LIFE CYCLE COST AWARENESS AMONG ARCHITECTS: THE CASE OF TURKEY

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Ece KAYAŞ

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We approve the thesis of **Ece KAYAŞ**

Assoc. Prof. Dr. H. Murat GÜNAYDIN
Supervisor

Assist. Prof. Dr. S. Zeynep DOĞAN ERDOĞMUŞ
Committee Member

Instructor Dr. Ela ÇİL
Committee Member

Assoc. Prof. Dr. Serdar KALE
Committee Member

Assoc. Prof. Dr. Suat GÜNHAN
Committee Member

30 June 2009

Assoc. Prof. Dr. H. Murat GÜNAYDIN
Head of the Architecture Department

Prof. Dr. Hasan BÖKE
Dean of the Graduate School of
Engineering and Sciences

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ABSTRACT

LIFE CYCLE COST AWARENESS AMONG ARCHITECTS: THE CASE OF TURKEY

Building construction industry considers both construction and life-cycle cost (LCC) of a building as an important success factor for projects. In order to achieve the lowest cost of product, the study of LCC enables comparative cost assessments to be made over a specified period of time; taking into account relevant economic factors in terms of both initial costs and future maintenance and operational costs the latter of which are generally ignored in building industry especially at the design stage. For this research, the methods of LCC such as *present worth cost approach* and *equivalance annual cost approach* were evaluated. The objectives of this study are (1) to analyse these LCC analysis methods, in order to identify those that are being employed by architects practising in Turkey and (2) define the life-cycle costing awareness among architects working in building industry and architectural offices in Turkey. For this reason, a questionnaire survey was developed and sent to freelance architects. A total of 114 participants took part in this research. Some results appear that many architects expand LCC calculations in the design process that this condition is really important for LCC. Most of architects use LCC when making investment decisions but they do not take maintenance cost into consideration. The lack of significant input-cost data and lack of experience appears to be the most important problem in this respect.

Keywords: Life-Cycle-Costing, Methods, Building Construction, Production-Process oriented approaches, Design process, Architects, Turkey

ÖZET

MİMARLAR ARASINDAKİ YAŞAM DÖNGÜSÜ MALİYETİ FARKINDALIĞI: TÜRKİYE'DEN ÖRNEKLER

Bina yapı endüstrisi, projeler baz alındığında, hem yapım maliyetini, hem de yaşam döngüsü maliyetini (YDM) önemli bir başarı faktörü olarak görür. YDM yaklaşımı, ürünlerdeki en düşük maliyeti sağlamak amacıyla, başlangıç maliyetinin yanı sıra yapı endüstrisinde ve özellikle tasarım evresinde göz ardı edilen gelecekteki işletme ve onarım-bakım maliyeti gibi bütün ilgili ekonomik faktörleri hesabına katarak, belli zaman aralıklarında tekrar etmek üzere karşılaştırmalı maliyet değerlendirmesi yapar. Bu araştırma için, *şimdiki değer maliyet analizi yaklaşımı* ve *yıllık maliyet analizi yaklaşımı* gibi YDM analiz metotları değerlendirilmiştir. Bu çalışmanın amaçları, (1) Türkiye'deki mimarlar tarafından uygulanan YDM analiz metotlarını tanımlamak ve böylece bu bilginin elde edilmesini sağlamak için, bu metotları araştırmak ve (2) Türkiye'de bina endüstrisi ve mimari ofislerde serbest çalışan mimarlar arasındaki YDM farkındalığının derecesini araştırmak ve belirlemektir. Bu sebeple, anket formu geliştirilmiş ve bu form mimarlara dağıtılmıştır. Çalışma örneklemi toplam 114 katılımcı mimar'dan oluşmaktadır. Sonuçların bir kısmı, Türkiye'deki mimarların YDM hesaplamalarını tasarım süreci içerisinde yayarak kullandıklarını gösteriyor ki bu durum YDM için oldukça önemli. Bir kısım sonuçlar da, birçok mimar'ın yatırım kararı alırken YDM'yi kullandığını ama onarım-bakım maliyetini dikkate almadıklarını gösteriyor. Bu konuda, projeye dair ilk veri ve maliyet bilgisi eksikliği ve mimarlar arasındaki deneyim eksikliği en çok gözlenen problemlerdendir.

Anahtar Sözcükler: Yaşam Döngüsü Maliyeti, YDM metotları, Bina yapımı, Ürün-Süreç 'e yönelik yaklaşım, Tasarım süreci, Mimar, Türkiye

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CHAPTER 1

INTRODUCTION

As in all manufacturing fields, achievement of the lowest cost of both initial investment cost and Life-cycle cost is an important consideration in building construction. *Life-cycle costing* (LCC) is a concept which aims to optimise the total of all costs required both to build and operate a project throughout its lifetime (Bull, 1993, Kleyner and Sandborn, 2007). Studies have equally shown that with the commercial building industry under heavy financial stress, increasingly more architects and engineers are looking to life-cycle cost analysis internationally to help reduce cost as far as they can (Kirk and Dell'Isola, 1995, Dunk, 2004). However, institutions of higher education, as well as a progressive number of architectural offices and construction firms continue to produce or support managers who lack awareness of the importance of LCC (Toor and Ofori, 2007). These managers' day-to-day work involves management of activities and achievement of the short-term goals of the project such as conforming to budget, schedule, and quality. They are focused on these short-term goals and subservient to delivering the project on schedule. They mostly end up managing their teams and day-to-day work rather than leading their people to achieve long-term objectives. This mindset that dominates in project management today renders managers more production-oriented than process-oriented. Life cycle cost awareness, on the other hand, entails recognizing the importance of process, especially design process (Toor and Ofori, 2007).

Design decisions require choice of construction structure, building materials and facility installations (Giudice et al., 2005). This is often accompanied by errors in investment through an inadequate economic control of decisions. Switzer (1963) stated that 25% of the total cost of construction investments were estimated to owe to errors made at the design stage. Thus, it can be said that the design process has an impact on LCC. In addition to this recognition, Trippett (1985) observed that, "Life-cycle costing is one of those things we talk about, read about and in theory we apply, but in practice most of us do not have the time or inclination to get involved with it." As the list of references at the end of this thesis demonstrates, an increasing body of literature produced world-wide has suggested that life cycle cost analysis is of vital importance to firms as international competition rises and technological change intensifies and it can be actualized as from use of LCC at the beginning of the design process. Since 1985, recognition of the importance of LCC has risen worldwide (Kirk and Dell'Isola, 1995, Dunk, 2004).

1.1. Research Objectives

There still remains much work to be done related to the subject of LCC in Turkey construction sector. With this aim, this thesis is concerned with the investigation of architects' knowledge and usage about LCC. This thesis comprises research in the discipline of architecture with a concentration in the field of construction project management. Within project management its concern is with the area of LCC. The objectives of this thesis are (1) to outline LCC analysis methods and parameters included LCC calculation in order to identify those that are being employed by architects and by means of the data thus obtained, (2) to measure awareness of life-cycle costing among architects by the method of the questionnaire in order to establish the importance of LCC and (3) to appraise the distance which we need to traverse toward full implementation nationwide. Therefore, as a summary, the present research objectives are to describe the importance of LCC and to conduct an investigation of the degree of awareness of life cycle costing among architects working in building industry and architectural offices in Turkey.

1.2. Definition of Terms

Before going into the details of the subject, however, some definitions should be offered. The essential terms to be defined are *life cycle costing*, *production-oriented* and *process-oriented*, along with a number of their derivatives it is going to encountered below.

There appears to be a consensus among the academic researcher in the field on the definition of LCC. The field specialists more or less offer the same definition: "LCC is a technique which enables comparative cost assessments to be made over a specified period of time; taking into account all relevant economic factors both in terms of initial costs and future operational costs" (ISO15686). Thus, "LCC is the sum of the present value of investment and operating costs for the building and service systems, including those related to maintenance and replacement, over a specified life span" (Hasan et al., 2007). In the context of buildings, LCC consists of analyzing initial capital cost, occupation costs, operating and maintenance costs and the costs which are benefited from its disposal (Arditi and Nawakorawit, 1999). Therefore, LCC is briefly the economic analysis of a building's entire life span.

One of the fundamentally important aspects of LCC, which is of equally great importance to this study of LCC awareness, is that LCC analysis is undertaken across the entire phase of the building process. As Perera et al. (1999) have pointed out, "The life-cycle costs are the costs associated with the product in any phase of the life-cycle." This basic definition tells us that LCC is a mode of analysis that needs to be undertaken at different points in the process of the initial project completion as well as periodically after project delivery in order to be repeated throughout the building's life-span. In other words, it may be claimed that LCC is conceived as a tool to be implemented distinctly at almost any point of an asset's life cycle in order to assess the least cost option among competing alternatives (Fabrycky and Blanchard, 1991). LCC covers assessments of costs in all steps in the life cycle. Moreover, Gluch and Baumann's study (2004) suggests that the LCC approach has an expanded life cycle perspective, and thus considers not only investment costs, but also operating costs during the product's estimated lifetime.

The LCC approach is based on the evaluation of different alternatives in the process of design in order to achieve the lowest cost of product (Woodward, 1997, Jiang et al., 2004). This approach derives from the fact that a building as a body consists of a large number of components and their further sub-components with a different life span. Each of these components invites different choices that will affect its LCC. Therefore, each component of building will have its own life cycle while the building overall will command its own. In order to evaluate all of these costs of the components, there are a few methods such as *present worth cost approach*, *equivalance annual cost approach*, *value-oriented LCC approach*, *base case approach*, *the approximate LCC method* and *rigorous method*. By utilizing these methods, a building's overall cost can be projected and a decision can be reached as to which offers the least cost in the life cycle.

As regards the comparison of production- and process-oriented approaches, firstly, production oriented approach can be defined that business concerned itself primarily with production, manufacturing, and efficiency issues. Focus point is just the production. It would not be incorrect to argue that the non-western world remains largely production-oriented. Especially in Asian countries such as Japan, China it is found that rapid productivity is the main goal in the construction industry (Schwenninger, 2006). Schwenninger (2006) argues that this is why, production LCCs are not of concern in these countries. On the other hand, production LCCs are taken into consideration and evaluated in the process-oriented approach. The concept of the process-oriented approach is formulated in ISO 9000:2000 as follows: "A systematic identification and management of the processes implemented in an organization and, primarily, ensuring their interaction can be regarded as the process approach, like that LCC needs to be managed in the process." As it is seen above, LCC essentially admits of implementation within a process-oriented approach, in contradistinction to the production-oriented traditional approach to building.

Finally, yet another aspect of the definition of LCC that is scientifically extremely important is its relationship to Life Cycle Management (LCM). LCC is a tool within LCM, which in turn is an application of life cycle thinking in management towards sustainable production and consumption (Krozer, 2008). LCM should be used to provide information on reliability factors for accounting purposes and help to develop and implement maintenance policy for the building. In addition to these, it monitors the performance of a building and provides the necessary feedback to LCC planning. The latter's function is to identify the differences between planning and performance (Flanegan and Norman, 1987).

1.3. Scope and Limitations of the Research

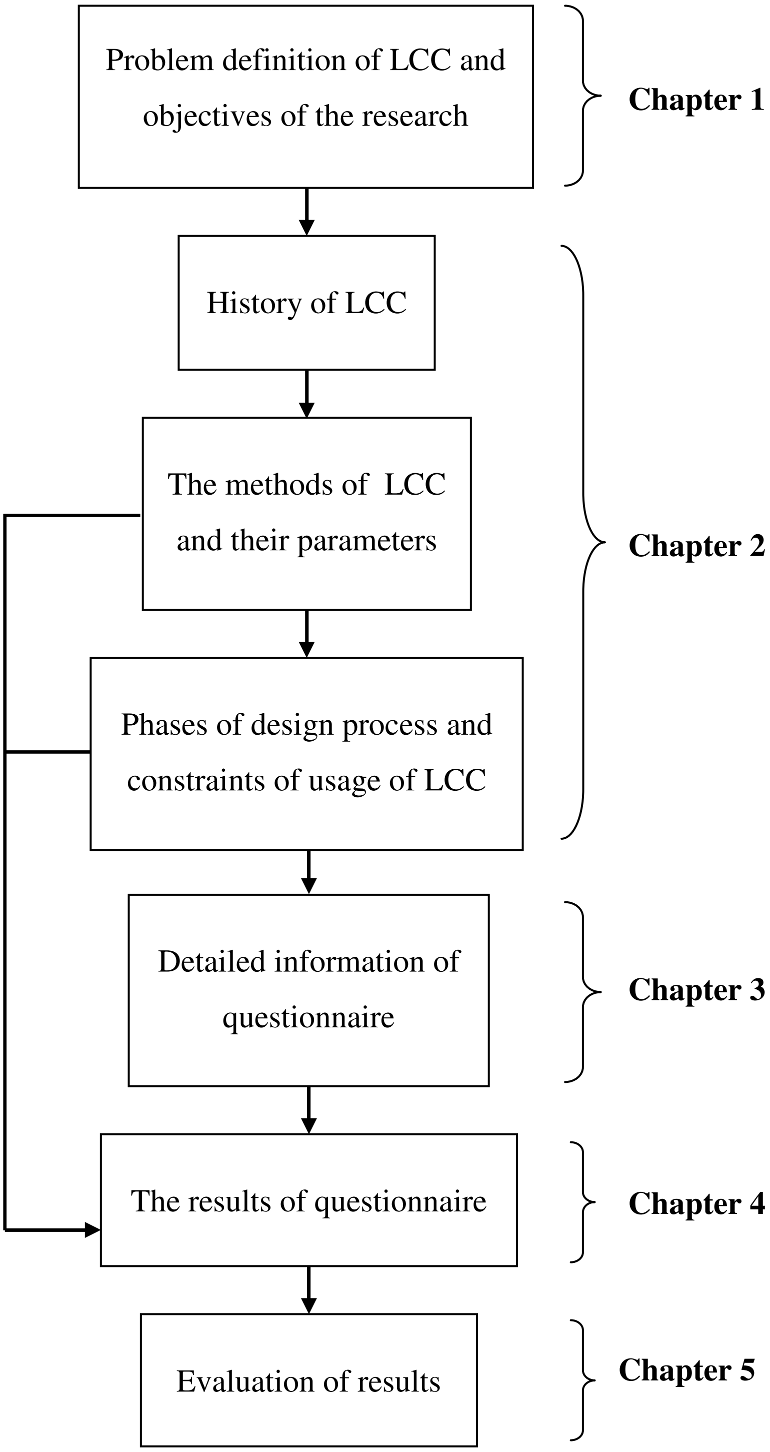
The empirical aspect of the research that comprises this thesis has been conducted in Aegean region in Turkey (i.e., İzmir, Manisa and Aydın provinces) with 114 architects.

