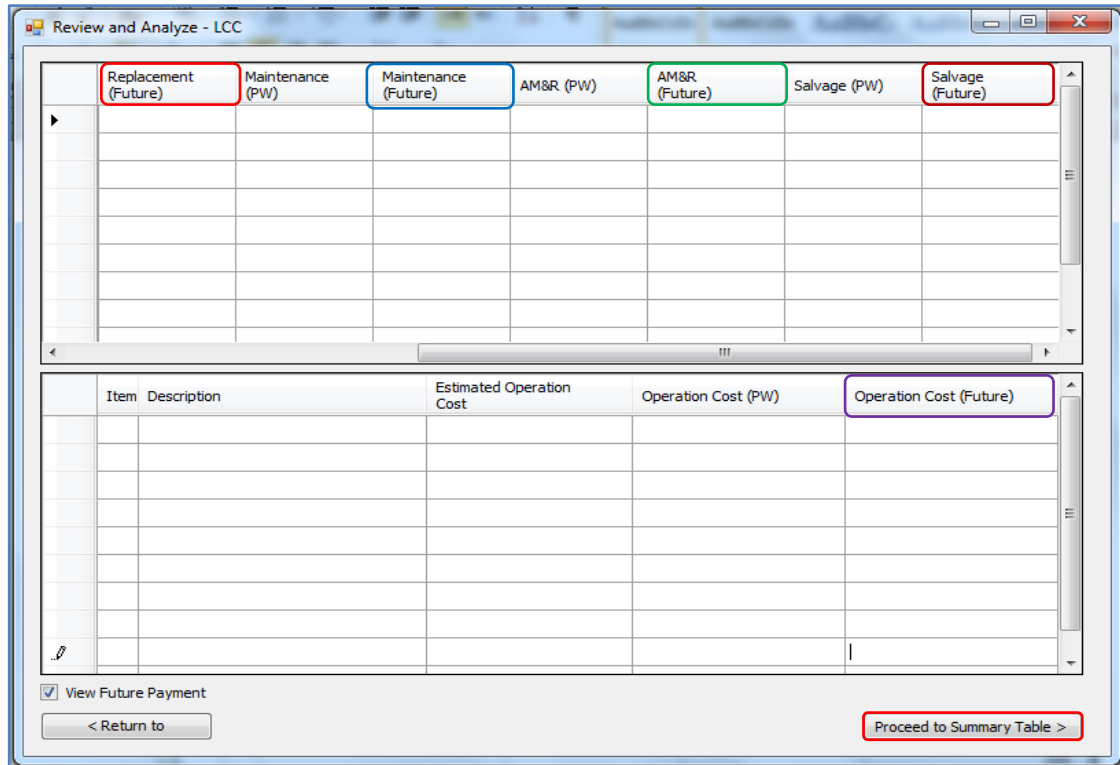


Figure 24: Review and Analyze (Future Worth)

After identifying all the results of both methods, the user must know the summation of these values for the project. For this purpose, the user should click on “Proceed to Summary Table” at the bottom-right of the window. “Summary Table” window will then be opened, in which the user will see the total costs for project including total initial cost for the project and total replacement for entire project, etc. Also, in this window, the summation of the total costs in both present worth and annualized cost will be provided, as shown in Figure 25.

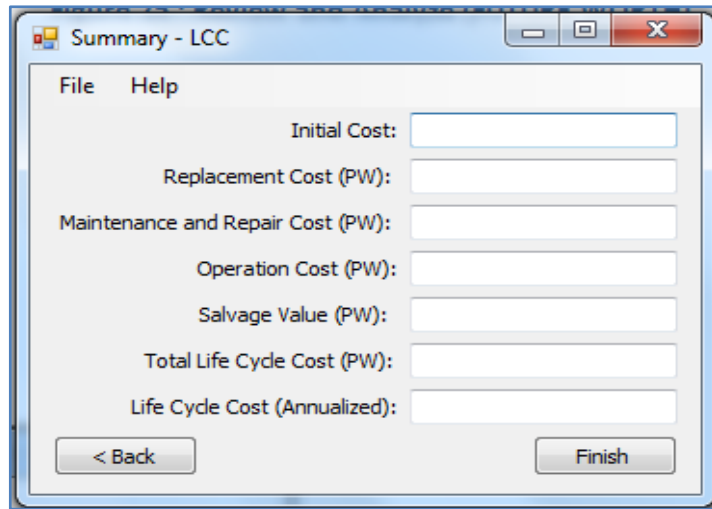


Figure 25: Summary Table

After completing the calculation of all the costs of the project during its service life, the user must save the data. This work can be done by clicking on “Finish” at the bottom-right of the window, or selecting “Export Database” from the “File” menu at the top of the window in the tool bar which will save information on the computer, as shown in Figure 26.

“New” command in “File” menu is used when the user wants to analyze a new project. This command can be used instead of closing the program and opening it again.

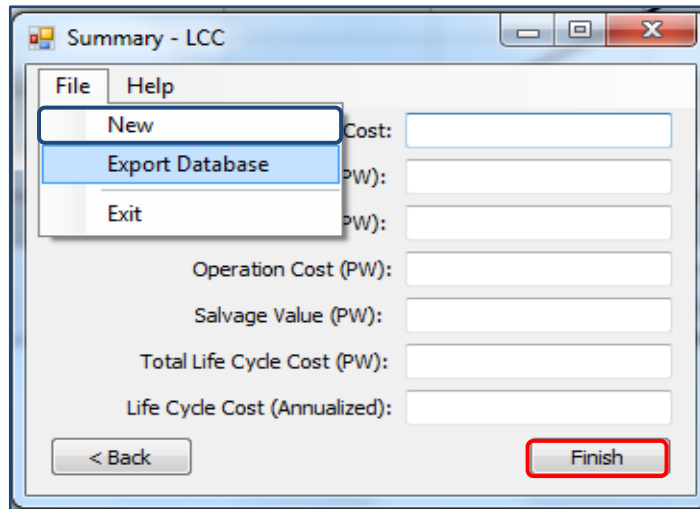


Figure 26: Summary Table (“File” menu)

6.4 Case Study

‘Building of Student Activity Center’ of Eastern Mediterranean University in North Cyprus has been selected in order to test the program and verify the authenticity and accuracy of the results.

The data used in this study were obtained and collected from the director of Technical Affairs Department, and the section chief of installations, technical services office in the Technical Affairs Department of Eastern Mediterranean University (Hamed et al., 2012).

Student Activity Center building shown in Figure 27 is located in Eastern Mediterranean University, close to university main gate. The construction was completed in January 2002. The single story building is approximately $1906m^2$.

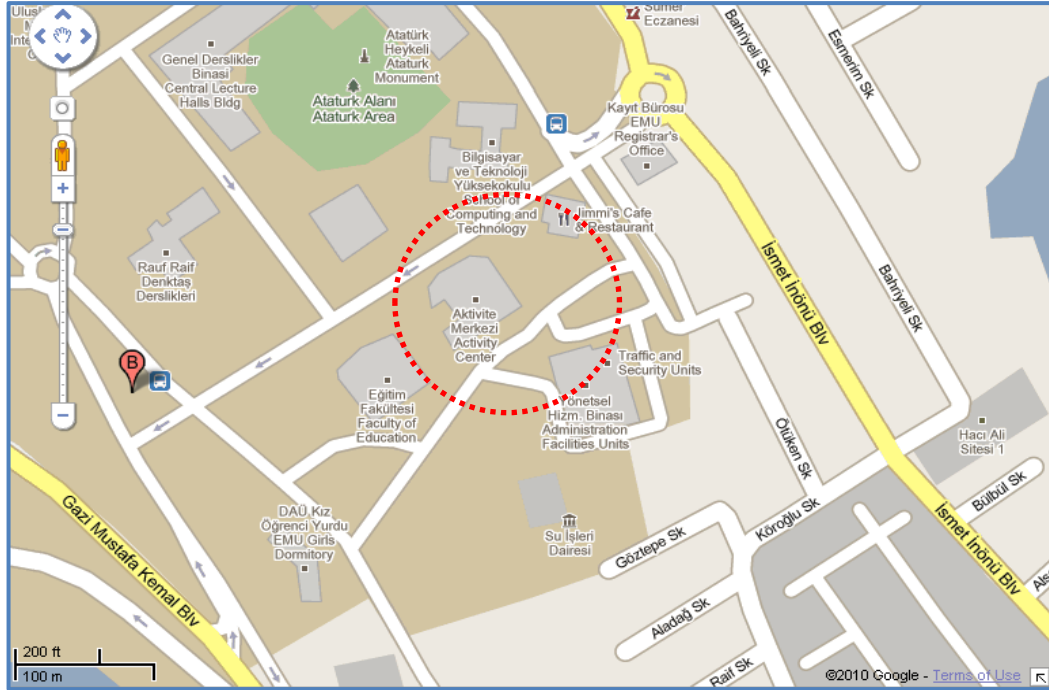


Figure 27: Activity Center, Eastern Mediterranean University

Activity Center was constructed to function as multi non-academic purposes in order to present the student activities like seminars, after school clubs, photograph exhibitions, gatherings, student music and dance performances, and special events. Furthermore, all international university activities are programmed and delivered in this center.

The building is divided to different spaces such as; administrative offices, multi-functional hall with 250 person capacity, stage with back stage room, billiard club, computer lab, storages, change rooms for males and females, meeting room, court yard, open corridor, dark room, acoustic room, lobby and music rooms. There are eleven employees in the center consisting of six staff, two research assistant and three cleaning staff (Hamed et al., 2012).

This study tried to assess the Life Cycle Cost Analysis (LCCA) of the Activity Center building of 60 years life time upon life cycle cost fundamentals like time value of money, basic equivalent economic approaches, inflation and all relevant costs correspondingly.