There are five chapters in this thesis. In this context, Table 1.1. presents a summation of the structure of this study. As a scope of this thesis, after an introduction chapter giving brief information about LCC in building sector, in Chapter 2, a formal literature review was conducted to ensure a comprehensive collection of information pertinent to this research. It discusses various articles directly concerning LCC and so presents the development of LCC. Then, LCC' methods which analyze the cost performance and their parameters are summarized. Moreover, after definition of LCC analysis and its process, phases of design process where LCC calculations are implemented are explained. Finally, some constraints which prevent architects to use of LCC are defined.

Chapter 3 titled as the "methodology" explains how the survey instrument was developed and used to gather data. It also explains how the surveys were distributed and how the field studies were conducted. It describes in detail all methodological aspects of the different stages of research. Moreover, statistical methods which are used to analyze results of the questionnaire were described. Following the methodology section is the results section.

Chapter 4 analyzes questionnaire results. This chapter discusses the information that was obtained using the survey instrument. Results were evaluated by using statistical methods such as *factor analysis* and *Friedman rank test.* The last chapter of this thesis is the "conclusions". Chapter 5 interprets these results towards a better understanding of the awareness of architects and discusses suggestions for further research. Appendicies consists of the original questionnaire form in Turkish and English translation of the questionnaire.

Table 1.1. Structure of the study



CHAPTER 2

REVIEW OF THE LITERATURE

This chapter discusses the activities in, and phases on, establishing and implementing the LCC of buildings in the world. Moreover, it is intented to make LCC understandable and usable by the architects. For this chapter, the theoretical part involves a detailed literature research and the design of an outline within which to understand and evaluate the relevant literature. As an important issue to explain before mentioning all of properties of LCC is the motivation of the use of LCC.

The first reason of implementation of LCC analysis is energy scarcity. More and more energy becomes really important in the world and for sure in Turkey. On December, 2008, regulations of energy performance in buildings came into force in Turkey (T.C. Resmi Gazete, 2008). This regulations necessitate the implementation of energy performance analysis of buildings in order to acquire minimum value of energy. It is certain that LCC analysis include also energy performance analysis.

The other reason is the life expectancy of buildings so that buildings with long lives influence initial costs. Thirdly, efficiency of operation and maintenance costs has significant impact on overall cost of a building project that they should be reduced by LCC analysing. For these reasons, finally, it can be said that the larger the investment the more important LCC analysis become.

2.1. History of LCC

The theory of the LCC derives from the 1930s in USA and its implementation was first developed in the mid-1960s to support the US Department of Defence (DoD) for assessment of use of alternative military equipment (Gluch and Baumann, 2004). Its importance in defence was stimulated by findings that operation and support costs for typical weapon systems accounted for as much as 75% of the total cost (Gupta, 1983). However, most of the methodologies developed by the DoD were not intended for use for design but for procurement purposes (Asiedu and Gu, 1998). DoD practitioners have found two valuable by-products of LCC:

1. Life-cycle costing requires a comprehensive review with a long list of questions and answers. As a result, the asset design is more detailed before bidding than when LCC is not used.

2. Budget forecasts are better, because more-realistic cost and time schedules are developed. Companies gain a more-comprehensive understanding of operating costs.

First applications of LCC approaches in the building sector in Europe or United States dates back to the 1970s when this analytic tool was used to evaluate and compare relative benefits of alternative energy design options in buildings and its building applications continue to function in this capacity (Cole and Sterner, 2000). Therefore, it can be said that energy cost does play a major role in the long-term costs in use, but it is the only one of the many cost factors that must be considered and understood if the architect is to make meaningful design decisions.

Relevant to the beginning of LCC, substantial work has been done on the energy saving issue. Actually most of the LCC work that is applied in practice is due energy savings (Kirk and Dell'Isola, 1995). Especially after the 1973 oil crises, the energy policy agenda has changed significantly in most countries and also in Turkey (Hepbasli and Utlu, 2004, Kavak, 2005). In Turkey, the first regulation related to energy efficiency entitled ‘Protection rules from heat effects in buildings’ was published in February 1970. Other regulation dates back to 1972 and was published by the Ministry of Energy and Natural Resources. Regulatory view of energy in Turkey strategically focuses on a prime target, i.e. minimizing ‘heating’ energy consumption in buildings.

It is hard to speak about application of LCC approach as a whole in building construction. Although the analysis of the energy efficiency is based on 1970s in Turkey, when the historical background of the LCC approach is studied in building projects in Turkey, it is seen that it is not much different from the development that is observed in Europe or United States, but the difference is that the starting point is somehow 20 years late (1990s). This aspect can be supplied by evaluation of sustainable architecture because sustainable architecture contains LCC approach and considers the ecological, social, cultural, spiritual, aesthetic and economic conditions of the building. By taking activities based on environment into consideration, it can be said that research on sustainable architecture is observed in early 1990s in Turkey (Arsan, 2008). Because of the lack of the data related to LCC in Turkey, it can not properly be claimed that these early investigations were LCC implementations. Thus, the needed historical background can be obtained from other international researches in order to start the collection of data for future research that will be carried out in Turkey, after the evaulation of people’s knowledge/awareness about LCC.

The past decade has seen enormous interest in the life-cycle of buildings and many of the characteristics of green building are established within this context. Green designs (sustainable design) typically have important operating benefits for low energy and water operation costs, lower maintenance costs because of more robust design. On the other hand, although reducing operating and maintenance costs are beneficial in their own rights, and the cost savings can be considerable, these components often actually viewed a very small percentage of the total costs incurred in many buildings. Over a 40 year life cycle of a typical office building, the cost of people to process information (i.e., salaries) have been estimated in order of 92% of the total costs incurred in an office, the operating, maintenance and replacement costs nearly 6-8%, and the remaining 2% for the cost of the building itself (Cole and Sterner, 2000). As such, resisting to make progressions in 2-8% of the costs may be seen as economical marginal if it could potentially conflict with occupant productivity or other aspects of user satisfaction. However, for many clients such a comprehensive view of costs may not be useful in making decisions about alternative building design options. Isolating the building operation and maintenance cost can account for nearly 55% of the total cost seen over a 40 year life cycle (Flanegan and Norman, 1987) and in this case the LCC methodology is a useful tool.

Studies geared directly toward developing and assessing LCC awareness among architects remain surprisingly few. A thorough review of existing literature on a given subject matter, sources of information on “Life cycle costing” was conducted in order to locate. Once the key words had been identified, the appropriate search tools and databases were identified. As a key word “Life cycle costing” was used to search it in databeses. In order to cover engineering, architecture and economic literature related to life-cycle costing, a range of search engines and databases were used. Extensive searches were conducted across the following databases: Informaworld, ScienceDirect, American Society of Civil Engineers (ASCE) and Emerald. References narrowed down by journal title. Refereed journals used in literature review are as follows: Engineering, Construction and Architectural Management (ECAM), Construction Management and Economics (CME), Building Research and Information, Building and Environment, International Journal of Production Research, International Journal of Product

Economics, International Journal of Project Management, Journal of Construction Engineering and Management, Journal of Infrastructure Systems and Journal of Architectural Engineering.

Table 2.1. presents the number of breakdown of the articles based on “Life cycle costing” in respect of appointed journals. At the end of searching, 139 articles were found and their range of publishing year is 1981-2009. In other words, relevant articles for almost past 25-30 years were collected. Out of these articles, 7 articles use the questionnaire method. After the evaluation of these articles, merely 3 of them try to measure participants’ use of LCC on the international scale. Table 2.2. indicates these 3 previous research studies in order to compare them.

First article is titled “*Life-cycle costing and its use in the Swedish building sector*” by Sterner (2000). Sterner’s study evaluates client’ awareness about LCC. It was investigated what extent Swedish developers and clients use LCC estimations. It consists of a well classification of design phases, parameters included in LCC calculation and constraints which prevents to use LCC calculations.

Second article on survey of LCC is titled “*Life cycle cost based procurement decisions: A case study of Norwegian Defence Procurement projects*” by Tysseland (2007). This study evaluates project leaders’ attitude and knowledge about LCC.

Third article is titled “*The contractor's use of life cycle costing on private finance initiative (PFI) projects*” by Swaffield and McDonald (2008). It investigates the attitudes and opinions of staffs working in building contracting organisation about the importance and use of LCC within PFI projects during the procurement process.

Table 2.1. The breakdown of the articles based on "Life cycle costing"

DATABASES	JOURNALS	NUMBER OF ARTICLES	RANGE OF YEAR
INFORMAWORLD	Building Research and Information	14	(2000-2009)
	Construction Management and Economics	19	(1985-2008)
SCIENCEDIRECT	International Journal of Project Management	19	(1987-2008)
	International Journal of Production Research	5	(1999-2008)
	International Journal of Product Economics	15	(1994-2008)
	Building and Environment	31	(1981-2009)
ASCE	Journal of Infrastructure Systems	11	(1996-2004)
	Journal of Architectural Engineering.	4	(2002-2007)
	Journal of Construction Engineering and Management	3	(1996-2004)
EMERALD	Engineering, Construction and Architectural Management	18	(1997-2008)
	TOTAL	**139**	**(1981-2009)**

Table 2.2. Comparison of previous research studies on survey of LCC

AUTHOR / COUNTRY / YEAR	FOCUSES	KEY FINDINGS	SAMPLE / KEY INFORMANTS
Sterner, E. Sweden 2000	• What extent Swedish developers and clients use life cycle cost estimations, • In which phases they use it, • What their perception of the limitations.	• The parameters that are usually included in a LCC calculation are investment, energy and maintenance costs, • LCC calculations are usually performed in the design phase of projects, • The use of LCC is limited, • In turn, limited experience and lack of relevant input data in using LCC calculations are major constraints.	Survey of 53 Clients
Tysseland, B. E. Norway 2007	• The effect of project uncertainity on use of LCC, • The effect of Information symmetry on use of LCC, • The project leader's attitude and knowledge about LCC.	• Project uncertainty negatively affects the use of LCC-based procurement decisions, • Less goal conflict exists between projects' leaders with a positive attitude towards LCC and the principle, than between the principle and project leaders with a less positive attitude towards LCC, • Information symmetry between the principal and the agent really makes a unique contribution to the use of LCC based procurement decisions, • Lack of knowledge, with regard to LCC, leading to less use is empirically supported.	Survey of 78 Project leaders
Swaffield, L. M. and McDonald, A. M. United Kingdom 2008	• Investigate attitudes and opinions about regarding the importance and use of life cycle costing within private finance initiative (PFI) projects during the procurement process, • The subsequent effects on the maintenance budgets of the facilities management contractor within the PFI consortium.	• Participants had a good knowledge/understanding of PFI contracts and what is meant by the term LCC, that LCC is a decision-making tool and that there are different mechanisms are available to estimate LCCs at the early stage of a project, • Participants were aware of the importance of LCCs within PFI projects, and were aware of the maintenance requirements of the construction works when procuring new works, • Because of some constraints or difficulties (i.e., busy times, pressure from managers, lack of experience) they sometimes do not consider LCCs and instead procure products on the basis of lowest capital cost.	Survey of 37 Quantity surveyors working in building contracting organisation, and 4 semi-structured interviews

2.2. Cases of LCC Applications

Recently several research projects have been carried out aimed at developing the LCC methodology for the construction industry and placing LCC in an environmental context (Abraham and Dickinson, 1998, Aye et al., 2000, Bogenstatter, 2000, Sterner, 2000, Jiang et al., 2003, Mithraratne and Vale, 2004, Giudice et al., 2005, Kleyner and Sandborn, 2007).

One example is Abraham and Dickinson's study (1998) of the disposal of a building in which LCC calculation is used to quantify disposal costs. Aye et al. (2000) used LCC to analyse a range of property and construction options for a building. Bogenstatter (2000) advocate the usability of performing an LCC calculation in the early design phase. A model is developed using specific characteristic values of LCC, i.e. standardised typological figures. The study suggests defined specifications from similar buildings as key solutions to the usability problem. Sterner (2000) developed a model for the evaluation of tenders, where LCC methodology is used to calculate the total energy costs for buildings. Jiang et al. (2003) developed an analytical framework in order to solve the problem how to select the best alternative. The main idea was to give different significance to the under-budget quantity and over-budget quantity. After a year, Mithraratne and Vale (2004) developed a method at University of Auckland for a detailed life cycle analysis of an individual house in New Zealand based on the embodied and operating energy requirements and life cycle cost over the useful life of the building. It was thought that it is harder to compare one design with another for architects or designers. Therefore, it is useful for a designer to have a tool, which allow a building to be estimate its value at the design phase. By using Mithraratne's and Vale's tool, various design alternatives and strategies can be compared with one another depend on the performance over their useful lifetime.

For automotive sector, LCC calculation is also used. For instance, Giudice et al. (2005) developed a systematic method which presents environmental considerations in the selection of the materials used in components, meeting functional and cost performance requirements while minimising the environmental impact associated with the product's entire life-cycle. Besides, in same sector, Kleyner and Sandborn (2007) developed an optimal product validation plan for a quantitative solution that minimizes the life cycle cost of a product. The model utilizes the inverse relationship between the cost of product validation activities and the expected cost of repair and warranty returns.

2.3. Objectives of LCC

The primary objective of LCC is to provide a technique which has the potential for the correct financial evaluation of buildings and replace the traditional methods based on the initial costs of the building project. LCC objectives can be put in order as follows (Flanegan and Norman, 1987):

1. Identifying the total cost commitment rather than concentrating on the initial capital costs,

2. Facilitating an effective choice between alternative methods of achieving a stated objective,

3. Detailing the current operating costs of assets such as individual building elements (i.e. heating systems, roof coverings), or complete building systems,

4. Identifying those areas in which operating costs might be reduced, either by a change in operating practice e.g. hours of operation, or by changing the relevant system,

5. Determining the factors of maintenance costs in order to lessen it.

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

1. Affordability studies: Impact of a system or project's LCC on longterm budgets and operating results can be measured.

2. Source selection studies: For these studies, by using LCC analysis, estimated LCC among competing systems or suppliers of goods and services can be compared.

3. Design trade-offs: They influence design aspects of buildings and equipment that directly impact LCC.

4. Repair level analysis: For this type of studies, LCC quantify maintenance demands and costs rather than using rules of thumb such as "... maintenance costs ought to be less than 'x' % of the capital cost of the equipment."

5. Warranty and repair costs: Suppliers of goods and services along with endusers need to understand the cost of early failures in equipment selection and use. By using LCC this can be achieved.

6. Suppliers' sales strategies: They can merge specific equipment grades with general operating experience and end-user failure rates using LCC to sell for best benefits rather than just selling on the attributes of low, first cost.

2.4. Methods of LCC

LCC methods play major role in its calculation. It is not easy to reduce all product (building) cost. A building as a body consists of many components, each having further sub-components each with a different life span. For instance, there are a number of different ways to heat a building such as a wood stove or solar heating. There are different ways to illuminate it such as candles or electricity. Each of these ways of heating and illuminating will necessitate use of different materials and objects for sustenances. Each component of the system will have its own life cycle while the system overall will command its own. In order to calculate overall components' LCC, there are a few methods. By utilizing these methods, a building's whole cost can be projected and a decision reached as to which offers the least cost in the life cycle. For doing this, one of the basic attributes of the LCC technique is discounting where all costs are transferred to common point in time allowing comparisons between different design solutions to be made. Generally, the following cost analysis model is adopted in which the life-cycle cost is calculated as follows (Celik, 2006):

$$LCC = C + M + R - S \tag{2.1}$$

where C is the capital/investment cost, M is the operation and maintenance cost, R is the repair and replacement/alteration cost and S is the salvage value. According to literature, the most commonly prefered methods of LCC which are named as historical LCC methods are:

- Present worth cost approach,
- Equivalance annual cost approach.

and the other methods which are named as contemporary LCC methods are:

- Value-oriented LCC approach,
- Base case approach,
- The approximate LCC method,
- Rigorous method.

<u>Present worth cost approach</u>

The present worth cost approach (PWC) allows for a more detailed evaluation of future costs. By utilizing PWC method, all initial and future costs over the life cycle of the building are individually converted into their present value equivalents and then added up. When using this method, effects of two factors should be ignored. One is the inflation rate which defines future costs and the other is the interest rate which determines the present value of the future costs (Bledsoe, 1992, Thorbjoern, 1992, Sheen, 2005, Aktacir et al., 2006). These variations are rather effective, especially in Turkey. The PWC method without considering inflation is calculated by using this equation:

$$P = F \frac{1}{(1+i)^n} \tag{2.2}$$

This equation applies when inflation is taken into account:

$$P = F \frac{(1+f)^n}{(1+i)^n} = F \left[\frac{1+f}{1+i} \right]^n \tag{2.3}$$

If the present value of equal payment at the end of ‘n’ years is calculated (without inflation), the equation is:

$$P = A \left[\frac{(1+i)^n - 1}{i\ (1+i)^n} \right] \tag{2.4}$$

Equivalance annual cost approach

An implications of the equivalance annual cost approach (EUAC) are more readily understood in the context of business decisions. Moreover, it is more clear to compute than the PWC method in the case of a regular annual series of payments, particularly if the capital is obtained through loans. By the EUAC method, it can be seen how the total costs relate to ability of the project to generate the income needed to pay for them, on a year by year basis. Therefore, the EUAC represents the summation of the annual capital cost and the annual operating cost (Thorbjoern, 1992, Sheen, 2005). Its equation is:

$$A = P \left[\frac{i\ (1+i)^{n}}{(1+i)^{n} - 1} \right] \tag{2.5}$$

Both of these methods have some variables which are symbolized like below:

P = Present worth

F = Future sum

A = Equal payment series

i = interest rate

f = inflation rate

n = number of periods

Value-oriented LCC approach

Value-oriented LCC approach focuses the components of product. When first two method calculates only production cost, this method evaluate the whole life cycle costs of product by allocating product as to its functions and value view. Furthermore, this method is a process-oriented that the costs are classified according to many different processes and resources (Janz et al., 2005).

Base case approach

This approach involves comparison between LCC of a new product and a product which is a representative sample implemented in advanced. In other words, it enables comparative LCC estimation (Lutz et al., 2006). This method can be applied to the whole product, or to different parts or components of product. In order to apply this method some simulation programs are used such as Monte Carlo simulation which selects sample in several uncertain variables by exposing the many possible consequences of embarking on a project (Meredith and Mantel, 2002).

The approximate LCC method

Like base case approach, by applying the approximate LCC method, the comparative LCC estimation is made between the different product concepts. In this method, Artificial neural network (ANN) is used as a model, therefore, it is not required to set up a new model for each time. ANNs are generated from algorithms. An ANN model can help the designers to make knowledgeable decisions at the early phases of the design process. It should be indicated that with an ANN model, it is possible to acquire a quite precise forecasting, even when there is an adequate information in the early stages of the design process (Günaydın and Doğan, 2004, Dombaycı and Gölcü, 2009). Costs of different design alternatives are estimated easily because detailed information is not necessary for approximate LCC method (Park et al., 2007).

Rigorous method

Rigorous method calculates life cycle costing sensitively with algorithmic checking of correctness. This method required a longer computation time and the codes for LCC model require rather more memory. For this reason, its implementation is realy hard (Okada et al., 2008).

2.5. Cost Models and Parameters Included In LCC Calculation

As well as the methods of LCC which will be mentioned below, some calculation models take part in LCC applications. Cost models used to forecast life-cycle system characteristics range from simple to complex in nature. Determination of these models depend on the user of LCC and the content of the project. These models are structured three general categories: conceptual, analytical, and heuristic (Asiedu and Gu, 1998).

'Conceptual models' consist of a set of hypothesized relationships expressed in a qualitative framework. These models are not mathematical. Generally, they are very flexible and can accommodate a wide range of systems. Their intention is typically to excite the idea process, though they are limited when it comes to formal analysis (Sherif and Kolarik, 1981).

'Analytical models' are usually based on mathematical relationships designed to describe a particular aspect of a system under certain conditions or assumptions (Asiedu and Gu, 1998). These assumptions tend to limit the ability of the model to show the actual system performance. The scope of the limitation is directly related to the complexity of the system (Sherif and Kolarik 1981).

'Heuristic models' are ill-structured analytical models. They are employing approach that produces a possible solution but oftentimes it is not an optimal solution (Asiedu and Gu, 1998). Computer simulation and Monte Carlo techniques are typically used in heuristic models.

Whole life cycle model usually require the development of submodels for different cost categories in different life cycle phases. In order to generate these models, there are some parameters. These are as follows.

Investment cost

The development and implementation costs required to make a project fully operational are investment cost. It includes; all purchases, lease or finance costs, hourly labour cost, hourly productivity, cost of land, cost of transport, installation, training, personal and purchased services and so forth. This investment is made in the zero year (Year 0) before production activities begin (Thorbjoern, 1992).

Energy cost

Energy costs is a cost of generating energy for a particular system. The energy cost consists of separate costs for natural gas or oil, and electricity. It can be classified in 'operation cost'. Energy costs are often difficult to predict accurately in the design phase of a project. Assumptions must be made about use profiles, occupancy rates, and schedules, all of which impact energy consumption. At the initial design stage, data on the amount of energy consumption for a building can come from engineering analysis or from computer programs (Lutz et al., 2006).

Maintenance cost

The maintenance cost typically includes the cost of labor, regularly scheduled adjustments and inspection to protect a building so that it goes on to supply the same comfort and appliances-resources and the cost of parts to perform repairs (Woodward, 1997, Arpke and Strong, 2006). Furthermore, decoration, fabric of building (i.e., roof, external walls), services (i.e., heating and ventilation) are took place in this cost. It can be used as the term ‘occupancy cost’ (Thorbjoern, 1992, Perera et al., 1999, Lutz et al., 2006). Over the last three decades, organisations and individuals have been trying to draw the attention towards the economic significance of building maintenance expenditure.

Alteration cost

It is the cost of changes to the interior arrangement or other physical characteristics of an existing facility or installed equipment so that it can be used more effectively for its currently designated purpose or adapted to a new use. Alterations may include work referred to as improvement, conversion, remodeling, and modernization of building. It could be included under the category of regular maintenance cost (Thorbjoern, 1992).

Acquisition cost

The acquisition costs refer to the overall costs of purchasing an asset. It is price (including the closing costs) and all fees required to obtain a property and goods-services or to purchase another company or the cost effect of alternative sources of funds and gearing (Woodward, 1997). Insurance costs, replacement of manufacturing equipment, freight costs, raw materials, and any element that goes into the creation of the good or service has to be considered when determining the true cost of acquiring new assets such as property or even new customers.

Salvage value

It is the estimated value of an asset at the end of its useful life. In accounting, the salvage value of an asset is its remaining value after depreciation. It plays a larger role in life cycle cost analysis involving machinery or vehicles, for example, than for buildings. Production machinery made of metal always can be sold at least for scrap at the end of its useful life, perhaps even for second-hand use. Therefore, its salvage value must be estimated and included in the analysis (Thorbjoern, 1992).

Environmental costs

The environmental costs relates to all costs incurred in relation to environmental damage and protection. It is difficult to specify environmental costs from other costs in the corporate accounting system. The insufficient recording of environmental costs in corporate accounting systems is identified as a major obstacle for the successful implementation of corporate environmental accounting tools (Gluch and Baumann, 2004).

Interest rate

The term structure of interest rates is a useful predictor for the future movement of important economic variables, not least of all, short-term interest rates, inflation, and economic activity (McMillan, 2009). It can be defined as a key instrument for financial research that it is a time value of the money. Interest rates is an extremely useful tool, not only for finance, but also for macroeconomics (Gimeno and Nave, 2009).

Life-cycle

The lifetime is a standart concept of a building wherein it goes through a construction phase, an operating and maintenance phase and a demolition phase. It is the age at which product is retired from service (Lutz et al., 2006). It is important to acknowledge that different kinds of life cycles are considered in LCC (Gluch and Baumann, 2004). Based on the length of the life cycles, products can be classified into three general categories. These are large scale, mid scale, and small scale (Lee and Melkanoff, 1993). Table 2.3. presents these classifications. The distinction between the different types of cycles is important from a life cycle analysis perspective because the types of tradeoffs and analytical models that are employed for a large scale development effort might not be as effective for a small scale process (Lee and Melkanoff, 1993).

Table 2.3. Product classification by length of life-cycles
(Source: Adapted from Lee and Melkanoff, 1993)

LIFE-CYCLE		
Large scale	**Mid scale**	**Small scale**
• Multiple, multi-year, on-going development cycles • Decade length operational life • Multiple comlex subsystems • High infrastructure development and maintenance • Continuing sales value	• 1-5 year development cycles • 1-5 year operational life • Critical subsystems • Low field infrastructure support costs	• Less than 1 year development cycles • Less than 2 year operational life • Simple subsystems • Little or no field support costs

Using these parameters, there are many different approaches to developing cost models for life-cycle cost analysis. The more parameters are choosen, the more complex is the model and the more time takes the LCC calculation in order to perform an analysis.

2.6. LCC Analysis

The LCC analysis (LCCA) is a methodology to forecast the costs of a proposed product during its progression phase. LCC analysis is used during the development process to measure product cost performance in each life cycle stage and provide quantitative feedback about the effects of design decisions among the different stages. Traditionally project success or performance is measured on the triple constraints; time, budget and overall quality (Gemünden et al., 2005). However the triple constraint has often only included the research-development and investment phases of the project, not the operation-support and disposal phases. If architects still think that their future (for example promotion) is based on the fact that the procurement projects are finished on time and within the original investment budget, their attitude towards the use of LCC based investment decisions will most likely increase the operation and maintenance costs (Tysseland, 2007). Therefore, LCC analysis which consider whole costs of construction projects is used for measurement of cost performance.

In 1976, Harvey prepared the general procedure for LCC analysis. These procedure is shown in Figure 2.1. It includes four steps to arrive LCC. One of the procedure step is the cost elements of interest. They are all the cash flows from acquisition to disposal at the end of its life. Defining the cost structure consists of grouping costs in order to introduce potential trade-offs. Figure 2.2. illustrates these cost categorisation. It consists of engineering and development; production and implementation; and operating costs. The developed condition of these categorisation will be defined in section 2.6.1. "Processes of building project for LCC analysis". A cost estimating relationship is a mathematical evidence for forecasting purposes, the cost of an item or activity. Establishing the method of LCC formulation contains defining an appropriate method in order to interpret the asset's LCC (Woodward, 1997).

For LCC analysis, Kaufman (1970) also developed a formulation including eight steps to arrive LCC. Figure 2.3. presents these steps. It is the more comprehensive procedure than Harvey's. First step is to define operating profile. It is the periodic cycle and contains the modes of start up, operating and shut down. Second step is an establishment of the utilisation factors indicated in what way equipment will be functioning. Third step is an identifying all the cost elements (i.e. initial cost, operation cost et al.). After these steps, as in order defining the critical cost parameters and calculation all costs at current prices are coming. Sixth step of Kaufman procedure is an increasing current costs at assumed inflation rates which mentioned above in methods of LCC. Discount all costs to the base period is the seventh step. It is known that money which has a time value and the cash flows developing in different time periods are discounted back to the main period to warrant equatability. Finally, collecting discounted costs to establish the net present value is the last step in order to reach LCC (Woodward, 1997).