6.4.1 Application of LCCA for Activity Center and Testing of Developed Computer System

This section explains the calculation of life cycle costs including present worth and future worth of the selected project “Student Activity Center Building” at Eastern Mediterranean University. When the program is run, the user must select the new project option in “Template of Life Cycle Cost Analysis” window in order to start working with LCCA, as can be seen in Figure 28.

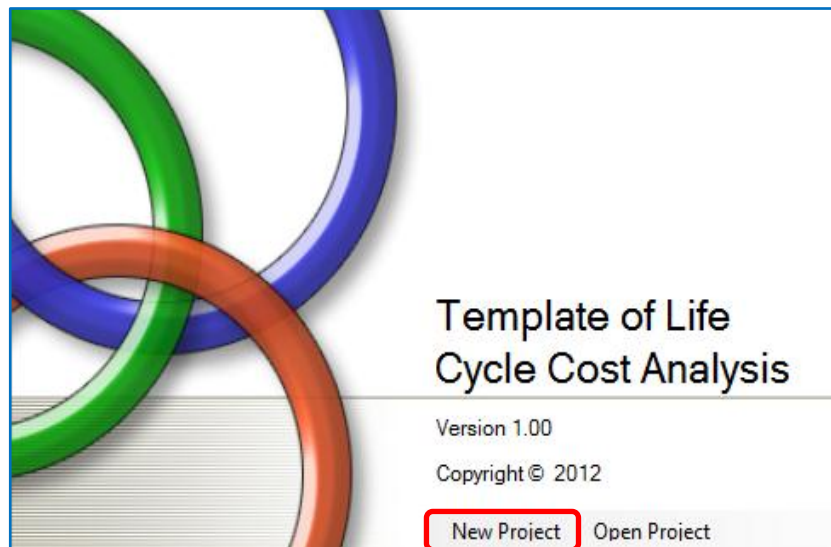


Figure 28: Template of Life Cycle Cost Analysis (Activity Center)

In this study, the service life of the building “n” is assumed to be 60 years. Moreover, the average inflation of Turkish Lira ‘f’ within 60 years is about 9% per annum and the interest rate of Turkish Lira ‘i’ is accepted as 8% given by Turkish central bank, as shown in Figure 29.

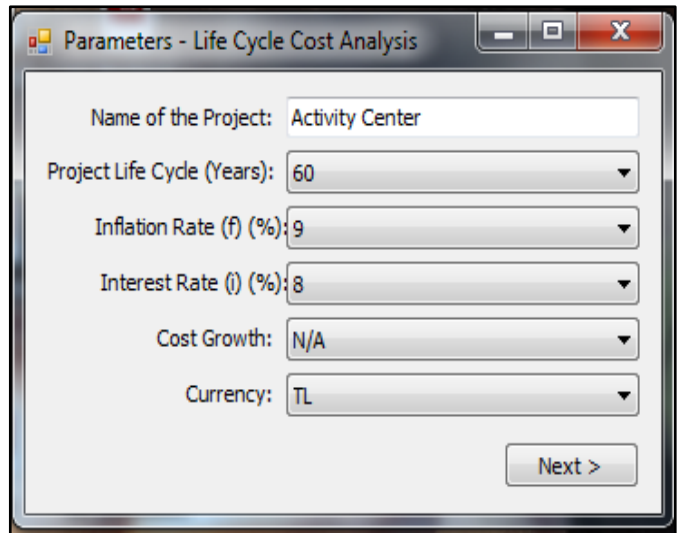


Figure 29: Parameters - Life Cycle Cost Analysis (Activity Center)

After entering the information related to the project in “Parameters - Life Cycle Cost Analysis” window, the user must click on “Next”, then “Life Cycle Cost Analysis” window will open which shows the inflated interest rate value. In the next step, all the costs related to life cycle cost such as initial cost, replacement cost, maintenance cost, operations cost and salvage cost should be entered and identified for the program as shown in Figure 30.

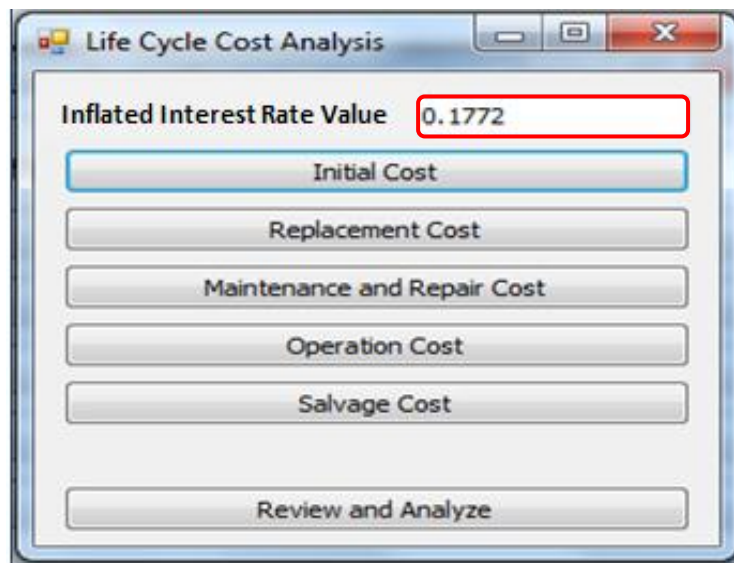


Figure 30: Life Cycle Cost Analysis (Activity Center)

All different costs related to design and construction of Activity Center were entered through “Initial Cost” as shown in Figure 31.

After finished entering initial cost, available and estimated replacement costs were entered based on the data obtained from the Technical Affairs Department, such as Air Conditioning System which is assumed to be totally replaced every 15 years with 10% extra payments over initial cost (Hamed et al., 2012), as shown in Figure 32.

After finishing entering all the replacement data, using “Back” button and returning to “Life Cycle Cost Analysis” window, maintenance and repair costs were entered through “Maintenance and Repair Cost” window. According to Technical Affairs Department - EMU, the external painting was considered to be renewed every 5 years with only 75% of initial external painting cost, also doors and windows were considered to be renewed in yearly based with only 0.35% of initial doors and windows cost, as shown in Figure 33.

In the next step and after entering all maintenance costs, all the estimated operation costs such as electricity consumption, water consumption, cleaning cost including cleaning materials and wages for employees (six administrative staff, three cleaning staff and two administrative assistants) which were obtained from Technical Affairs Department – EMU were entered as can be seen in Figure 34.

Item	Description	Unit Type	Quantity	Unit Cost	Initial Cost	Additional Notes
1	Project Design					
2	Fees	project	1	7500		
3	official fees %10					According the TRNC legislation...
4	Construction					
5	Cleaning and lev...	m3	227.7	5		
6	Compacted soil	m3	881.5	25		
7	Large Gravel	m3	341.5	50		
8	Concrete C25	m3	910.35	125		
9	Concrete C14 u...	m3	74	110		
10	Concrete C14 fo...	m3	228	110		
11	Steel	ton	91	1750		
12	Form Works	m2	5162	20		
13	Brick walls External	m2	1058	50		
14	Brick walls Internal	m2	2627	28		
15	Plastering	m2	6345	30		
16	Internal painting	m2	4995	15		
17	External painting	m2	1350	15		
18	Floor Tiling	m2	2021.4	30		
19	Skirting Tiles	m	3685	6		
20	Wall Tiling	m2	144	38		
21	Plumping Works	LS	1	193044.618		
22	Electrical Works	LS	1	321741.03		

< Back

Figure 31: Initial Cost (Activity Center)

Item	Description	Unit Type	Quantity	Unit Cost	Initial Cost	Replacement (R)	R Every (Years)	Extra Payment Cost (% of Initial Cost)	Additio
12	Form Works	m2	5162	20	103240	<input type="checkbox"/>			
13	Brick walls External	m2	1058	50	52900	<input type="checkbox"/>			
14	Brick walls Internal	m2	2627	28	73556	<input type="checkbox"/>			
15	Plastering	m2	6345	30	190350	<input type="checkbox"/>			
16	Internal painting	m2	4995	15	74925	<input type="checkbox"/>			
17	External painting	m2	1350	15	20250	<input type="checkbox"/>			
18	Floor Tiling	m2	2021.4	30	60642	<input type="checkbox"/>			
19	Skirting Tiles	m	3685	6	22110	<input type="checkbox"/>			
20	Wall Tiling	m2	144	38	5472	<input type="checkbox"/>			
21	Plumping Works	LS	1	193044.618	193044.618	<input checked="" type="checkbox"/>	10	1.5	
22	Electrical Works	LS	1	321741.03	321741.03	<input type="checkbox"/>			
23	A/C system	LS	1	428988.04	428988.04	<input checked="" type="checkbox"/>	15	10	
24	Landscaping	LS	1	17500	17500	<input type="checkbox"/>			
25	Water proofing	m2	2065.1	30	61953	<input checked="" type="checkbox"/>	10	5	
26	Steel Roof	LS	1	35000	35000	<input type="checkbox"/>			
27	Doors and Wind...	m2	803.246	187	150207.002	<input checked="" type="checkbox"/>	20	15	
28	Furniture	LS	1	250000	250000	<input checked="" type="checkbox"/>	20	10	
29	Site costs			0	0	<input type="checkbox"/>			
30	Mobilizations	LS	1	5000	5000	<input type="checkbox"/>			
31	Control	Annual	1	42000	42000	<input type="checkbox"/>			
32	Energy and Water	Annual	1	14400	14400	<input type="checkbox"/>			

Figure 32: Replacement Cost (Activity Center)