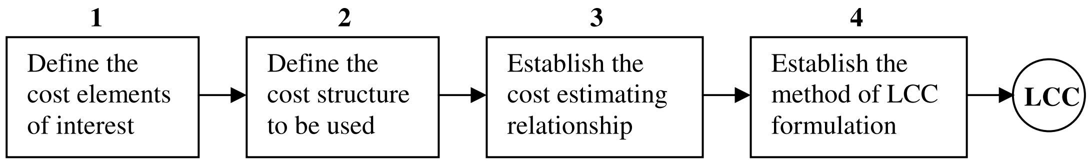


Figure 2.1. Harvey's life cycle costing procedure
(Source: Adapted from Harvey, 1976)

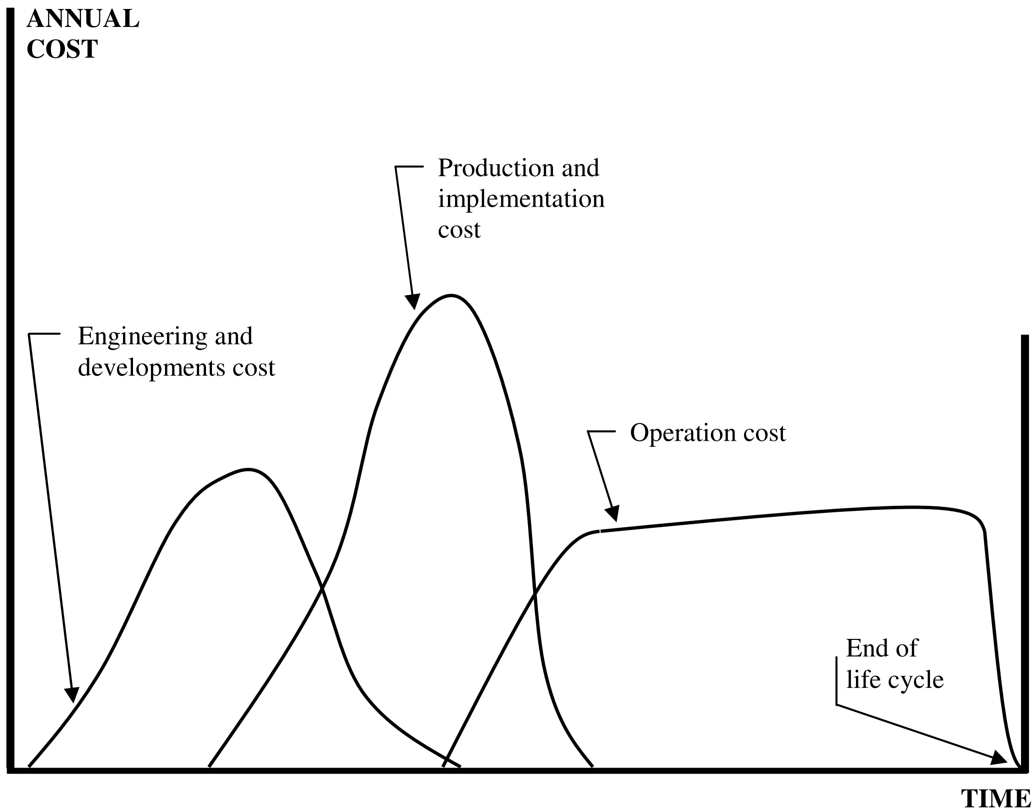


Figure 2.2. Cost categorisation
(Source: Adapted from Woodward, 1997)

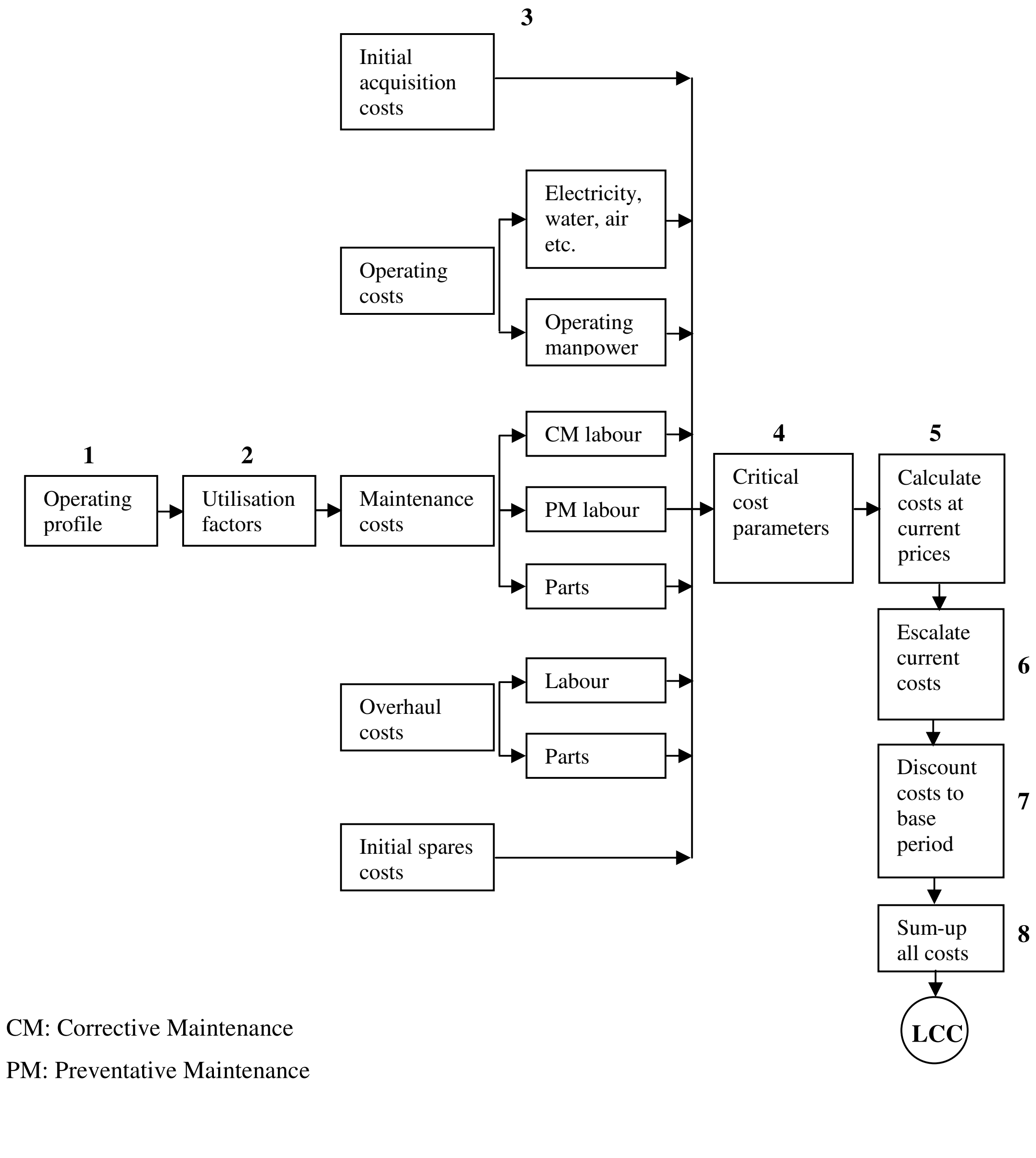


Figure 2.3. Kaufman's life cycle costing procedure
(Source: Adapted from Kaufman, 1970)

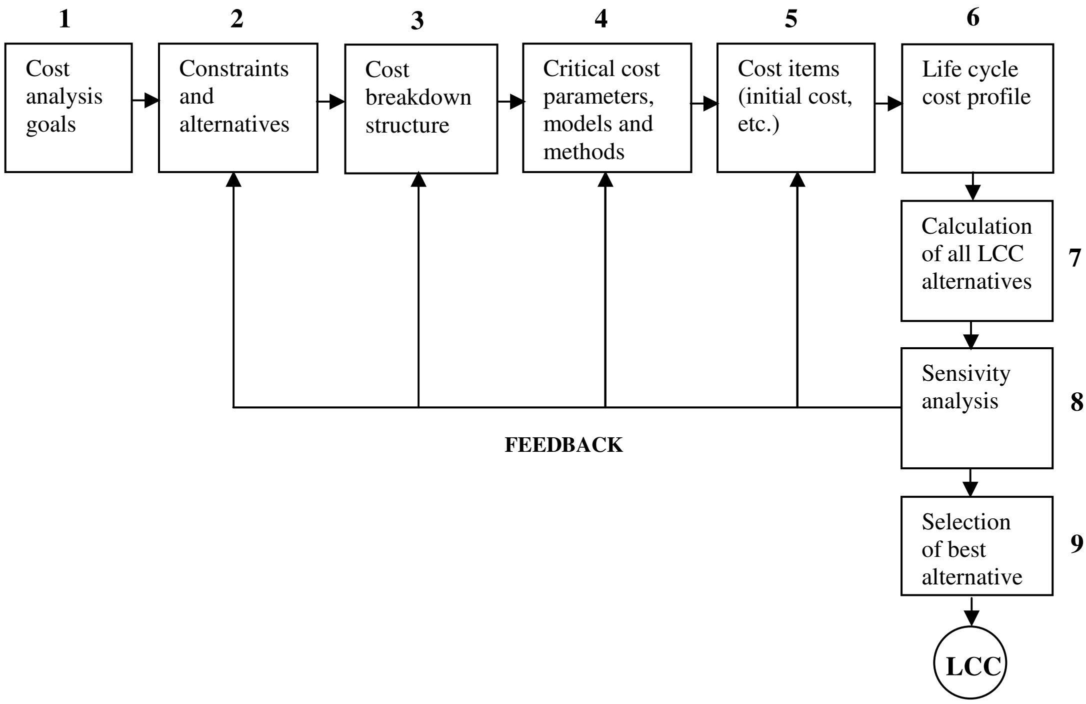


Figure 2.4. Recent life cycle costing procedure
(Source: Adapted from Asiedu and Gu, 1998, Cole and Sterner, 2000, Dunk, 2004, Mithraratne and Vale, 2004, Aktacir et al., 2006, Lutz et al., 2006

Recently, when performing LCC studies, the life cycle costing analyst (i.e., Asiedu and Gu, 1998, Cole and Sterner, 2000, Dunk, 2004, Mithraratne and Vale, 2004, Aktacir et al., 2006, Lutz et al., 2006) has to carry nine activities which are giwen below and shown in Figure 2.4.:

1. Establish and describe the main cost analysis goals. This is an obvious starting point.
2. Define constraints and feasible alternatives for the decisions.
3. Prepare cost breakdown structure. Include in these events all applicable future activities associated with research, development, production, construction,installation, commissioning, operation, maintenance, and disposal.
4. Identify parameters, its models and method.
5. Identify cost items to be considered (i.e., initial cost data, salvage values).
6. Develop life cycle cost profile.

7. Calculate the final LCC for all alternatives using an appropriate cost model.. The process is based on finance mathematics and usage of them.
8. Perform required economic evaluation (sensivity analysis). In the overwhelming majority of cases, the model should include a sensitivity analysis. Sensitivity analysis consists of evaluating the results displayed by a model.
9. Select best value alternative

An important initial step is the classification of the analysis' objectives and the bounding of the problem such that it can be studied in an efficient and timely manner. After sensivity analysis (eighth step) if the result is not approximate or required for product, the structure of identify constraints, parameters et al. step in again. Through early implementation, cost analysis can not only influence the final design by providing the relevant cost information but can also contribute to cost reduction by identifying cost drivers and how changes in design parameters affect cost (Asiedu and Gu, 1998).

2.6.1. Processes of building project for LCC analysis

For LCC analysis, all of these issues are generated in the process of a building project. This is illustrated in Figure 2.5. which shows that the earlier the LCC, the more importance the possibility for cost reduction and the lower the cumulative costs of the project (Kirk and Dell'Isola, 1995). These processes consists of five subprocesses as in order:

<u>Inception process</u>

Getting first impression about building and interaction between customer and architect defines this process. It developes as an idea in design process.

<u>Design process</u>

It includes idea/conceptual phase, planning phase applying preliminary design, design phase implementing design and shop drawings, and procurement phase including documentation. These phases will be mentioned.

Construction process

After months of planning, design, site selection, financing and marketing, construction process of building project exists by bidding the project and embarking. This process contains an implementation of project, building or assembling of infrastructure. It can be defined as the translation of paper or computer based designs into reality.

Operation & Maintenance process

It starts after the end of construction of building. It is an operation of energy, water efficiency, indoor air quality, durability etc. and repairing of a building or its systems or components. This process relates to health and safety of a building.

Demolition

It refers end of life of building. When the building is of no use to anyone or cannot be repaired anymore, it needs to be pulled down.

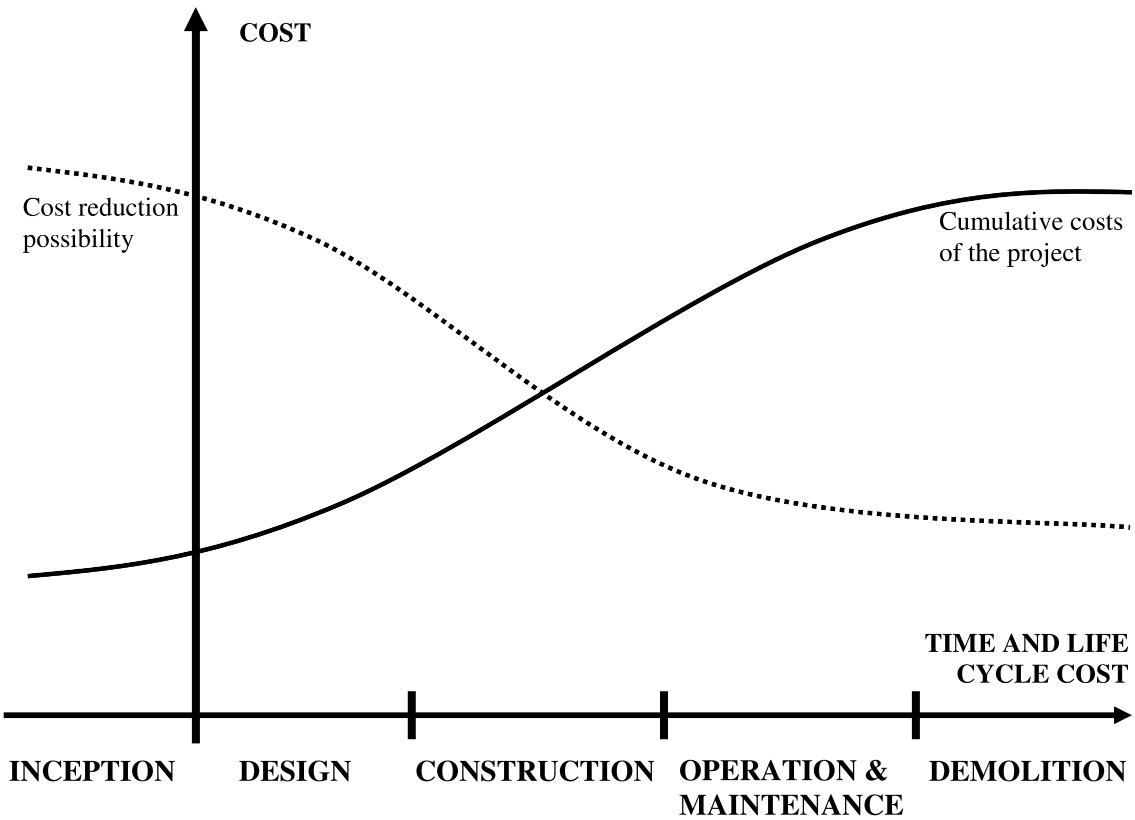


Figure 2.5. Phases of building project
(Source: Adapted from Kirk and Dell'Isola, 1995)

Life cycle costs are total costs from inception to disposal for both equipment and building projects. Architects perform LCC analysis especially in first two process named inception and design. These are named as a design process which will introduced comprehensively in section 2.6.2. “Phases of design process”. The other process is related to firm developing the product. While the firm must know the total cost of the product, the designer is only interested in the costs that he/she can control. Some of the costs incurred in the life of the product are not as a result of the design. These costs are related to the `way we do things’ in construction process (Asiedu and Gu, 1998). It can be said that while architects analyze LCC in design process including operation and maintenance cost, firms are just related to construction process. Besides, operation and maintenance cost almost exceed the initial purchase price for construction of that item as much as ten times. On the other hand, although construction cost immediately appears as an investment cost, operation and maintenance costs occur slowly throughout life time of a building. That is why, an importance of operation and maintenance costs in LCC calculation is understood subsequently. The most important mission for the designer therefore is to understand the relationship between cost information and design decisions.