Item	Description	Unit Type	Quantity	Unit Cost	Maintenance (M)	M Every (Years)	% of Initial Cost	Annual Maintenance and Repair (AM&R)	AR&M Every (Years)	AM&R % of Initial Cost (%)
12	Form Works	m2	5162	20	<input type="checkbox"/>			<input type="checkbox"/>		
13	Brick walls External	m2	1058	50	<input type="checkbox"/>			<input type="checkbox"/>		
14	Brick walls Internal	m2	2627	28	<input type="checkbox"/>			<input type="checkbox"/>		
15	Plastering	m2	6345	30	<input type="checkbox"/>			<input type="checkbox"/>		
16	Internal painting	m2	4995	15	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	1.5
17	External painting	m2	1350	15	<input checked="" type="checkbox"/>	5	75	<input type="checkbox"/>		
18	Floor Tiling	m2	2021.4	30	<input type="checkbox"/>			<input type="checkbox"/>		
19	Skirting Tiles	m	3685	6	<input type="checkbox"/>			<input type="checkbox"/>		
20	Wall Tiling	m2	144	38	<input type="checkbox"/>			<input type="checkbox"/>		
21	Plumping Works	LS	1	193044.618	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	0.52
22	Electrical Works	LS	1	321741.03	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	0.85
23	A/C system	LS	1	428988.04	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	1
24	Landscaping	LS	1	17500	<input type="checkbox"/>			<input type="checkbox"/>		
25	Water proofing	m2	2065.1	30	<input type="checkbox"/>			<input type="checkbox"/>		
26	Steel Roof	LS	1	35000	<input type="checkbox"/>			<input type="checkbox"/>		
27	Doors and Wind...	m2	803.246	187	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	0.35
28	Furniture	LS	1	250000	<input type="checkbox"/>			<input checked="" type="checkbox"/>	1	0.22
29	Site costs				<input type="checkbox"/>			<input type="checkbox"/>		
30	Mobilizations	LS	1	5000	<input type="checkbox"/>			<input type="checkbox"/>		
31	Control	Annual	1	42000	<input type="checkbox"/>			<input type="checkbox"/>		
32	Energy and Water	Annual	1	14400	<input type="checkbox"/>			<input type="checkbox"/>		

Figure 33: Maintenance and Repair Costs (Activity Center)

Item	Description	Estimated Operation Cost
1	electricity consumption	66000
2	water consumption	13076.52
3	cleaning cost	12600
4	wages	476400
*		

Figure 34: Operation Cost (Activity Center)

After entering all operation costs, salvage cost must be entered to the program. In this project, the salvage cost for entire project was calculated by putting tick in front of salvage cost for the entire project and demolition cost at the top left of the window. According to Technical Affairs Department - EMU, the salvage cost was considered to be 40% of the initial cost (Altuntaş, 2004). The demolition cost was considered to be 4% of the initial cost according to Technical Affairs Department – EMU (Hamed et al., 2012), as shown in Figure 35.

Demolition cost is equal to zero when the owner decides to sell the building.

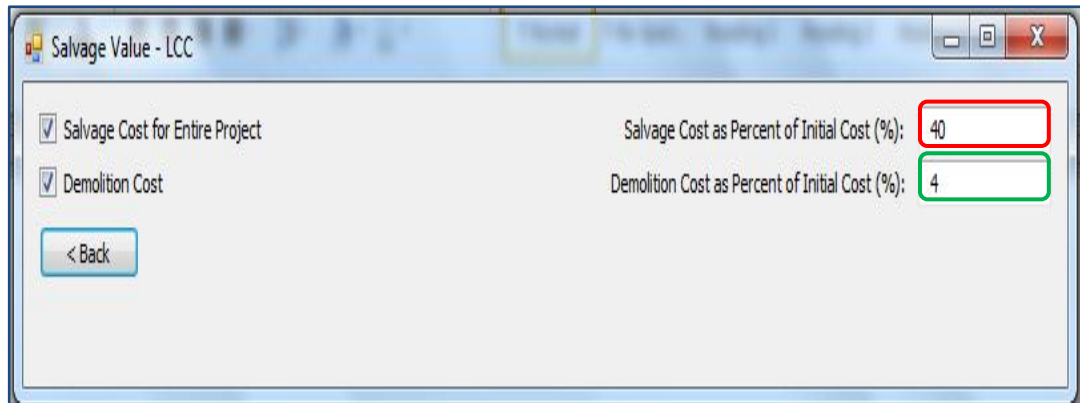


Figure 35: Salvage Cost (Activity Center)

After entering salvage cost, the user should click “Back” button and return to “Life Cycle Cost Analysis” window, to select “Review and Analyze” command, as shown in Figure 36. In this window, total cost in present worth for each item like the initial cost for each item, replacement cost and maintenance cost, etc. will be presented. By selecting “View Future Payment” option a new columns will be added in the same window, showing present worth (PW) and future worth (FW) for entire project, as shown in Figures 37, 38, and 39.

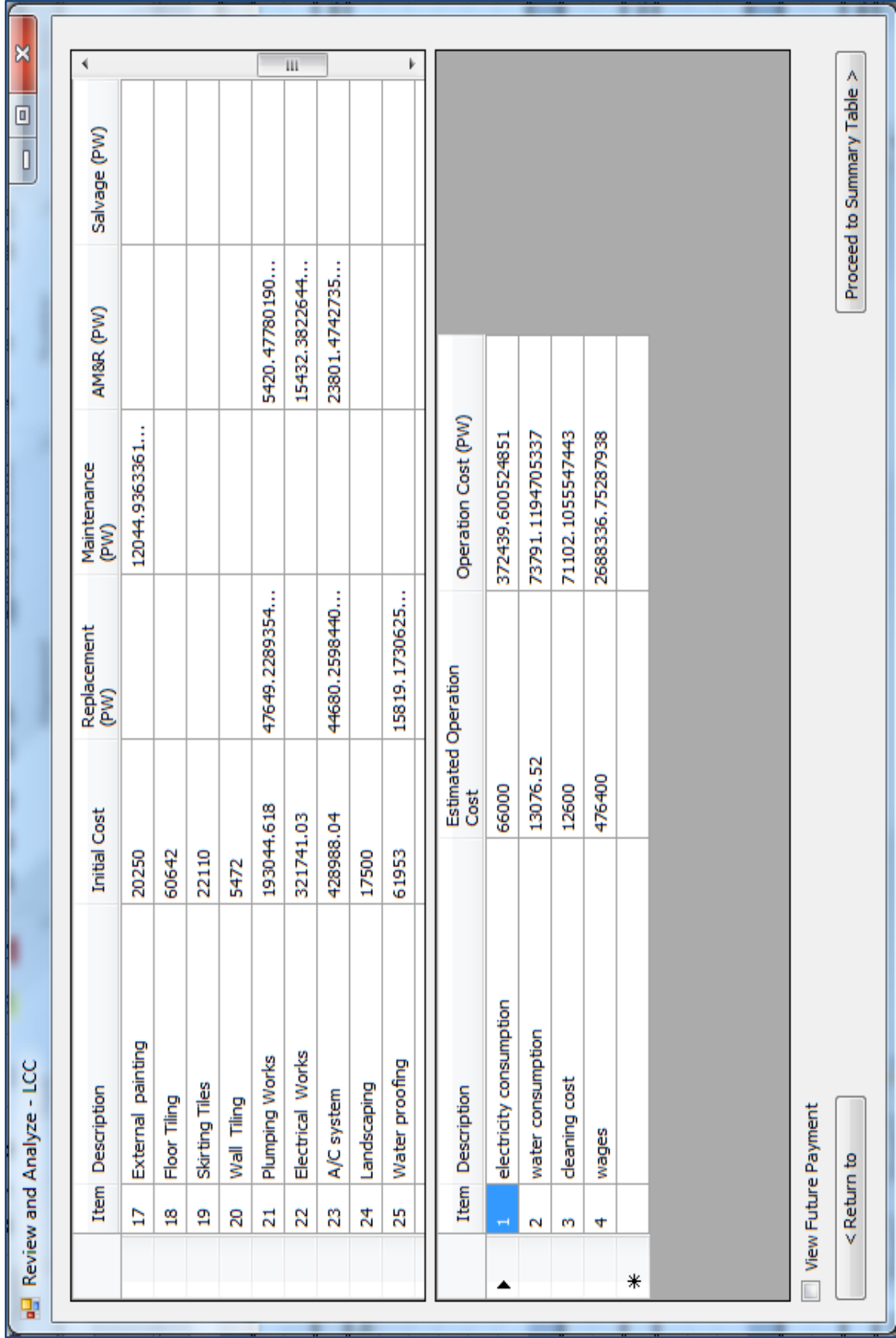


Figure 36: Review and Analyze (Present Worth-Activity Center)