In phases of building project, six factors should be thought by designers and firms (San-Jose et al., 2007):

Environment

The different locations and integration alternatives of a building in the environment should be considered. Furthermore, the different possibilities of using “ecological” materials which generates a lower environmental impact, reducing energy consumption, should be considered. The construction process originates affections in the environment, as emissions in to atmosphere, spills into the water, occupation and dirtiness of soils. Throughout the useful life of a building, during its use stage, it will also have impacts on the environment, via water and electricity consumptions, not to mention generation of process waste. Furthermore, at the end of its useful life, one must study the possibilities of its reuse or benefiting from the materials comprising the same, likewise promoting selective demolition activities and waste management as per the recycling possibilities thereof.

Economy

Economy involves the effective use of materials, site area and also the proper and logical cost of construction. The building economical needed occurs not only during its construction stage but also operation and maintenance stage during its useful life. This concept may be occurred by architects' preferences without high cost or impossible construction. From the sustainability viewpoint, co-ordination of resources to be used up by a building throughout its useful life obtains great importance. This aspect refers to energy consumptions, especially electricity for lighting, ventilation and air conditioning of the same, likewise the process water consumption. A further opportune energy consumption to be considered is that corresponding to machinery transport of materials inside the building. This requirement could be assessed using LCC analysis that the factor of economy is the main subject of this study.

Social

Building social component as an economic support or activity, makes it an employment generator; likewise human relations among workers, quality of the inner environment.

Safety and industrial risk prevention

Safety understood as the physical integrity of people, particularly in construction and deconstruction process; likewise maintenance works, which must be particularly relevant to minimize accidents.

Functionality

Building functionality with a view to correct execution of the activity for which it was designed. The capacity of building adaptation to the process should be studied to prevent using new enlargements in the event of company growth, reducing the employment of new materials, economic costs and waste generated.

Aesthetics

Building aesthetics is another value to be born in mind with a view to maintain the architectural asset; likewise preservation of the city, or company image. The aesthetic degree gains importance in design phase. Often, the owner company promotes constructing the building with the corporate image, i.e. identifying and granting it greater prestige, thereby identifying the aesthetical requisite as a sustainable aspect to be considered.

2.6.2. Phases of design process

Numerous researchers believe that design decisions bear significant effects on the running costs of buildings over their entire life span (Stone, 1975). "As small as is the design cost of the building, it is the decisions that the designer makes that have the greatest impact on the total life cycle cost of the building" (Perkins, 1975). In addition to this, Law (1984) has claimed that "it is the designer who, by his skill as a planner and his ability technically, can make the greatest impact on future life costs." Basing ourselves on Weston and Brigham (1981), moreover, it may be argued that designers, in particular, should keep in mind that it is the whole life of a system that should be the main concern, even if only one component of that system is designed. Studies have showed that the design of the product influences between 70% and 85% of the total cost of a product. Therefore, designers can practically reduce the LCC of products by giving required consideration to life cycle implications of their design decisions (Dowlatshahi, 1992, Asiedu and Gu, 1998, Westkamper et al., 2000).

In order that give the designer quick and accurate estimates of the financial consequences of his/her design decisions and procedures to determine optimal design parameters, some tools should be developed. CAD systems can provide the necessary integration of design and cost engineering (Westney, 1983, Wierda, 1988, Thorbjoern, 1992). This integration can be accomplished by constructing, on the CAD system, design cost and optimization models. For these integrations, LCC should take place into design process which can be broken into four phase:

<u>Idea/Conceptual phase</u>

In this phase, designers develop critical concepts about a problem and identify goals, potential opportunities and attributes. This mental activity is based on bringing together the characteristics of an architectural subject. As a good project begins with great amount of courage, creative thinking and awareness of resources available.

Planning phase

The project planning phase is the second phase in the project life cycle in design process. In this phase, conceptual studies are developed. Designers carry the design problem to the platform of materiality, or material sensuousness regard as project requirements based on user. Project plan becomes clear.

Design phase

Designer's idea goes from a sketch, through CAD (computer aided design) and development and into a physical prototype. Each and every element of the project is incorporated into the plans and documents. Project is planed in the form of the final product of a design process and they shall be ready for biding. This progress is continued by relationship of client and designer.

Procurement phase

At the end of design phase, goods and/or services are acquired at the best possible total cost of ownership. In this phase expected sustainable design requirements are selected and design deliverables including goals, design analysis, documentation of the sustainable design features are obtained.

2.6.3. Tools of building project for LCC analysis

In order to perform an LCC analysis in building project, datas related to building should be define before determining parameters, methods et al. Table 2.4. presents these input data needed to perform LCC for a building.

In the lack of real data, as the case is for planned buildings, estimates can be based on past experiences. Data on costs, lifetimes and energy use of different building types and building components can be gathered from forecasting standards that provide data for an 'average' building. On the other hand, because of regional differences, the location of a building has a large impact on its final life cycle cost (Gluch and Baumann, 2004). For instance, fees and taxes can alter and the location can also be more or less sensitive to environmental effects, which makes the data received from standards not applicable for the situation in hand.

Table 2.4. A sample of input data needed to perform LCC for a building
(Source: Adapted from Gluch and Baumann, 2004)

Investment cost data	Operation and maintenance data	Project specific data
• Building cost • Site cost • Design fees • Salvage value • Demolition costs • Other	• Administration • Energy • Water • Waste water • Material • Cleaning • Maintenance • Insurance cost • Rates • Taxes • Other	• Type of building • Type of design • Type of building material • Location • Lifetime periods • Other specific data

2.7. Constraints of use of LCC

Many architects are prevented or forced to use life-cycle costing by some constraints or difficulties. These are summarised as follows:

There is a need to deal with impalpable data because, in some cases they have a decisive role to play (Flanagan et al., 1989). On the other hand, lack of significant input data and lack of appropriate, relevant and reliable historical information and data are the other constraints (Bull, 1993). In addition, costs of data collection are huge (Ferry and Flanagan, 1991). Furthermore, the time needed of data collection and the analysis process may leave inadequate time for the essential dialogue with the decision-maker and the re-run of alternative options. This is one of the reasons why computerised models are valuable.

On the light of analyst or architects who analyze cost performance, it is hard to estimate many factors such as life cycles, future operating and maintenance costs, and discount and inflation rates. Discount rate which affects the result significantly is the critical variable. Inflation may be considered as a general increase of prices of goods and services over time in the economy as whole, without a corresponding increase in value (Kirk and Dell'Isola, 1995). Choosing a discount rate which is too high will bias decisions in favour of short-term low capital cost options, while a discount rate which is to low will give an undue bias to future cost savings. Since the accuracy of choosing a certain discount rate is uncertain, the result of an LCC calculation can always be questioned. Despite this problem, there are possibilities to lessen the uncertainties in the result by performing sensitivity analyses where parameters, which are of the greatest importance to the result, can be varied.

Moreover, lack of experience in using the calculation models is another constraint. Besides, complex models include with many parameters is the other constraints to make use of LCC difficult.

The lack of universal methods, standart formats and useful software are also the reason for limited use of LCC (Cole and Sterner, 2000). Lack of industry standards is the other constraint. It is accepted for describing the life-cycle behavior of facilities and their internal processing systems (Abraham et al., 1998).

When it is evaluated from the part of the industry, it is seen that lack of motivation in cost optimisation is one of the difficulties because the design and cost estimating fees are usually a percentage of the total project cost. Besides, there is no clear definition of the buyer, seller, and their responsibilities towards the operating and maintenance costs.

Finally, it can be said that there is a lack of understanding on the part of the client (Bull, 1993). This may increase the possibility of subjective decision making. The presence of multiple aspects of needs desired by clients (Chinyio et al., 1998). On the other hand, they generally do not want to pay extra cost for LCC calculation.

2.8. Summary

At the direction of these chapter, it can be said that an important part of this research defined. All of these knowledges are concerned with questionnaire. Different articles provided different views of what costs are considered in the system life-cycle. For example, in some articles costs such as marketing and disposal costs were captured in the life-cycle costing methodology, however in others they were not (Fabrycky and Blanchard, 1991, Sherif and Kolarik, 1981). Therefore, the survey will include a question for the respondent on what phases and costs are included in their life-cycle cost forecasts. In other words, the design process, parameters included in LCC calculation, methods of LCC and constraints which prevent to use of LCC took part in questionnaire.

When literature is evaluated, major prints can be summarized as follows:

1. It is widely recognised that the building industry needs to replace the traditional method of investment, based on capital cost, with the life-cycle costing technique based on total cost parameters. Therefore, an effective approach to decision-making must be concerned with the overall life-cycle cost.
2. Life-cycle cost in building industry is well established theoretically, but little used in practice.
3. Development of cost models for life-cycle costs in building industry is still at an early stage. There is a more than enough amount of current cost models on LCC describing the principle components of LCC.
4. Constraints causing difficulties in the practical use of LCC are mainly lack of sufficient cost data and choice of discount rate.

CHAPTER 3

METHODOLOGY

The research methodology of this thesis has both an empirical as well as a theoretical component. After the fundamental definitions of the concept and procedures of life cycle costing were derived from literature, this chapter introduces the empirical aspect of the study. It includes the stages of identifying the character and number of subjects to be interviewed, conducting preliminary research toward the preparation of the questionnaire, implementation of the pilot study and questionnaire, and the drawing of conclusions.

3.1. Pilot Study

The questionnaire was tested using a pilot study. In this pilot study, field interviews were conducted to identify any missing variables and verify that the questions were clearly understood by the respondents. 11 architects with avarage 7 years of experience participated to the pilot study.

3.2. Sample

The research methodology centered around the administering of a survey questionnaire. The questionnaire comprised of 27 questions. The relationship data was collected from architects who do practice in İzmir Region. In order to increase the health of the study it is tried to involve participants as much as possible. The questionnaires were administered to 173 architects (participants) by distributing and collecting at an appointed time. Out of the 173 answers, 39 responses had high levels of missing data and 20 papers of survey did not arrive back. Therefore they have not been evaluated. The remaining 114 responses were complete. That is, a total of 114 participants took part in the research.

3.3. Key Informant

The target population of the survey of this study includes practicing architects. The participants were identified by the Chambers of Architects of İzmir, Turkey. Architects who took part in seminar “consultation council of independent architects” in Kuşadası in November 8-9th 2008 gave answers to questionnaire. All architects have their private offices. Their reason of being that organization is to dicuss the occupational problems and to redound other architects awareness about these problems. That is why, the participants in that organization are quite important for this research. They answered the questionnaire of this research in order to evaluate their awareness degree of LCC. As Libben and Titone (2008) claimed, “Awareness is operationally defined as a conscious understanding of the stimulus hierarchy organization, such that the participant is able to verbally describe their understanding to the experimenter.”

3.4. Research Instrument

After the pilot study, the questionnaire was developed. It was designed in a simple “tick-it” format to facilitate easy completion. A Likert scale was generally adopted. The questionnaire consists of four main parts. These parts’ form was presented in Appendix A and B.

The first part is participants’ demographic information including age, gender, work capacity and project types of offices. The age of the sample group was ranged between 21- 60 and over years including seven choices. Besides, their gender was defined. Work capacity was categorized from 0-3000m² to 12000m² and over. It consists of five choices. Project types contains house and business, tourism facility, social facility, health and public building and interior design. These demographic informations was evaluated by multi item ordinal scales.

Second part of the questionnaire was generated from methods of LCC which were discussed in Chapter 2. This part was interpreted using a five point Likert-type scales. There was six methods. It has been tried to reach participants’ use and knowledge of LCC methods. That is why, the format of Likert-type scale was generated like below:

Never hear_, hear_, know_, sometimes use_ and often use_

Third part consists of parameters included in LCC calculation. At this part, participants' use of LCC parameters and costs included in their life-cycle cost forecasts has been measured using a five point Likert-type scales. Because of this, the format of Likert scale was generated like below:

Certainly use_, partially use_, uncertain_, partially disuse_ and certainly disuse_

Finally, at last part of the questionnaire, some questions related to the partipicants and surrounding of them were asked in order to asses their knowledge about LCC. These are occured from first five question of last part. These questions were interpreted also using a five point Likert-type scales. Participants' agreement and disagreement levels has been evaluated with the format which is given below:

Usually_, often_, sometimes_, seldom_ and never_

Furthermore, sixth and seventh question of last part has been evaluated with multiple choice questions. At these questions, phases of design process where LCC calculation is implemented and some constraints which prevent architect to use life-cycle costing were asked. Differences between participants for these ranked questions were investigated using a Friedman rank test to see if there were any significant differences between ranks assigned by architects.

3.5. Research Method

After communication with architects, utilizing these definitions the findings were interpreted using Excel and Statistical Package for the Social Sciences (SPSS) which provides a statistical analysis and data management system in graphical environment. It was utilized in compiling results obtained in the present research in order to arrive at clear conclusions with minimal error margin.

First, answers were represented in numerical code and entered manually. Second, mean and standart deviation values of the answers of questionnaire are calculated utilizing the programme of Excel. The results were obtained in pie charts and bar charts. Margin of error for charts also is given. Finally, for comprehensive evaluation of architects' demographic information and awareness degree, some analysis techniques was used in SPSS. These are factor analysis and Friedman test.

Factor Analysis

Factor analysis is the name of a class of multivariate statistical methods that can be used to describe and classify large groups of variables (Brejda et al., 2000, Kaspar et al., 2004). It is mostly used to develop questionnaires. It can be used to identify relationships among groups of variables, and when examined may suggest an underlying common factor that explains why these variables are correlated. In other words, it is a data reduction method. Although factor analysis is a conventional mathematical model typically used for condensation of large number of variables into fewer groupings, it is still being extensively employed in the research for its several benefits. There are two approaches to factor analysis: "principal component analysis" (the total variance in the data is considered); and "common factor analysis" (the common variance is considered). Factor analysis is calculated by using this equation:

$$Y_i = \beta_{i0} + \beta_{i1}F_1 + \beta_{i2}F_2 + (1)e_i \qquad (3.1.)$$

where Y is a variable, β is a factor loading, F is a factor and e is an error value.