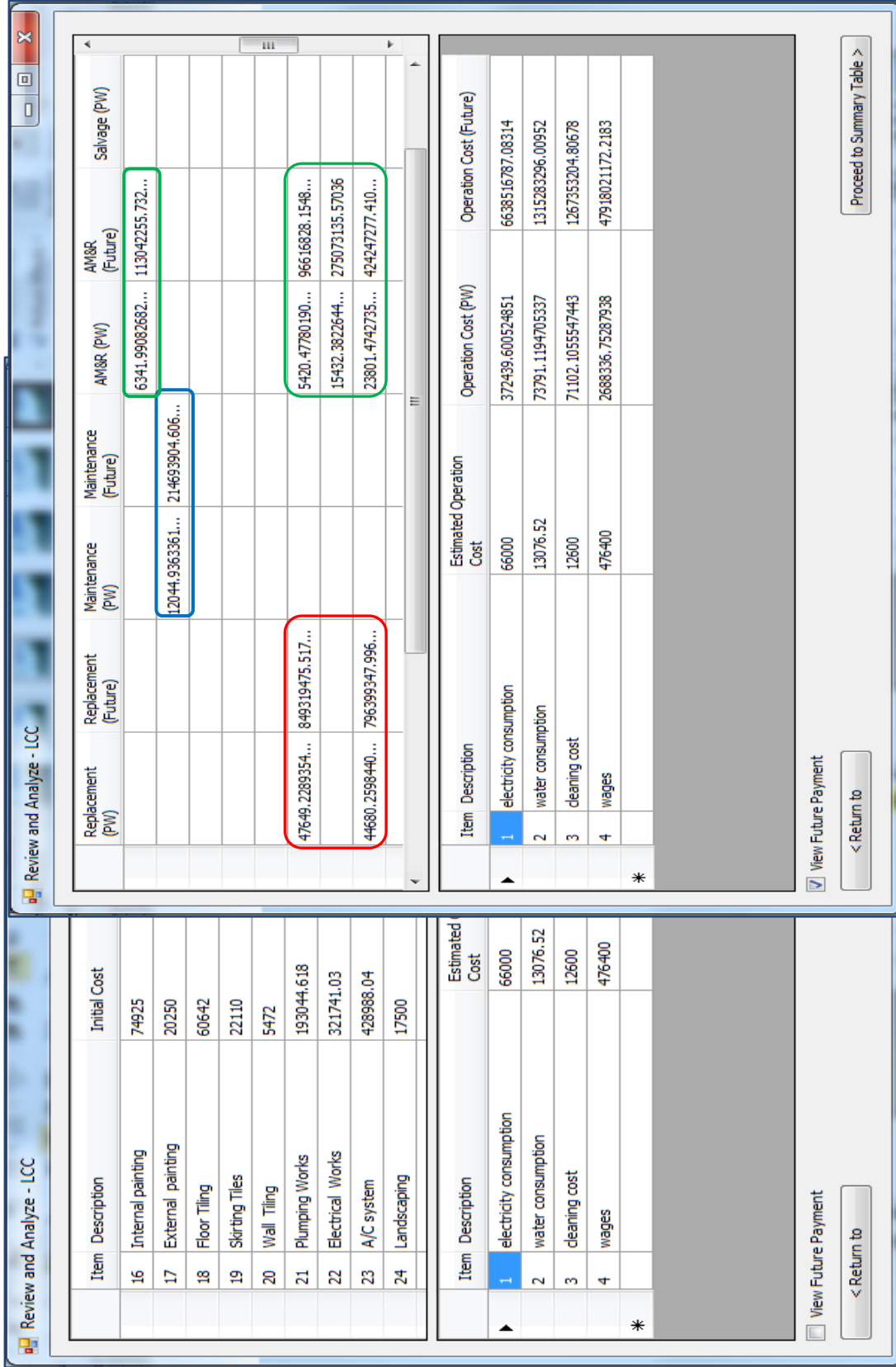


Figure 37: Review and Analyze (Future Worth-Activity Center) (1)

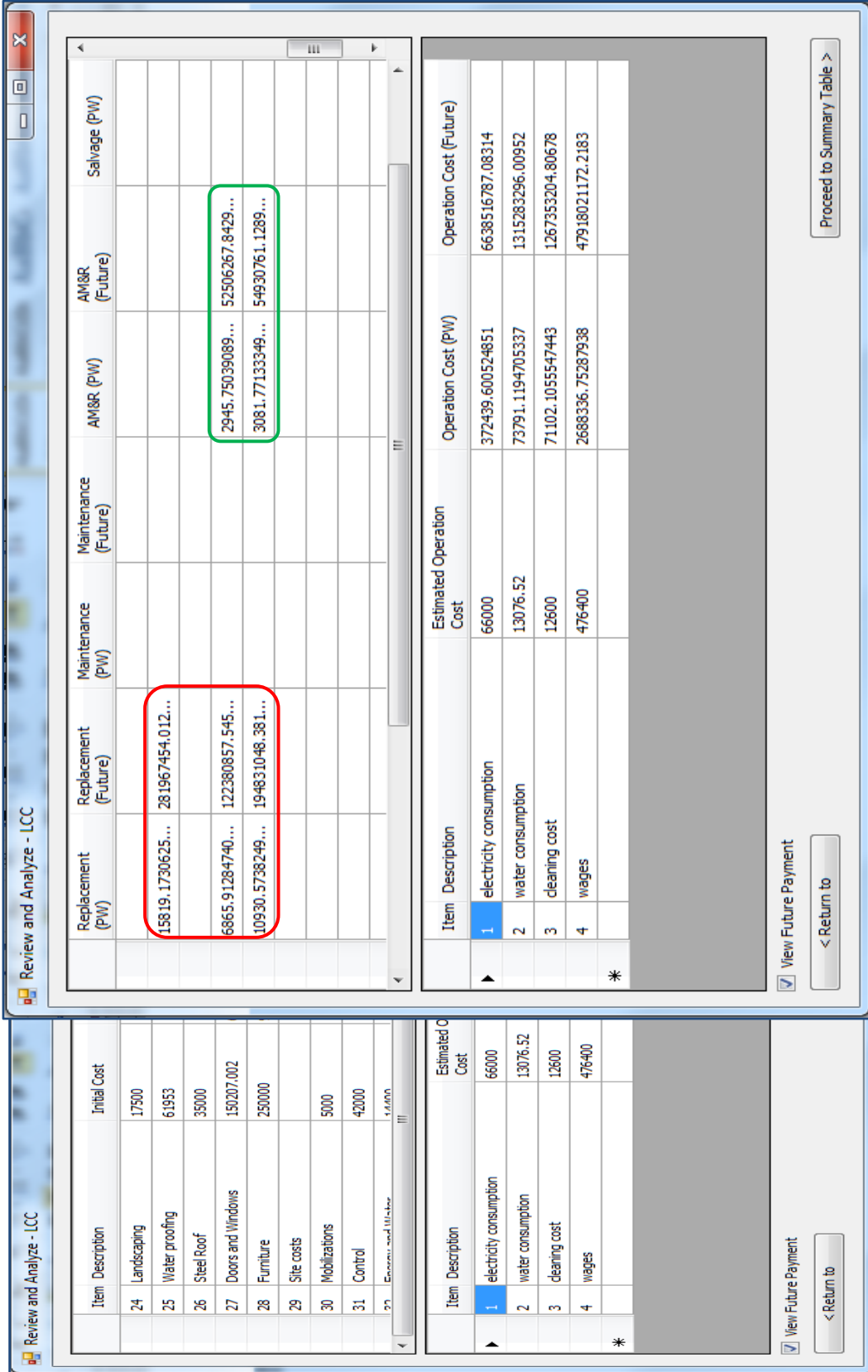


Figure 38: Review and Analyze (Future Worth-Activity Center) (2)

Item	Description	Estimated Operation Cost	Operation Cost (PW)	Operation Cost (Future)
1	electricity consumption	66000	372439.600524851	6638516787.08314
2	water consumption	13076.52	73791.1194705337	1315283296.00952
3	cleaning cost	12600	71102.1055547443	1267353204.80678
4	wages	476400	2688336.75287938	47918021172.2183

Figure 39: Review and Analyze (Future Worth-Activity Center) (3)

After finding all the results of the costs for the case study with both present worth and future worth methods, the user must know the summation of these costs for the project which can be achieved by clicking “Proceed to Summary Table” at the bottom-right of the window. In “Summary Table” window, the user will see the total costs for project such as total initial cost for the project and total replacement cost for entire project together with the summation of the total costs in both present worth method and annualized method, as can be seen in Figure 40.

Component	Value
Initial Cost:	2480293.44
Replacement Cost (PW):	125945.148514433
Maintenance and Repair Cost (PW):	69068.7832272024
Operation Cost (PW):	3205669.57842951
Salvage Value (PW):	-50.0945361649378
Total Life Cycle Cost (PW):	5880926.85563498
Total Life Cycle Cost (Annualized):	1042158.7068747

Figure 40: Summary Table

6.4.2 Manual Calculations

In order to check the accuracy of the program results, manual calculation will be carried out to be compared with.

This section clarifies the manual calculation of life cycle cost method including present worth and future worth of Activity Center building. During these calculations, the building life (n) is assumed to be 60 years. Moreover, the average inflation of Turkish Lira ‘ f ’ within 60 years is assumed to be about 9% per annum and the interest rate of Turkish Lira ‘ i ’ is accepted as 8% provided by Turkish Central Bank .

Firstly, the inflated interest rate (if) has to be calculated. Then, inflated interest rate will take place in the P/F formula $(\frac{1}{1+if})^n$.

Inflated interest rate value is a rate composed of both interest rate and inflation rate which is closer to the real life and it can be calculated from the equation (6.1):

$$i_f = i + f + i \times f \quad (6.1)$$

Where:

i_f is inflated interest rate,

I is interest rate, and

F is inflation rate (Ayorlo, 1995; Blank & Tarquin, 2005 b).

Based on the assumption of this study:

The inflated interest rate (i_f) = $0.08+0.09 + 0.08 \times 0.09 = 0.1772 \times 100 = 17.72\%$

All present worth and future payments are calculated as follows:

$$PW = Px\left(\frac{1}{1+i_f}\right)^n \quad (6.2)$$

$$F = Px(1 + i_f)^n \quad (6.3)$$

Where,

P is the present amount (estimated cost),

F is the future payment,

i_f is the inflated interest rate which is equal to 0.1772 in present study, and

n is the service life of the project (Kirk & Dell'Isola, 1995).

6.4.2.1 Initial Cost

The first step in performing LCCA of a project is to identify all the initial investment costs of the project. Initial investment costs are costs that will be incurred before the occupation of the facility. All initial costs are to be added to the LCC at their full

value. These costs were found one by one in detail by measuring and calculating the amount of every item in the construction of building and multiplying them by their unit costs (all the costs were obtained from the Technical Affairs of Eastern Mediterranean University in North Cyprus). Then, the total initial cost was found out by summing the costs of all items as shown in Table 4.

6.4.2.2 Maintenance and Renewal Costs

The second step in LCCA of a project is to define all the future maintenance and repair costs of the project.

Renewal costs are unexpected expenses that are required to extend the life of a building system without replacing the system. For instance is the repair of a broken window. This is an unexpected event that does not necessitate replacement of the entire window unit, only change the broken pane.

Maintenance costs include costs of external painting and annual maintenance and repair costs such as internal painting, plumping works and air conditioning system etc.

Maintenance Cost

- **External Painting**

Initial cost of external painting = 20,250TL (Table 4).

The painting to be renewed every 5 years with 75% of initial external painting cost (Hamed et al., 2012), as shown in Table 5.

Table 4: Total initial cost for Activity Center Building

INITIAL COST (TL)						
Items	Sub-Items(Including Workmanship)	Quantity	Unit	Unit Cost (TL)	Estimated	Present Worth
Project Design						
Fees		1	project	7500	7500	7500
	official fees %10	According the TRNC legislations the education institutions are exempted				
Construction						
	Cleaning and leveling	227.7	m ³	5	1138.5	1138.5
	Compacted soil	881.5	m ³	25	22037.5	22037.5
	Large Gravel	341.5	m ³	50	17075	17075
	Concrete C25	910.35	m ³	125	113793.75	113793.75
	Concrete C14 under footing	74	m ³	110	8140	8140
	Concrete C14 for GF	228	m ³	110	25080	25080
	Steel	91	ton	1750	159250	159250
	Form Works	5162	m ²	20	103240	103240
	Brick walls External	1058	m ²	50	52900	52900
	Brick walls Internal	2627	m ²	28	73556	73556
	Plastering	6345	m ²	30	190350	190350
	Internal painting	4995	m ²	15	74925	74925
	External painting	1350	m ²	15	20250	20250
	Floor Tiling	2021.4	m ²	30	60642	60642
	Skirting Tiles	3685	m	6	22110	22110
	Wall Tiling	144	m ²	38	5472	5472
	Plumping Works	1	LS	193044.62	193044.62	193044.62
	Electrical Works	1	LS	321741.03	321741.03	321741.03
	A/C system	1	LS	428988.04	428988.04	428988.04
	Landscaping	1	LS	17500	17500	17500
	Water proofing	2065.1	m ²	30	61953	61953
	Steel Roof	1	LS	35000	35000	35000
	Doors and Windows	803.246	m ²	187	150207	150207
	Furniture	1	LS	250000	250000	250000
Site costs						
	Mobilizations	1	LS	5000	5000	5000
	Control	1	Annual	42000	42000	42000
	Energy and Water	1	Annual	14400	14400	14400
	Other costs	1	LS	3000	3000	3000
Total Initial Cost (Present Worth)						2,480,293.44

Table 5: The external painting to be renewed every 5 years

Item	Year	Interest Factor	Estimated Cost	Present Worth	Future Payment
External Painting	5	0.4423	15187.5	6717.43	34337.55
	10	0.1957	15187.5	2972.19	77606.03
	15	0.0865	15187.5	1313.72	175578.03
	20	0.0383	15187.5	581.68	396540.47
	25	0.017	15187.5	258.19	893382.35
	30	0.0075	15187.5	113.91	2025000
	35	0.0033	15187.5	50.12	4602272.73
	40	0.0015	15187.5	22.78	10125000
	45	0.00065	15187.5	9.87	23365384.62
	50	0.0003	15187.5	4.56	50625000
55	0.00013	15187.5	1.97	116826923.08	
Total External Painting Cost				12046.42	209147024.86

The total PW of renewal cost for the external painting = 12,046.42 TL

Note: the system is not renewed in the 60th year as it is the assumed end of the economic life of the building.

Annual Maintenance & Repair Costs (TL)

a) Internal Painting

Initial cost of internal painting = 74,925 TL (Table 4).

According the Technical Affair Department the maintenance cost to be as 1.5% of the initial internal painting cost.

Annual maintenance internal painting costs = $1.5\% \times 74,925 = 1,124$ TL/Year

b) Doors and Windows

Initial cost of doors and windows = 150,207 TL

According the Technical Affair Department the maintenance cost to be as 0.35% of the initial doors and windows cost.

Annual maintenance doors and windows costs =0.35% x 150,207 =526 TL/Year

All the annual maintenance and repair costs for internal painting and doors and windows are included in Table 6.

Table 6: The interest factors and PW payments for the annual maintenance costs of the internal painting and doors and windows.

ANNUAL MAINTENANCE & REPAIR COST (TL)							
Internal Painting					Doors and windows		
Year	Interest Factor	Estimated Cost	Present Worth	Future Payment	Estimated Cost	Present Worth	Future Payment
0							
1	0.8495	1124	954.84	1323.13	526	446.84	619.19
2	0.7216	1124	811.08	1557.65	526	379.56	728.94
3	0.6198	1124	696.66	1813.49	526	326.01	848.66
4	0.5207	1124	585.27	2158.63	526	273.89	1010.18
5	0.4423	1124	497.15	2541.26	526	232.65	1189.24
6	0.3757	1124	422.29	2991.75	526	197.62	1400.05
7	0.3192	1124	358.78	3521.3	526	167.9	1647.87
8	0.2711	1124	304.72	4146.07	526	142.6	1940.24
9	0.2303	1124	258.86	4880.59	526	121.14	2283.98
10	0.1957	1124	219.97	5743.48	526	102.94	2687.79
11	0.1662	1124	186.81	6762.94	526	87.42	3164.86
12	0.1412	1124	158.71	7960.34	526	74.27	3725.21
13	0.12	1124	134.88	9366.67	526	63.12	4383.33
14	0.1019	1124	114.54	11030.42	526	53.6	5161.92
15	0.0865	1124	97.23	12994.22	526	45.5	6080.92
16	0.0735	1124	82.61	15292.52	526	38.66	7156.46
17	0.0625	1124	70.25	17984	526	32.88	8416
18	0.0531	1124	59.68	21167.61	526	27.93	9905.84
19	0.0451	1124	50.69	24922.39	526	23.72	11662.97
20	0.0383	1124	43.05	29347.26	0	0	0
21	0.0325	1124	36.53	34584.62	526	17.1	16184.62
22	0.0276	1124	31.02	40724.64	526	14.52	19057.97
23	0.0235	1124	26.41	47829.79	526	12.36	22382.98
24	0.012	1124	13.49	93666.67	526	6.31	43833.33
25	0.017	1124	19.11	66117.65	526	8.94	30941.18
26	0.0144	1124	16.19	78055.56	526	7.57	36527.78
27	0.0122	1124	13.71	92131.15	526	6.42	43114.75
28	0.0104	1124	11.69	108076.92	526	5.47	50576.92
29	0.0088	1124	9.89	127727.27	526	4.63	59772.73
30	0.0075	1124	8.43	149866.67	526	3.95	70133.33
31	0.0064	1124	7.19	175625	526	3.37	82187.5
32	0.0054	1124	6.07	208148.15	526	2.84	97407.41
33	0.005	1124	5.62	224800	526	2.63	105200
34	0.004	1124	4.50	281000	526	2.1	131500
35	0.0033	1124	3.71	340606.06	526	1.74	159393.94
36	0.003	1124	3.37	374666.67	526	1.58	175333.33

37	0.0024	1124	2.70	468333.33	526	1.26	219166.67
38	0.00203	1124	2.28	553694.58	526	1.07	259113.3
39	0.002	1124	2.25	562000	526	1.05	263000
40	0.0015	1124	1.69	749333.33	0	0	0
41	0.00125	1124	1.41	899200	526	0.66	420800
42	0.0011	1124	1.24	1021818.18	526	0.58	478181.82
43	0.0009	1124	1.01	1248888.89	526	0.47	584444.44
44	0.0008	1124	0.90	1405000	526	0.42	657500
45	0.00065	1124	0.73	1729230.77	526	0.34	809230.77
46	0.00055	1124	0.62	2043636.36	526	0.29	956363.64
47	0.00057	1124	0.64	1971929.82	526	0.3	922807.02
48	0.0005	1124	0.56	2248000	526	0.26	1052000
49	0.00034	1124	0.38	3305882.35	526	0.18	1547058.82
50	0.0003	1124	0.34	3746666.67	526	0.16	1753333.33
51	0.00024	1124	0.27	4683333.33	526	0.13	2191666.67
52	0.00021	1124	0.24	5352380.95	526	0.11	2504761.9
53	0.0002	1124	0.22	5620000	526	0.11	2630000
54	0.00015	1124	0.17	7493333.33	526	0.08	3506666.67
55	0.00013	1124	0.15	8646153.85	526	0.07	4046153.85
56	0.00011	1124	0.12	10218181.82	526	0.06	4781818.18
57	0.0000915	1124	0.1	12284153.01	526	0.05	5748633.88
58	0.00008	1124	0.09	14050000	526	0.04	6575000
59	0.00007	1124	0.08	16057142.86	526	0.04	7514285.71
60	0.00006	0			0		
Total cost			6343.15	108989425.96		2947.48	50639548.1

The total PW of annual maintenance cost for the internal painting = 6,343.15 TL

And, the total PW of annual renewal cost for the doors and windows = 2,947.48 TL.

c) Plumbing Works

The cost elements of the plumbing system are as follows:

Initial cost of the plumbing system including all piping works and WC closets and sinks is calculated to be = 193,044.62 TL (Table 4).

The maintenance cost to be as 0.52% of the whole system cost (Hamed et al., 2012).

Annual maintenance costs = $0.52\% \times 193,044.62 = 1,004$ TL/year.

d) Air Conditioning System

In this building, a central operating Air Conditioning system is installed and according to the technical department in the school, its cost was about 428,988.04

TL with an annual maintenance of 1% of the initial cost, as shown in Table 7.