Friedman Rank Test

Friedman's test is a nonparametric test to compare three or more matched groups. This, like many non-parametric tests, uses the ranks of the data rather than their raw values to calculate the statistic. If the significance value (p) is near zero, there is a significant degree of differences among participants' rankings. This indicates that participants' rank orders are not consistent (Hogg and Ledolter, 1987, Hollander and Wolfe, 1999). Friedman's test assumes a model of the form:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk} \qquad (3.2.)$$

where μ is an overall location parameter, α_i represents the column effect, β_j represents the row effect, and ε_{ijk} represents the error.

Margin of error

The margin of error is a statistic expressing the amount of random sampling error in a survey's results. The larger the margin of error, the less faith one should have that the poll's reported results are close to the "true" figures; that is, the figures for the whole population. Moreover, the larger the sample size is, the smaller the margin of error. It is calculated by using this equation:

$$\pm 0.98/\sqrt{n} \qquad (3.3.)$$

where n represents the number of paticipants.

3.6. Summary

The methodology of the study, description of the research population, participants, instruments, procedure, and data collection have been described above. The results to the questions of the questionnaires are analysed through SPSS software.

CHAPTER 4

FINDINGS AND ANALYSES

4.1. Data Analyses and Results

This chapter presents data analysis and results of the questionnaire survey. The parts of questionnaire mentioned in Chapter 3 will particularly be analyzed from demographic informations of participants including age, gender, work capacity and project types of offices to parameters, cost models, LCC methods, phases of design process and costs included in estimating of life-cycle cost, and constraints which prevent the use of LCC. The analysis of data which is obtained from the questionnaire demonstrated the degree of LCC awareness among architects.

4.1.1. Analyses of Demographic Information

Research findings concerning demographic information shows that in terms of gender, female population was less than males, with 77 males and 37 females. Figure 4.1. presents gender of participants. At the end of data analysis, it was seen that there is not any important relationship between gender of participants and their knowledge about LCC.

Figure 4.2. shows a breakdown of the age profile of the participants. The age of the sample group ranges between 21- 60 and over years. The majority of the architects (participants) are found to be 31-40 and 51-60 age ranges. 31% of the respondents are 31-40 year-old and 24% of the respondents are 51-60 year-old. 21-25 year-old age group forms 4% of all participants. These rates indicate that participating architects are fairly experienced in profession life.

Besides, Figure 4.3. presents the evaluation of annual work capacity of architecs' offices. Work capacity of the participating architects seems to be almost equally divided into five groups. It can be seen that 27% of the participants to design 12000m² and more in a year. On the other hand, 20% of architects that are participating this study design 3000m² or less in a year. It may be thought that work capacity could relate regularly with age groups. However, no significant relationship found between work capacity and the age groups.

Figure 4.4. presents the most implemented project types for LCC calculation. Acording to this figure, house and business projects which was answered by 40% of the respondents and interior design projects which was answered by 27% of the respondents are the most implemented project types in architectural offices in Turkey. The other project types implemented by architects are respectively social facility, tourism facility and health and public building projects. LCC analysis is especially applied for complex and sophisticated projects with a higher initial cost such as social facility projects. On the other hand, participating architects implement LCC analysis to building design or interior design projects which are more simple projects than complex ones. Therefore, it may be claimed that the most of the participating architects might not adequately apply LCC analysis to their projects.

4.1.2. Analyses of The Methods of LCC

Table 4.1. presents architects' use and knowledge level of LCC methods. It indicates the mean and standart deviation values. Standart deviation value shows the degree of confidence of the architects' answers. For example, rigorous method was ranked in general aggreement (i.e. 1.11 of std.). On the other hand, equivalance annual cost approach was ranked in less aggreement (i.e. 1.31 of std.). From a thorough literature review, an order of usage of LCC analysis is presented as a number at right side of the names of LCC methods in Table 4.1., too. It is clear that present worth cost approach and equivalance annual cost approach is observed as the most employed methods in literature. On the other hand, it is seen that as to questionnaire results, instead of present worth and equivalance annual cost approach, value-oriented life-cycle cost approach and the base case approach which are component based methods are mostly used in Turkey. It indicates that participating architects are more interested in different components of product or building than its whole.

Figure 4.5. shows the graphic of Table 4.1. It was drawn by using methods' mean values. Their mean value was written on bars of graphic. The x-axis indicates the percentage of the architects' answers. It is observed from Figure 4.5. that rigorous and the approximate LCC methods are the less implemented methods which are more

computer based than the others. It is seen that because of the requirement of a longer computation time and more memory for the codes for LCC model, their implementation is perceived as difficult.

In order for a reasonable structure in the relationships between variables, and to classify them, factor analysis was applied to methods of LCC. To apply this analysis for extraction method, principal component analysis was used and for rotation method, varimax with Kaiser normalization was carried out.

Table 4.2. presents factor loading for the methods of LCC by rotated component matrix. It indicates that methods of LCC are classified into three groups. (1) *component based methods*, (2) *most employed methods* and (3) *computer based methods* which were mentioned above. Variables with factor loadings are greater than 0.5.

4.1.3. Analyses of The Parameters of LCC

Table 4.3. indicates the parameters that are usually included in LCC calculation in order of architects' usage frequency. It indicates the mean and standart deviation values. Standart deviation value shows the degree of confidence of the architects' answers. For example, investment cost was ranked in general aggreement (i.e. 1.24 of std.). On the other hand, interest rate was ranked in less aggreement (i.e. 1.49 of std.). As to Sterner (2000), in Swedish building sector, investment cost, energy cost and maintenance cost takes place first three phase. On the other hand, according to the survey results of this study, out of these parameters, investment, acquisition and energy costs have the greatest importance.

According to parameters mean, Figure 4.6. presents the graphic of Table 4.3. Parameters mean value was written on bars of graphic. Although maintenance cost has a real importance for LCC and also for Swedish building sector, it is seen that architects who work in İzmir and nearby cities in Turkey do not pay enough attention to this parameter. These findings indicate that participating architects do not evaluate construction project in life-cycle. These may arise from clients. They do not want to pay more investment cost. On the other hand, they do not consider that these may provide big profit from the maintenance costs.

Factor analysis was also applied to parameters. To apply this analysis for extraction method, principal component analysis was used and for rotation method, varimax with Kaiser normalization was choosen.

Table 4.4. presents factor loading for parameters included in LCC calculation by rotated component matrix. It indicates that nine parameters are classified into two groups: (1) *Simple* parameters which indicates cost models mostly applied in LCC calculation. It includes, investment cost, energy cost, maintenance cost, alteration cost and acquisition cost. (2) *Complex* parameters which refers cost model effecting all costs. It consists of salvage value, environmental cost, interest rate and life-cycle. Variables with factor loadings are greater than 0.5. It is seen that the parameters of complex models are in less use than the simple one. It may be claimed that forecasting of prospective interest rate and salvage value or life-cycle of building and environmental costs could be more difficult than the simple one.

4.1.4. Analyses of The Last Part of The Questionnaire

The sixth question in the last part of the questionnaire asked the respondent to identify the phases at which cost estimates were made. As to questionnaire results of this part, Figure 4.7. presents the different phases of the building process, from idea/conceptual to procurement, in which architects perform LCC estimations or calculations. For this evaluation, participants ranked these phases in priority order from 1 to 4. In order to evaluate their order, median rank value of phases was calculated by using friquences of participants' answers.

Table 4.5. presents mean value and median rank value of phases. In the light of the observation of median values, it can be said that LCC calculations are usually applied in 'idea phase' in construction projects in Turkey. On the other hand, this phase is in third order following the design and planning phases in Swedish study, according to Sterner (2000). Secondly, design phase has a big role in these calculations for participating architects. Third one is planning phase. The last phase for LCC calculation is procurement phase. It is observed that LCC calculation is being implemented from the beginning of the design process because the most applied phase is the idea phase which is the first phase of design process.

Moreover, in order to make it certain whether the participants' rank values represent a statistical difference, a Friedman rank test of the architects's rank orders for these four phases was conducted. Table 4.5. also presents the results of Friedman test which is a non-parametric analysis method. It is shown that a significance value (p) is 0.000 and it is small than 0.001. Therefore, there is a significant degree of differences among participants' rankings. This indicates that participants' rank orders are not consistent. Therefore, it may be said that architects are not in reality aware of the importance of design process. Literature review, contrary to this findings, shows that the design process is the most influential process of a building project in terms of LCC analysis.

Besides these, there are some reasons or constraints which prevent architects to use LCC calculation. It is required from the participants to order constraints from 1 to 3 in priority in the seventh question of the last part of the questionnaire. Figure 4.8. presents an order of constraints according to survey results. In order to evaluate their order, median rank value of constraints was calculated by using friquences of participants' answers. In the light of the observations of median values that three constraints have same values (2.00). Therefore, their order were evaluated utilizing mean value. Table 4.6. indicates mean and median values of constraints.

Moreover, in order to make it clear whether the participants' rank values represent a statistical difference, a Friedman rank test of the architects' rank orders for these three constraints was conducted. Table 4.6. also presents the result of Friedman rank test which is a non-parametric analysis method. It is shown that a significance value (p) is 0.018 and it is close to 1. Therefore, there is not significant degree of differences among participants' rankings. This indicates that participants' rank orders are consistent.

Accordingly, the lack of significant input data related to new materials or new operating systems is a main problem in Turkey. When literature is evaluated, it is seen in Chapter 2 that the same constraint is the main problem. Although the lack of experience in using the calculation models are the most important constraint as to Sterner' study (2000), in Turkey this constraint is the second problem. Complex models include with many parameters is the last constraint for both of them. These models take a long time to perform an analysis, that is, some architects think that these models are not convenient.

A few architects pointed out cost and time in questionnaire. They thought that LCC calculations take extra time, however clients may not pay extra costs and design fees. On the other hand, LCC calculations are the natural part of the design process. That is, it is not extra implementation and does not necessitate extra costs. Designers should be aware of this first and apply LCC calculations every time when they design a building.

Finally, the result of the questions related to participants and surrounding of them are evaluated in order to asses their knowledge about LCC. These are the first five questions of the last part of the questionnaire.

Figure 4.9. presents that the architects who took part in the study of the questionnaire *usually* evaluate technical solutions. This answer was supported by 44% of the respondents. Figure 4.10. and Figure 4.12. shows that architects also *usually* use different system solutions for lowest cost marked by 45% of the respondents and *usually* give an importance to LCC calculation marked by 52% of the respondents. For these three question, architects did not select last choice which is named as "*never*".

On the other hand, Figure 4.11. and Figure 4.13. presents that according to architects' answer, the members of their offices and the other architects surrounding of them *sometimes* use LCC calculation marked by 32% of the respondents and *sometimes* give an importance of LCC marked by 44% of the respondents. Last choice which is named as "*never*" has been also selected for these questions. Therefore, one may find the answers as contradictory. Further studies are needed for better understanding of the problem.