So the whole life cost of the Air Conditioning system is:

The annual maintenance cost = $0.01 \times 428,988.04 = 4,300$ TL/Year

Table 7: The interest factors and PW payments for the annual maintenance costs of the plumbing works and A/C system

ANNUAL MAINTENANCE & REPAIR COST (TL)							
plumping works				Air Conditioning system			
Year	Interest Factor	Estimated Cost	Present Worth	Future Payment	Estimated Cost	Present Worth	Future Payment
0							
1	0.8495	1004	852.9	1181.87	4300	3652.85	5061.8
2	0.7216	1004	724.49	1391.35	4300	3102.88	5958.98
3	0.6198	1004	622.28	1619.88	4300	2665.14	6937.72
4	0.5207	1004	522.78	1928.17	4300	2239.01	8258.11
5	0.4423	1004	444.07	2269.95	4300	1901.89	9721.91
6	0.3757	1004	377.2	2672.34	4300	1615.51	11445.3
7	0.3192	1004	320.48	3145.36	4300	1372.56	13471.18
8	0.2711	1004	272.18	3703.43	4300	1165.73	15861.31
9	0.2303	1004	231.22	4359.53	4300	990.29	18671.3
10	0.1957	0	0	0	4300	841.51	21972.41
11	0.1662	1004	166.86	6040.91	4300	714.66	25872.44
12	0.1412	1004	141.76	7110.48	4300	607.16	30453.26
13	0.12	1004	120.48	8366.67	4300	516	35833.33
14	0.1019	1004	102.31	9852.8	4300	438.17	42198.23
15	0.0865	1004	86.85	11606.94	0	0	0
16	0.0735	1004	73.79	13659.86	4300	316.05	58503.4
17	0.0625	1004	62.75	16064	4300	268.75	68800
18	0.0531	1004	53.31	18907.72	4300	228.33	80979.28
19	0.0451	1004	45.28	22261.64	4300	193.93	95343.68
20	0.0383	0	0	0	4300	164.69	112271.54
21	0.0325	1004	32.63	30892.31	4300	139.75	132307.69
22	0.0276	1004	27.71	36376.81	4300	118.68	155797.1
23	0.0235	1004	23.59	42723.4	4300	101.05	182978.72
24	0.012	1004	12.05	83666.67	4300	51.6	358333.33
25	0.017	1004	17.07	59058.82	4300	73.1	252941.18
26	0.0144	1004	14.46	69722.22	4300	61.92	298611.11
27	0.0122	1004	12.25	82295.08	4300	52.46	352459.02
28	0.0104	1004	10.44	96538.46	4300	44.72	413461.54
29	0.0088	1004	8.84	114090.91	4300	37.84	488636.36
30	0.0075	0	0	0	0	0	0
31	0.0064	1004	6.43	156875	4300	27.52	671875
32	0.0054	1004	5.42	185925.93	4300	23.22	796296.3
33	0.005	1004	5.02	200800	4300	21.5	860000
34	0.004	1004	4.02	251000	4300	17.2	1075000

35	0.0033	1004	3.31	304242.42	4300	14.19	1303030.3
36	0.003	1004	3.01	334666.67	4300	12.9	1433333.33
37	0.0024	1004	2.41	418333.33	4300	10.32	1791666.67
38	0.00203	1004	2.04	494581.28	4300	8.73	2118226.6
39	0.002	1004	2.01	502000	4300	8.6	2150000
40	0.0015	0	0	0	4300	6.45	2866666.67
41	0.00125	1004	1.26	803200	4300	5.38	3440000
42	0.0011	1004	1.1	912727.27	4300	4.73	3909090.91
43	0.0009	1004	0.9	1115555.56	4300	3.87	4777777.78
44	0.0008	1004	0.8	1255000	4300	3.44	5375000
45	0.00065	1004	0.65	1544615.38	0	0	0
46	0.00055	1004	0.55	1825454.55	4300	2.37	7818181.82
47	0.00057	1004	0.57	1761403.51	4300	2.45	7543859.65
48	0.0005	1004	0.5	2008000	4300	2.15	8600000
49	0.00034	1004	0.34	2952941.18	4300	1.46	12647058.82
50	0.0003	0	0	0	4300	1.29	14333333.33
51	0.00024	1004	0.24	4183333.33	4300	1.03	17916666.67
52	0.00021	1004	0.21	4780952.38	4300	0.9	20476190.48
53	0.0002	1004	0.2	5020000	4300	0.86	21500000
54	0.00015	1004	0.15	6693333.33	4300	0.65	28666666.67
55	0.00013	1004	0.13	7723076.92	4300	0.56	33076923.08
56	0.00011	1004	0.11	9127272.73	4300	0.47	39090909.09
57	0.0000915	1004	0.09	10972677.6	4300	0.39	46994535.52
58	0.00008	1004	0.08	12550000	4300	0.34	53750000
59	0.00007	1004	0.07	14342857.14	4300	0.3	61428571.43
60	0.00006	0			0		
Total cost			5421.67	93172333.12		23859.5	409714001.35

The total PW of annual maintenance cost for the Pumping Works = 5,421.67 TL

And, the total PW of annual maintenance cost for the Air Conditioning System = 23,859.5 TL.

e) Electrical Works

The cost elements of the electrical system are as follows:

Initial cost of the electric system including all piping, wiring and finishing works = 321,741.03 TL (Table 4).

According the Technical Affair Department the maintenance cost to be as 0.85% of the whole system cost. So the whole life cost of the electric system is:

The annual maintenance cost = $0.85\% \times 321,741.03 = 2,735$ TL

f) Furniture

Based on the data obtained from the Technical Affair Department, the annual furniture maintenance cost is calculated as 0.22% of its initial cost (Hamed et al., 2012). So the whole life maintenance cost of the furniture is:

$$\text{The annual maintenance cost} = 0.22\% \times 250,000 \text{ TL} = 550 \text{ TL}$$

All the annual maintenance and repair costs for furniture and electrical works are included in Table 8.

Table 8: The interest Factors and PW payments for the annual maintenance costs of the electrical works and furniture.

ANNUAL MAINTENANCE & REPAIR COST (TL)							
Year	electrical works				furniture		
	Interest Factor	Estimated Cost	Present Worth	Future Payment	Estimated Cost	Present Worth	Future Payment
0							
1	0.8495	2735	2323.38	3219.54	550	467.23	647.44
2	0.7216	2735	1973.58	3790.19	550	396.88	762.2
3	0.6198	2735	1695.15	4412.71	550	340.89	887.38
4	0.5207	2735	1424.11	5252.54	550	286.39	1056.27
5	0.4423	2735	1209.69	6183.59	550	243.27	1243.5
6	0.3757	2735	1027.54	7279.74	550	206.64	1463.93
7	0.3192	2735	873.01	8568.3	550	175.56	1723.06
8	0.2711	2735	741.46	10088.53	550	149.11	2028.77
9	0.2303	2735	629.87	11875.81	550	126.67	2388.19
10	0.1957	2735	535.24	13975.47	550	107.64	2810.42
11	0.1662	2735	454.56	16456.08	550	91.41	3309.27
12	0.1412	2735	386.18	19369.69	550	77.66	3895.18
13	0.12	2735	328.2	22791.67	550	66	4583.33
14	0.1019	2735	278.7	26840.04	550	56.05	5397.45
15	0.0865	2735	236.58	31618.5	550	47.58	6358.38
16	0.0735	2735	201.02	37210.88	550	40.43	7482.99
17	0.0625	2735	170.94	43760	550	34.38	8800
18	0.0531	2735	145.23	51506.59	550	29.21	10357.82
19	0.0451	2735	123.35	60643.02	550	24.81	12195.12
20	0.0383	2735	104.75	71409.92	0	0	0
21	0.0325	2735	88.89	84153.85	550	17.88	16923.08
22	0.0276	2735	75.49	99094.2	550	15.18	19927.54
23	0.0235	2735	64.27	116382.98	550	12.93	23404.26
24	0.012	2735	32.82	227916.67	550	6.6	45833.33
25	0.017	2735	46.5	160882.35	550	9.35	32352.94
26	0.0144	2735	39.38	189930.56	550	7.92	38194.44

27	0.0122	2735	33.37	224180.33	550	6.71	45081.97
28	0.0104	2735	28.44	262980.77	550	5.72	52884.62
29	0.0088	2735	24.07	310795.45	550	4.84	62500
30	0.0075	2735	20.51	364666.67	550	4.13	73333.33
31	0.0064	2735	17.5	427343.75	550	3.52	85937.5
32	0.0054	2735	14.77	506481.48	550	2.97	101851.85
33	0.005	2735	13.68	547000	550	2.75	110000
34	0.004	2735	10.94	683750	550	2.2	137500
35	0.0033	2735	9.03	828787.88	550	1.82	166666.67
36	0.003	2735	8.21	911666.67	550	1.65	183333.33
37	0.0024	2735	6.56	1139583.33	550	1.32	229166.67
38	0.00203	2735	5.55	1347290.64	550	1.12	270935.96
39	0.002	2735	5.47	1367500	550	1.1	275000
40	0.0015	2735	4.10	1823333.33	0	0	0
41	0.00125	2735	3.42	2188000	550	0.69	440000
42	0.0011	2735	3.01	2486363.64	550	0.61	500000
43	0.0009	2735	2.46	3038888.89	550	0.5	611111.11
44	0.0008	2735	2.19	3418750	550	0.44	687500
45	0.00065	2735	1.78	4207692.31	550	0.36	846153.85
46	0.00055	2735	1.5	4972727.27	550	0.3	1000000
47	0.00057	2735	1.56	4798245.61	550	0.31	964912.28
48	0.0005	2735	1.37	5470000	550	0.28	1100000
49	0.00034	2735	0.93	8044117.65	550	0.19	1617647.06
50	0.0003	2735	0.82	9116666.67	550	0.17	1833333.33
51	0.00024	2735	0.66	11395833.33	550	0.13	2291666.67
52	0.00021	2735	0.57	13023809.52	550	0.12	2619047.62
53	0.0002	2735	0.55	13675000	550	0.11	2750000
54	0.00015	2735	0.41	18233333.33	550	0.08	3666666.67
55	0.00013	2735	0.36	21038461.54	550	0.07	4230769.23
56	0.00011	2735	0.3	24863636.36	550	0.06	5000000
57	0.0000915	2735	0.25	29890710.38	550	0.05	6010928.96
58	0.00008	2735	0.22	34187500	550	0.04	6875000
59	0.00007	2735	0.19	39071428.57	550	0.04	7857142.86
60	0.00006	0			0		
Total cost			15434.62	265201138.8		3081.96	52950097.82
TOTAL MAINTENANCE COST (PRESENT WORTH)						69134.81	

The total PW of annual renewal cost for the electrical works = 15,434.62TL

And, the total PW of annual renewal cost for the furniture = 3,081.96TL.

The total PW of maintenance cost for the whole project = 69,134.81 TL.

6.4.2.3 Replacement Costs

The third step in the completion of the life cycle cost of a project is to define all the future replacement costs of the building.

Replacement costs are usually generated by replacement of a building system or component that has reached the end of its useful life.

a) Plumping Works

Plumping works initial cost = 193,044.62 TL (Table 4).

According the Technical Affair Department, the service life of the plumping works is 10 years due to the type of water in TRNC with an extra 1.5% of its initial cost, the replacement is not for all the system, because the PVC type has long life, but just for metal parts like valve and junction, as shown in Table 9.

Table 9: The plumbing system to be replaced in every 10 years

REPLACEMENT COSTS (TL)					
item	Year	Interest Factor	Estimated	Present Worth	Future Payment
Plumping Works	10	0.1957	195940.3	38345.52	1001227.9
	20	0.0383	195940.3	7504.51	5115934.7
	30	0.0075	195940.3	1469.55	26125373.3
	40	0.0015	195940.3	293.91	130626866.7
	50	0.0003	195940.3	58.78	653134333.3
Total cost				47672.27	816003736

b) Water Proofing

Water proofing membrane used two layers to cover the concrete slabs of the building with a total area of 2,065.1 m² with an expected life of 10 years. The total initial cost of the water proofing is 2065.1 m² x 30TL/m² = 61,953 TL. The service life of the Plumping Works is 10 years with an extra 5% of its initial cost, so the life cycle cost of the water proofing is shown in Table 10.

c) Furniture

The furniture is assumed to be replaced totally each 20 years with an extra 10% of its initial cost (Hamed et al., 2012), as shown in Table 11.

Table 10: The water proofing to be replaced in every 10 years

REPLACEMENT COSTS (TL)					
item	Year	Interest Factor	Estimated	Present Worth	Future Payment
Water Proofing	10	0.1957	65050.65	12730.41	332399.8
	20	0.0383	65050.65	2491.44	1698450.4
	30	0.0075	65050.65	487.88	8673420
	40	0.0015	65050.65	97.58	43367100
	50	0.0003	65050.65	19.52	216835500
Total cost				15826.82	270906870.2

Table 11: The Furniture is assumed to be replaced totally each 20 years

item	Year	Interest Factor	Estimated	Present Worth	Future Payment
Furniture	20	0.0383	275000	10532.5	7180156.658
	40	0.0015	275000	412.5	183333333.3
Total cost				10945	190513490

d) Doors and windows

The initial cost is 150,207 TL (Table 4). Its economic life is 20 years with an extra cost 15 % of its initial cost (Altuntaş, 2004; Hamed et al., 2012), as shown in Table 12.

Table 12: The replacement cost of the doors and windows

item	Year	Interest Factor	Estimated	Present Worth	Future Payment
Doors and windows	20	0.0383	172738.05	6616	4510131.91
	40	0.0015	172738.05	259	115158701.53
Total cost				6875	119668833.45

e) Air Conditioning System

The initial cost is 428,988.04 TL and its economic life is 15 years with an extra 10% of the initial cost (Hamed et al., 2012), as shown in Table 13.

Table 13: The replacement cost of the Air Conditioning System

item	Year	Interest Factor	Estimated	Present Worth	Future Payment
Air Conditioning System	15	0.0865	471886.84	40818.21	5455339.24
	30	0.0075	471886.84	3539.15	62918245.87
	45	0.00065	471886.84	306.73	725979760
Total cost				44664.09	794353345.1
TOTAL REPLACEMENT COST (PRESENT WORTH)				125983.16	

The total PW of replacement cost for the whole project = 125983.16 TL

6.4.2.4 Operation Costs

The fourth step before finishing the LCCA of the project is to define all the future operation costs which involves the annual costs, excluding maintenance and repair costs, involved in the operation of the facility. Most of these costs are related to building and security services.

Energy costs: This cost is associated with the ongoing energy consumption of the facility. This includes electricity, oil, natural gas, coal, and other fuels necessary for operation of the facility and its components, as shown in Table 14.

The whole life annual cost in PW is calculated as follows:

PW has to be calculated from the given annual payments for the 60 years and it is found by equations 6.5 and 6.6.

$$PWA = \frac{(1+i_f)^n - 1}{i_f (1+i_f)^n} \quad (6.4)$$

$$PW = A \times PWA \quad (6.5)$$

$$F = A \frac{(1+i_f)^n - 1}{i_f} \quad (6.6)$$

Where,

PWA is the present worth of annuity factor,

A is the uniform sum of money in each period,

F is the future payment,

i_f is the inflated interest rate which is equal to 0.1772 for this project,

n is service life of the project (Blank & Tarquin, 2005 a).

In this project, the present worth of annuity factor (PWA) will be calculated by equation 6.4.

Table 14: Operation costs

Operation COSTS (Annual Costs) (TL)						
Item	Sub-Item	Year	PWA	Estimated Cost	Present Worth	Future Payment
Electrical Consumption		60	5.643	66000	372438	6638516787
Water Consumption		60	5.643	13076.52	73790.8	1315283296
Cleaning Cost		60	5.643	12600	71101.8	1267353205
Wages	Administrative Staff (6)			324000		
	Cleaning Staff (3)			126000		
	Administrative Assistants (2)			26400		
Total Wages		60	5.643	476400	2688325.2	47918021172
TOTAL OPERATION COSTS (PRESENT WORTH)					3205655.8	57139174460

6.4.2.4 Salvage and Demolition costs

The last step in the completion of the LCCA of a project is to identify all the salvage costs of the project. Salvage costs in general are the estimated value of an asset at the end of its useful life.

Usually the salvage cost is generated by the end of the service life for project. In this case study and according to Technical Affair Department, the salvage cost is considered to be 40% of the initial cost of the project. The salvage cost can be found by selling or exchanging an asset at the end of its useful life, so the salvage cost for the project at the end of its service life (in this case study, the serves life is 60 years) is summation of all salvage costs of each item of the project at the end of its service life which make the salvage cost 40% of the initial cost in this case study (Altuntaş, 2004; Hamed et al., 2012), as shown in Table 15.

Table 15: Salvage costs

SALVAGE COSTS (TL)					
item	Year	PW Factor	Estimated Cost	Present Worth	Future Payment
For the entire project	60	0.00006	-992117.38	-59.53	-16535289600
Total Salvage Costs				-59.53	

Demolition costs are the cost of removing buildings or other structures from the property. It includes the costs of actual demolition plus rubbish disposal and removal from the site.

According to Technical Affair Department the demolition of the building is estimated to cost as 4% of initial cost after 60 years (Hamed et al., 2012), as shown in Table 16. It will be calculated by equation 6.2.

Table 16: Demolition cost

DEMOLITION COST (TL)					
item	Year	PW Factor	Estimated Cost	Present Worth	Future Payment
For the entire project	60	0.00006	99211.74	5.95	1653528960
TOTAL ALL SALVAGE COSTS (TL)				-53.57	-14881760640
TOTAL LIFE CYCLE COST (PW)				5881013.637	
TOTAL LIFE CYCLE COST (Annualized)				1042174.085	

6.5 Evaluation of the Results

The calculations were done both manually and by using the developed computer system.

The developed program finished the operation in only 27 minutes. However, the average duration of the same calculations by hand of four estimators was approximately 8 hours. That means the model is almost 17 times more time-efficient than manual life cycle cost calculations.

The accuracy of calculations of the developed program was compared with the accuracy of manual life cycle cost calculations. The results of the manual calculations and the results obtained by using the developed program are compared in Table 17 and an approximate difference of 0.0015% was obtained.

Table 17: Comparison of both results of manual calculations and results of developed system

Alternative	LCCA Result of Manual Calculation (TL)	LCCA Result of Developed System (TL)	Difference	Percentage (%)
Activity Center Project	5,881,013.637	5,880,926.856	86.781	0.0015

Finally, developed system and manual calculation were compared in terms of recalculation time due to some changes in the data. As an example, if the inflation rate was changed; the duration of the recalculation by hand was taken for four estimators on average as two hours and ten minutes. However, in the developed program, applying the inflation rate change in life cycle cost and then recalculations took only a few seconds. Therefore, the accuracy and efficiency of the developed program was evaluated as high.

The evaluation indicates that the developed program is properly working and reliable.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This study highlights LCCA techniques and methods in general. Student Activity Center building in the campus of Eastern Mediterranean University, North Cyprus was selected to apply a LCCA. Cost parameters and economic criteria of any construction project were identified in this study.

Computer system in Microsoft Visual Basic 2010 was developed and used in the LCC analysis. Selected construction building was investigated and its economic data were established and this data were input into the developed computer system. The developed computer system was tested with the collected data for the selected construction project. Verification of the results of the developed system was done by comparing the results obtained with the results of hand calculations.

When the results of manual calculations and results obtained by using developed system are compared, a difference of approximately 0.0015 percentages was obtained and the developed program finished the operation in only 27 minutes. However, the duration of the same calculations by hand of four estimators on average was approximately 8 hours. That means, the model is almost 17 times more time-efficient than manual life cycle cost calculations.