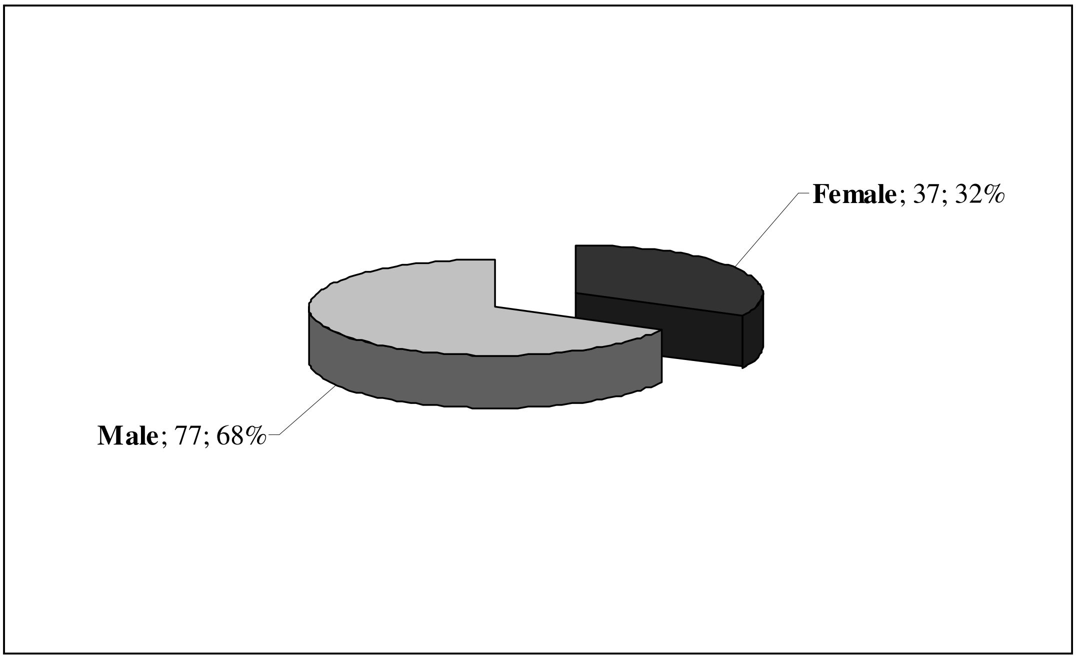


Figure 4.1. Gender of participants

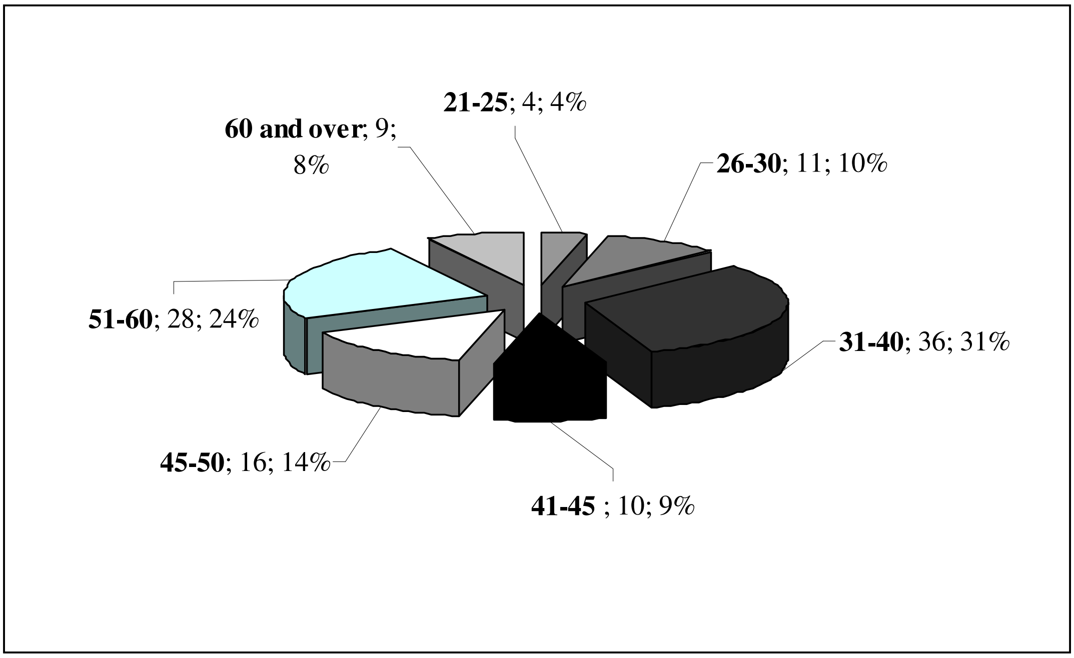


Figure 4.2. Age profile of participants

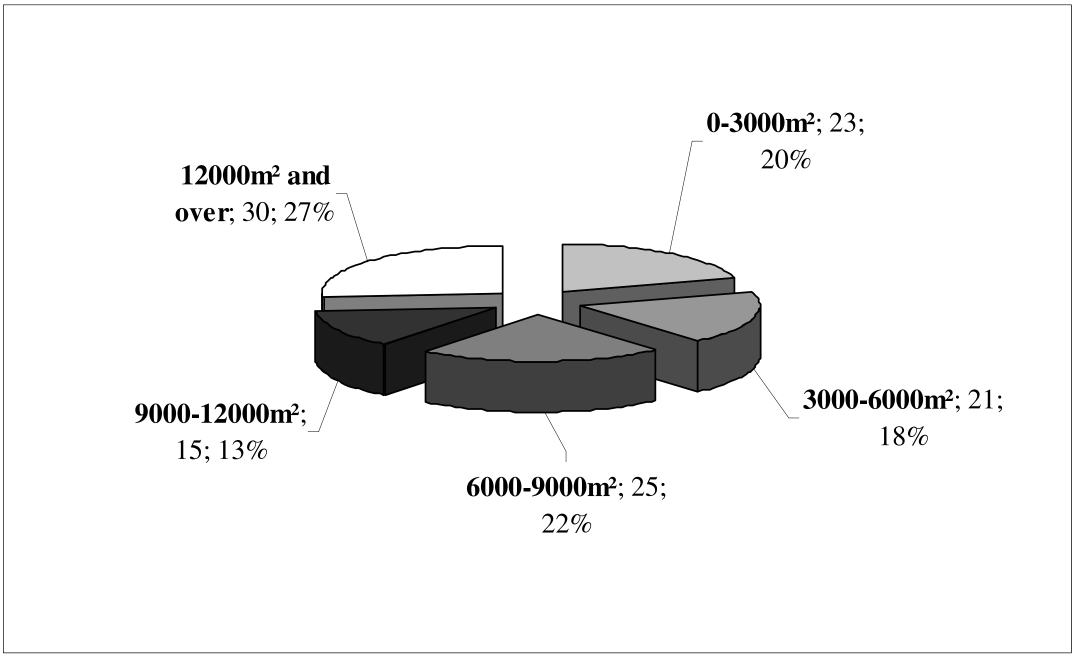


Figure 4.3. Work capacity of participants

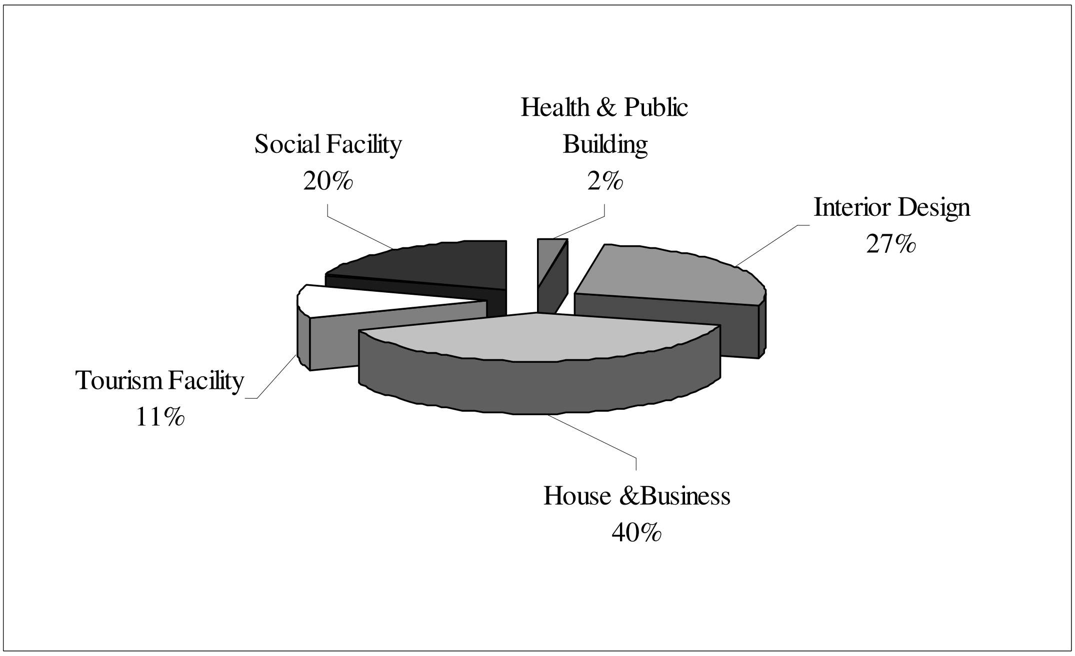
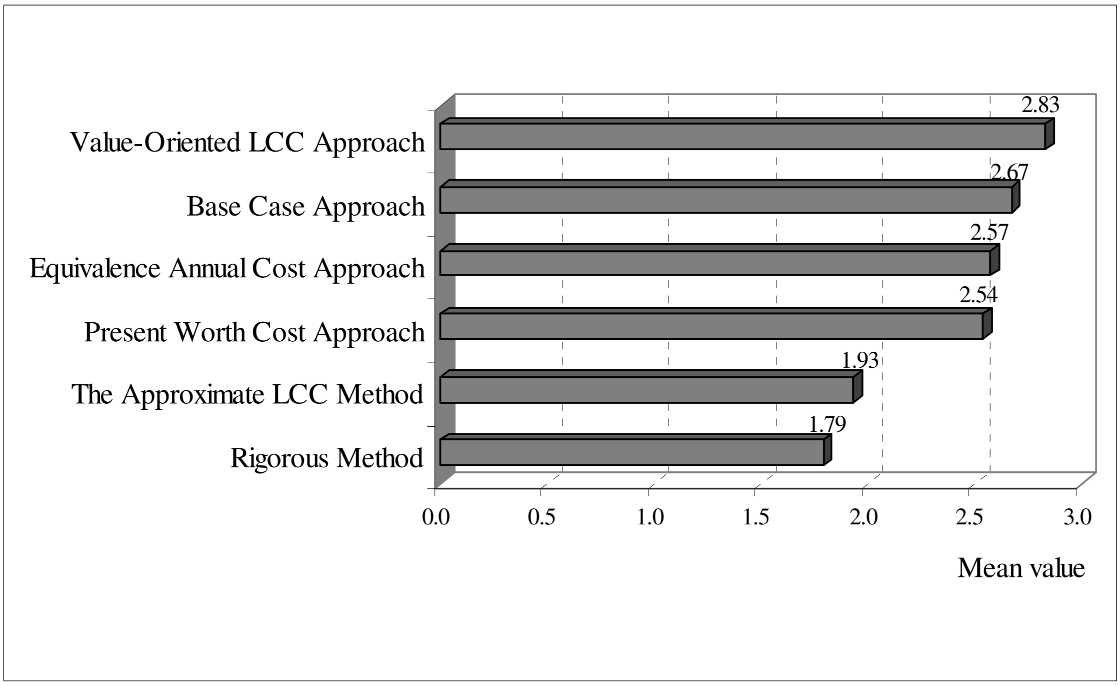


Figure 4.4. Types of project

Table 4.1. Use and knowledge order of LCC methods

B. LCC METHODS	**Mean**	**Std.**	**Previous Research Studies**[1]
1. Value-Oriented LCC method	2.83	1.27	3
2. Base case method	2.67	1.27	4
3. Equivalence Annual Cost Approach	2.57	1.31	2
4. Present Worth Cost Approach	2.54	1.23	1
5. The Approximate LCC method	1.93	1.12	5
6. Rigorous method	1.79	1.11	6

[1](Bledsoe, 1992; Thorbjoern, 1992; Sheen, 2005; Janz et al., 2005; Aktacir et al., 2006; Lutz et al., 2006; Park et al., 2007; Okada et al., 2008)



Margin of error = ±0.091

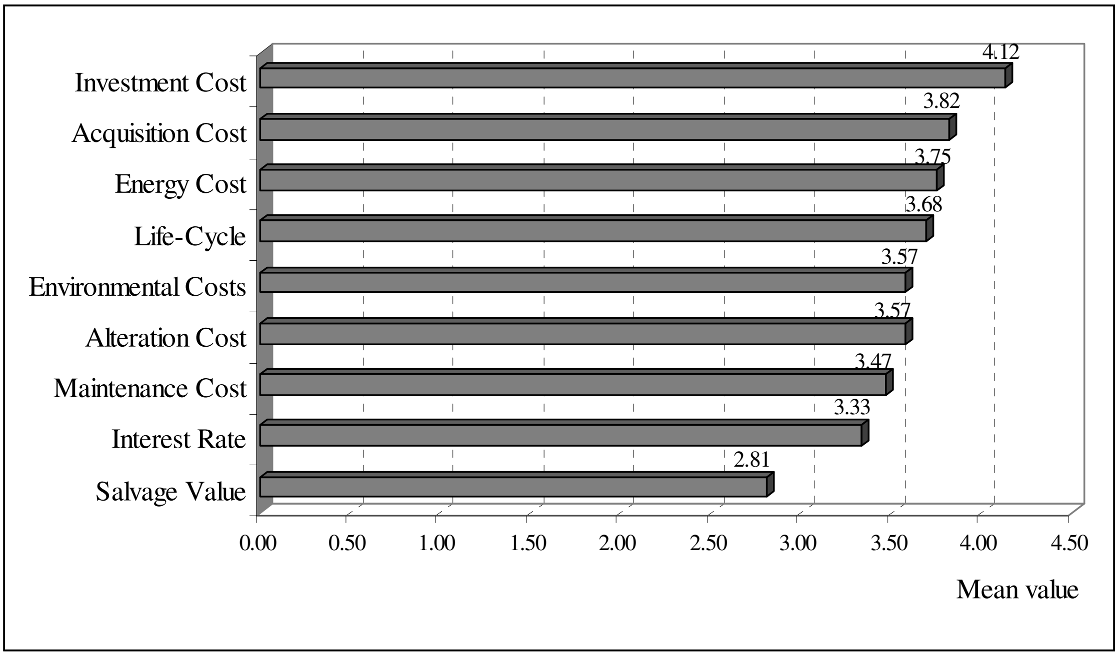
Figure 4.5. Use and knowledge order of LCC methods

Table 4.2. Factor loading for the methods of LCC by rotated component matrix

	Component		
	Component based	Most employed	Computer based
Value-Oriented LCC method	**0.82**	0.26	0.21
Base case method	**0.78**	0.22	0.33
EUAC method	0.26	**0.90**	0.12
PWC method	0.25	**0.77**	0.40
The Approximate LCC method	0.22	0.18	**0.87**
Rigorous method	0.35	0.28	**0.73**

Table 4.3. Parameters architects include in LCC estimations

C. PARAMETERS INCLUDED IN LCC CALCULATION	Mean	Std.
1. Investment cost	4.12	1.24
2. Acquisition cost	3.82	1.40
3. Energy cost	3.75	1.33
4. Life-cycle	3.68	1.36
5. Environmental cost	3.57	1.32
6. Alteration cost	3.57	1.35
7. Maintenance cost	3.47	1.40
8. Interest rate	3.33	1.49
9. Salvage value	2.81	1.48



Margin of error = ±0.091

Figure 4.6. Parameters architects include in LCC estimations

Table 4.4. Factor loading for the parameters by rotated component matrix

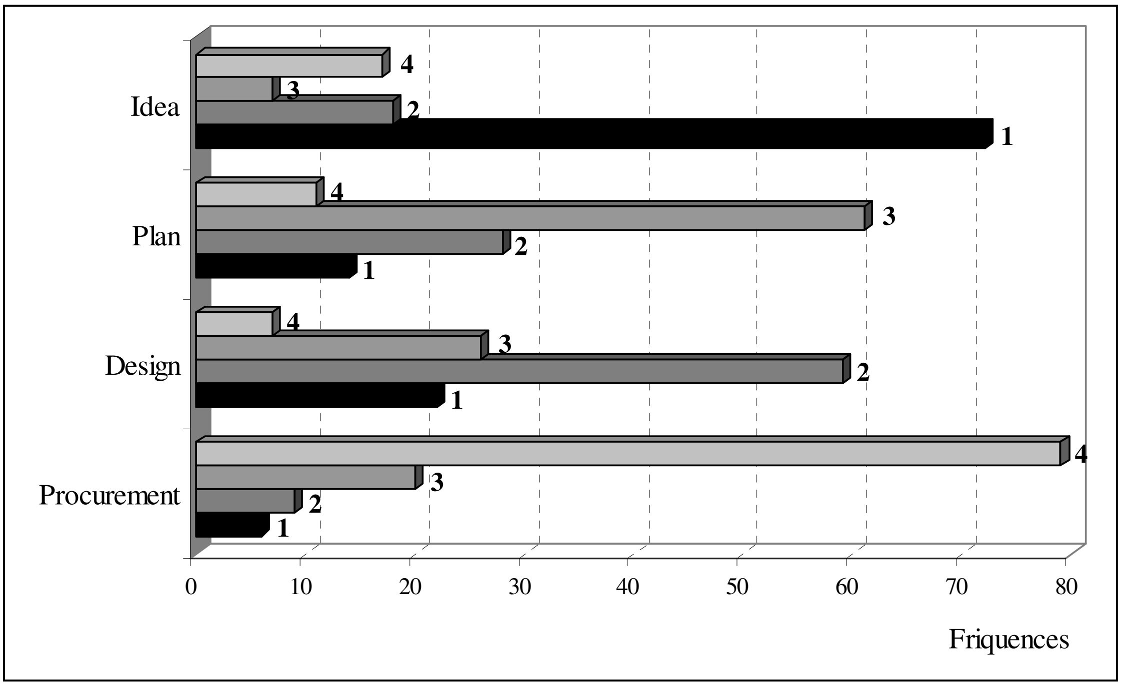
	Component	
	Simple	**Complex**
Investment cost	**0.87**	0.10
Energy cost	**0.87**	0.13
Maintenance cost	**0.69**	0.27
Alteration cost	**0.62**	0.43
Acquisition cost	**0.66**	0.36
Salvage value	0.02	**0.76**
Environmental cost	0.43	**0.67**
Interest rate	0.05	**0.73**
Life-cycle	0.39	**0.68**