Job description of estimators by this thesis is changed and one more extra work will be done by the estimators; not only to calculate the quantity and unit weight but also to provide the economical life time for every single item.

Verification indicates that the developed system is working and reliable.

7.2 Recommendations

Recommendations for further studies can be summarized as follows:

1. The computer system can be further developed for the evaluation of the non-monetary criteria of the project by using the weighted evaluation technique.
2. The computer system can be further developed for other LCC techniques such as confidence index and sensitivity approach.

REFERENCES

- Accounting For Management. (2011). *Engineering Economy*. Retrieved March 8, 2011, from accounting for management:
http://www.accountingformanagement.com/net_present_value_method.htm
- Ajorlo, G. (1995). *"Life Cycle Costing For Housing Project"*. Turkish Republic of Northern Cyprus: MSc Thesis, Eastern Mediterranean University.
- Alaska Department of education and early development. (1999). *"Life Cycle Cost and Analysis Hand book "*. Juneau, Alaska: State of Alaska.
- Albert, P. C. (1993). *"Value Management and Its Application in The Construction Industry"*. Australia: School of Building and Planning (University of south Australia).
- Altuntaş, D. (2004). *"Life Cycle Costing of Residential Buildings in Cyprus"*. Turkish Republic of Northern Cyprus: MSc Thesis, Eastern Mediterranean University.
- Ashworth, A. (2004). *"Cost Studies Of Building"*. England: Pearson Prentice Hall.
- Ayyub, B. M. (2003). *"Risk Analysis in Engineering and Economics"*. USA: Chapman & Hall/CRC.

Bierman, H. (2011). *"An introduction To Accounting And Managerial Finance"*. US: World Scientific connecting great minds.

Blank, L., & Tarquin, A. (2005 a). *"Engineering Economy"*. New York: McGraw-Hill.

Blank, L., & Tarquin, A. (2005 b). *Online Learning Center*. Retrieved June 1, 2012, from Engineering Economy: <http://www.mhhe.com/blank6>.

Bledsoe, J. D. (1992). *"Successful Estimating Methods"*. KingSton: RSMMeans, Construction Publisher & Consultants,.

Boussabaine, H. A., & Kirkham, R. J. (2004). *" Whole Life-cycle Costing, Risk and Risk Responses"*. UK: Blackwell Publishing Ltd.

Bull, J. W. (2003). *" Life Cycle Costing for Construction"*. UK: Taylor & Francis Group.

Casuncad, J. (2011). *"Ten Programming Languages For 2011"*. Retrieved 02 12, 2012, from <http://www.adamsoncompsci.com>

Che Mat, M. M. (1995). *"Value Management: An Effective Cost Optimization"*. Kuala Lumpur: Universiti Teknologi Malaysia.

Che Mat, M. M. (2002). *"Value Management: Principles and Applications"*. Malaysia: Prentice Hall.

Connaughton, J. N., & Green, S. D. (1996). *"Value Management in Construction :A client's guide"*. London: Construction Industry Research and Information Association.

Construction Cost Estimating Software. (2001). *"Construction Estimating Techniques"*. Retrieved 10 11, 2011, from <http://www.misronet.com>

Crow, K. (2002). *"Value Analysis And Function Analysis System Technique"*. Retrieved October 3, 2011, from Value Analysis: <http://www.npd-solutions.com>

Dallas, M. F. (2006). *"Value and Risk Management:a guide to best practice"*. UK: Blackwell Publishing Ltd.

Dangel, R. (1969). "Integrated Logistic Support (ILS) Implementation in the Naval Ship System Command". *ASE 6th annual technical symposium*, pp. 1-25.

Danile, C. M., & William, M. V. (2002). *"Cost Estimation Concepts & Methodology"*. U.S.: Environmental Protection Agency, Reserch Triangle Park.NC 27711.

Dell'Isola, A. J. (1988). *"Value Engineering in the Construction Industry"*. Washington: Smith Hinchman & Grylls.

Dell'Isola, A. (1997). *"Value Engineering Practical Application for Design, Construction. Maintenance & Operations"*. USA: R.S. Means Company, Inc.

- Dhillon, B. S. (2010). *"Life Cycle Costing for Engineers"*. New York: Taylor and Francis Group, LLC.
- Fellows, R., Langford, D., Newcombe, R., & Urry, S. (2002). *"Construction Management in Practice"*. USA: Blackwell Science, Inc.
- Flanagan, R., & Norman, G. (1981). *"Life Cycle Costing for Construction"*. London, England.: Royal Institution of Chartered Surveyors.
- Foxall, J. (2010). *"Sams Teach Yourself Visual Basic 2010 in 24 Hours"*. USA: Pearson Education, Inc.
- Fuller, S. (2010). *Life-Cycle Cost Analysis*. Retrieved Nov. 20, 2010, from Whole Building' Design Guide: <http://www.wbdg.org/index.php>
- Halvorson, M. (2010). *"Microsoft visual basic2010 step by step"*. USA: Microsoft Press.
- Hamed, H., Alyousif, A., & Naim, M. (2012, June 14). "Information about Activity Center Building in EMU". (P. Dağlı, & S. Omer, Interviewers)
- Hendrickson, C. (1998). *"Project Management for Construction"*. USA: Prentice Hall.
- Jackson, B. J. (2010). *"Construction Management JumpStart"*. Canada: Wiley Publishing, Inc., Indianapolis, Indiana.

- Jones, J. (2008). *"Future Worth, Annual Worth, and the Temporal Horizon"*.
Retrieved March 12, 2011, from Sunk Costs:
<http://www.ensc.sfu.ca/undergrad/courses/ENSC201/.../lecture4.html>
- Kelly, J., & Male, S. (1991). *"The Practice of Value Management: Enhancing Value on Cutting Cost"*. United Kingdom: The Royal Institution of Chartered Surveyor.
- Kelly, J., & Male, S. (1993). *"Value Management in Design and Construction"*. UK: The Taylor & Francis e-Library.
- Kelly, J., Male, S., & Graham, D. (2004). *"Value Management of Construction Project"*. Australia: Blackwell Science Ltd.
- Kesavan, R., Elanchezhian, C., & Ramnath, B. V. (2009). *"Process Planning And Cost Estimation"*. Delhi: New Age International (P) Ltd.,.
- Kirk, S. J., & Dell'Isola, A. J. (1995). *"Life Cycle Costing for Design Professionals"*. US: McGraw-Hill, Inc.
- Kishk, M., Pollock, R., & Al-hajj, A. (2003). *"Whole life costing in construction"*. UK: RICS Foundation.
- Leeuw, C. P. (2001). "Value Management: An Optimum Solution". *International Conference on Spatial Information for Sustainable Development*. South Africa.

- Liu, G. (2003). "A Frame for Implementing the Value Management in China's Construction Industry". *The Hong Kong Polytechnic University.*, Page 30.
- Macedo, M. C., Dobrow, P. V., & O'Rourke, J. J. (1978). "*Value Management for Construction*". New York: John Wiley & Sons.
- Microsoft Corporation. (2012). *Visual Studio 11 Beta*. Retrieved May 22, 2012, from www.microsoft.com/visualstudio/en-us
- Miles, L. D. (1989). "*Techniques of Value Analysis and Engineering*". USA: Lawrence D.Miles Value Foundation.
- Mubarak, S. (2005). "*Construction Project Scheduling and Control*". Pearson Education, Inc., Upper Saddle River, New Jersey 07458.
- Mukhopadhyaya, A. K. (2009). "*Value Engineering Mastermind*". United Kingdom: SAGE Publications Ltd.
- Naim, M. (2006). "*Life Cycle Costing For External Envelope Of Building*". Turkish Republic of Northern Cyprus: MSc Thesis, Near East University.
- National Research Council. (1991). "*Pay now or pay later, controlling cost of ownership from design throughout the service life of public buildings*". Washington: National Academy Press.

- Neap, H. S. (1999). *"Integration of Expert System With Value Management In construction for selection of External envelope of residential building in Cyprus"*. Turkish Republic of Northern Cyprus: PhD Dissertation, Eastern Mediterranean University.
- Newnan, D. G., Eschenbach, T. G., & Lavelle, J. P. (2004). *"Engineering Economic Analysis"*. New York: Oxford University Press. Inc.
- O'Brien, J. J. (1976). *"Value Analysis In design And Construction"*. USA: McGraw-.
- Ong, H. (2003). *"Quality and Value Management In Construction Industry"*. Malaysia.: Pro-Value Management.
- Panneerselvam, R. (2001). *"Engineering Economics"*. Delhi: Prentice-Hall in India.
- Park, C. S. (2004). *"Fundamentals of Engineering Economics"*. USA: Pearson Education, Inc.
- Pilcher, R. (1992). *"Principles Of Construction Management"*. London: The McGraw-Hill.
- PMBOK Guide. (2000). *"A Guide to the Project Management Body of Knowledge"*. USA: Project Management Institute, Inc.
- Revelle, C. S., Whitlatch, E., & Wright , J. (2003). *"Civil And Environmental System Engineering"*. USA: Pearson Prentice Hall.

SAVE. (2006). *Value Engineering & Value Analysis*. Retrieved feb. 10, 2012, from <http://www.value-eng.org>

Sengupta, B., & Guha, H. (2002). *"Construction Management And Planning"*. New Delhi: Tata McGraw-Hill.

Smith, S. A. (1934). Service reliability measured by probabilities of outage. *Electrical World*, 103:371–374.

Stephens, R. (2011). *"Stephens' Visual Basic Programming 24-Hour Trainer"*. Canada: Wiley publishing, Inc.

Thiry, M. (1997). *"Value Management Practice"*. USA: The Project Management Institute.

Venkataraman , R. R., & Pinto, J. K. (2008). *"Cost And Value Management In Projects"*. Canada: John Wiley & Sons, Inc.