Table 4.5. Priority of LCC for each phases of construction project

	Statistics			
	Idea phase	**Planning phase**	**Design phase**	**Procurement phase**
Number of participants (n)	114	114	114	114
Mean value (M)	1.73	2.61	2.16	3.51
Median rank value (Md)	1.00	3.00	2.00	4.00

Friedman Rank Test Results

Degrees of Freedom (df) = 3; Significance value (p) ≤ 0.001; Chi-Square (χ^2) =119.126



Margin of error = ±0.091; **1:** the most use, **2:** use, **3:** moderately use, **4:** the less use

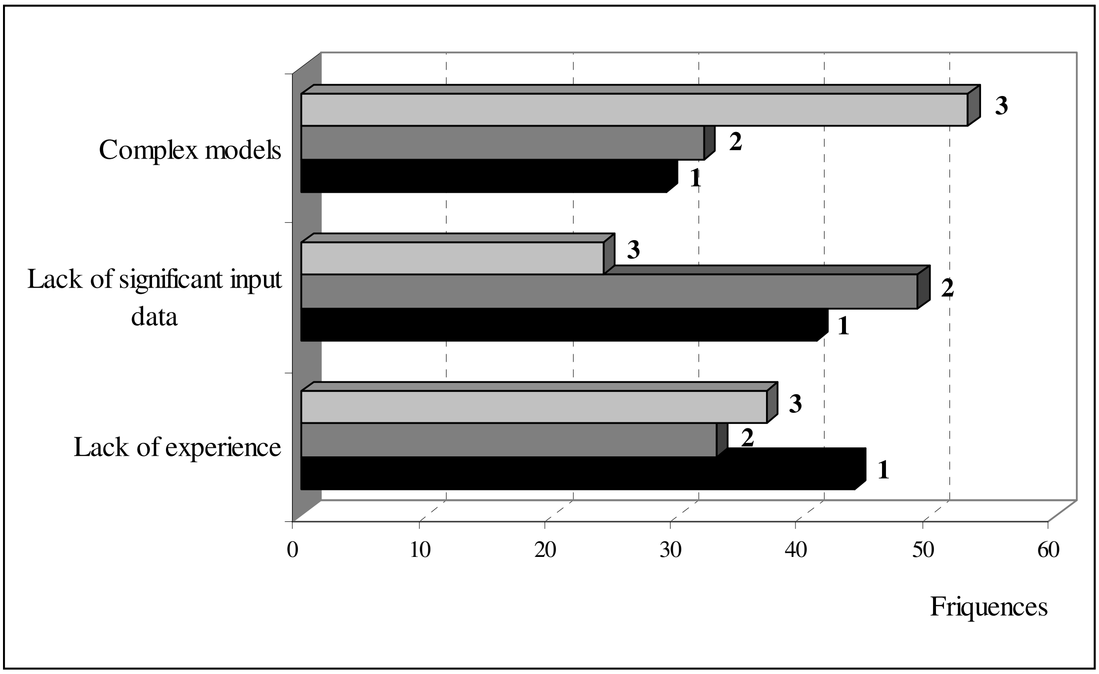
Figure 4.7. Phases of construction projects when LCC estimations are usually done

Table 4.6. Priority of constraints which prevent using LCC

	Statistics		
	Lack of experience	**Lack of significant input data**	**Complex models**
Number of participants (n)	114	114	114
Mean value (M)	1.94	1.85	2.21
Median rank value (Md)	2.00	2.00	2.00

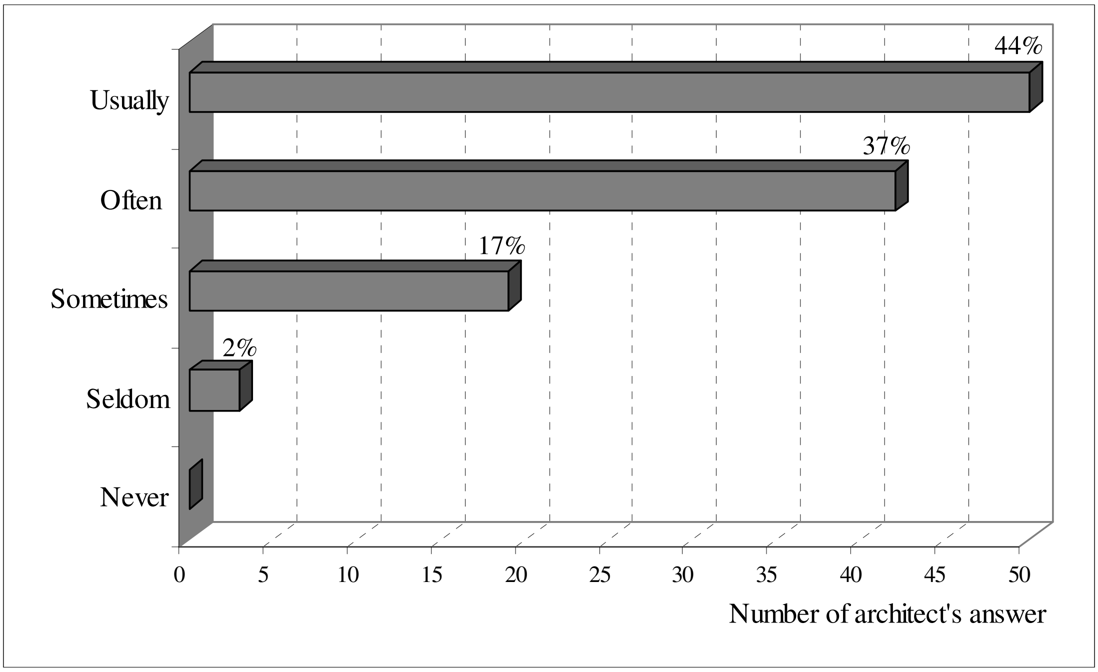
Friedman Rank Test Results

Degrees of Freedom (df) = 2; Significance value (p) = 0.018; Chi-Square (χ^2) = 8.018



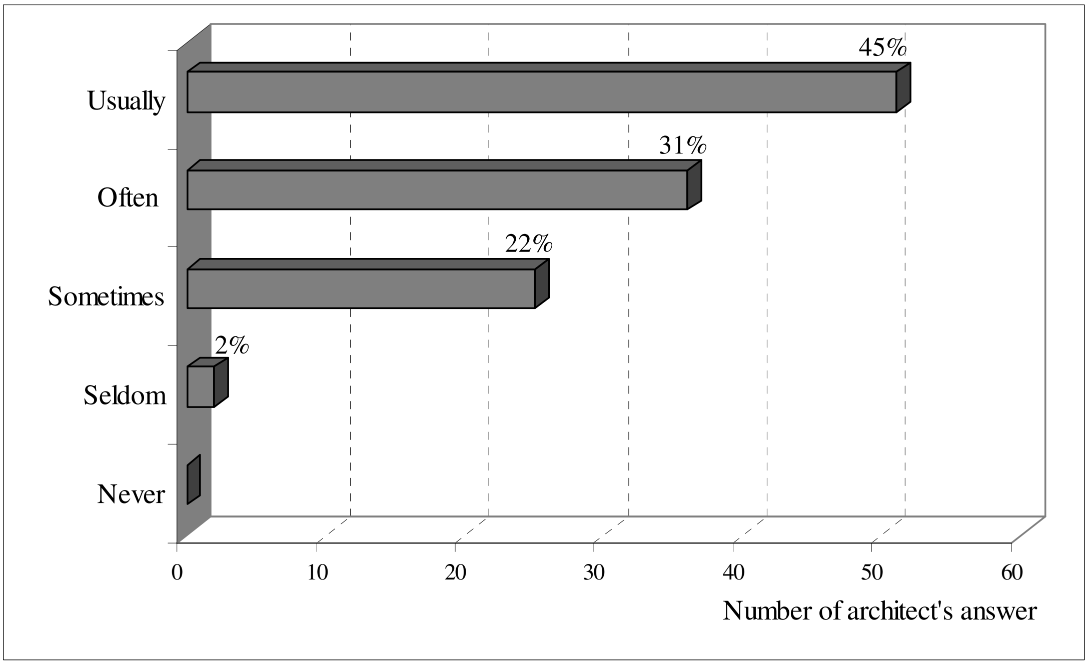
Margin of error = ±0.091; **1:** the most, **2:** moderate, **3:** the less

Figure 4.8. Constraints when calculating LCC



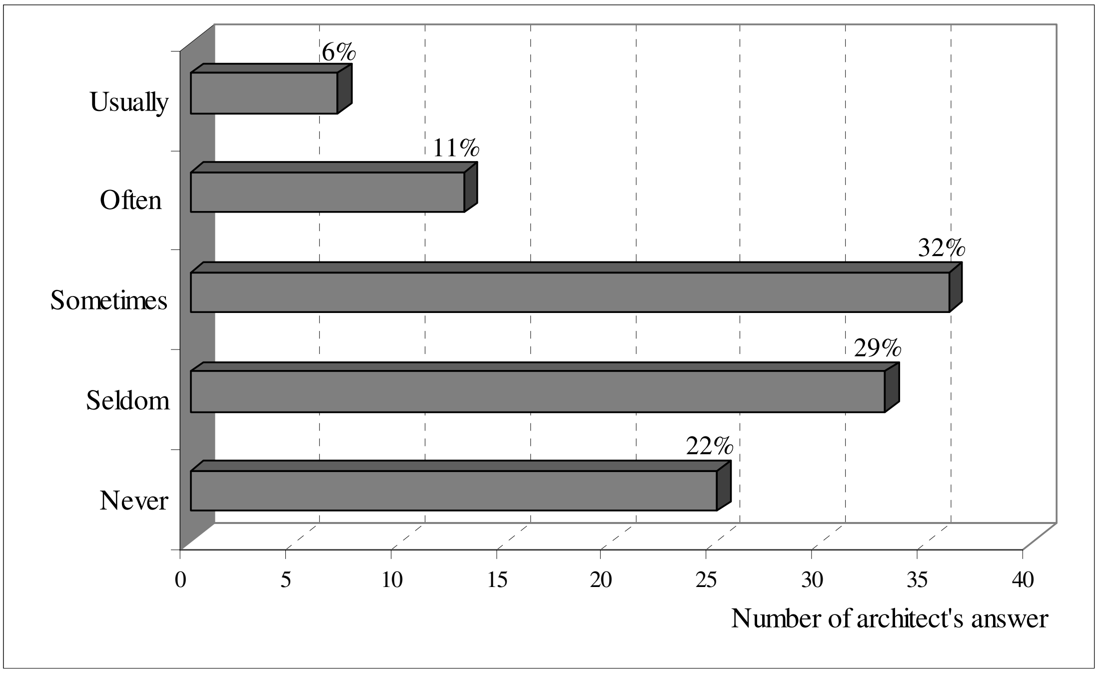
Margin of error = ±0.091

Figure 4.9. To evaluate technical solution for lowest cost



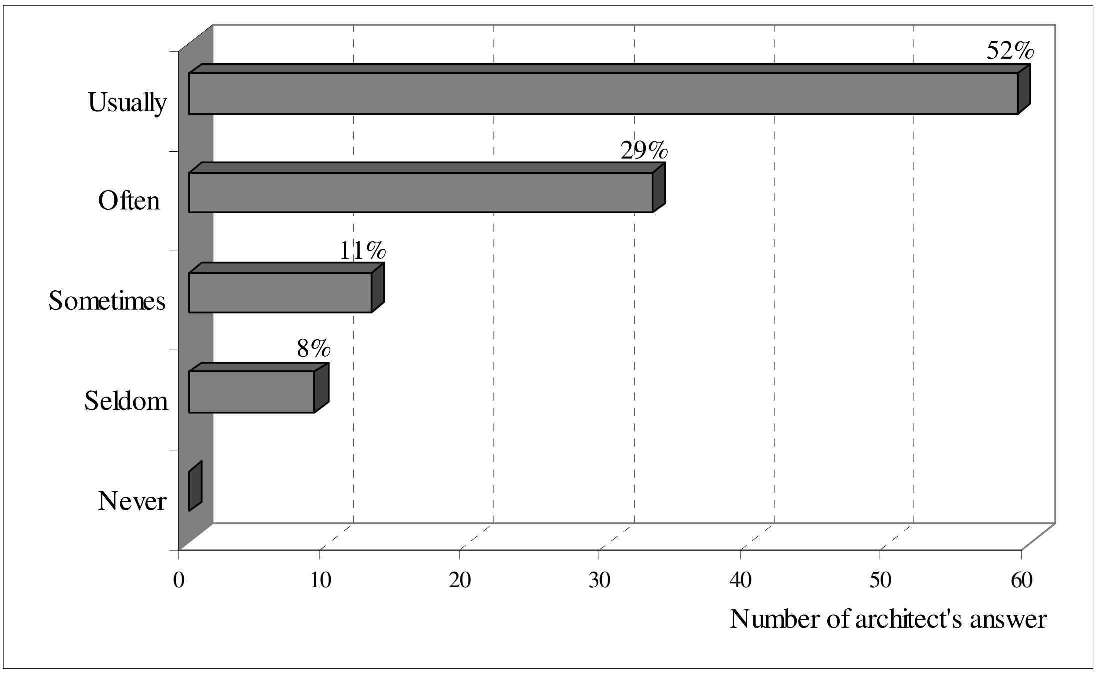
Margin of error = ±0.091

Figure 4.10. Use of different system solutions



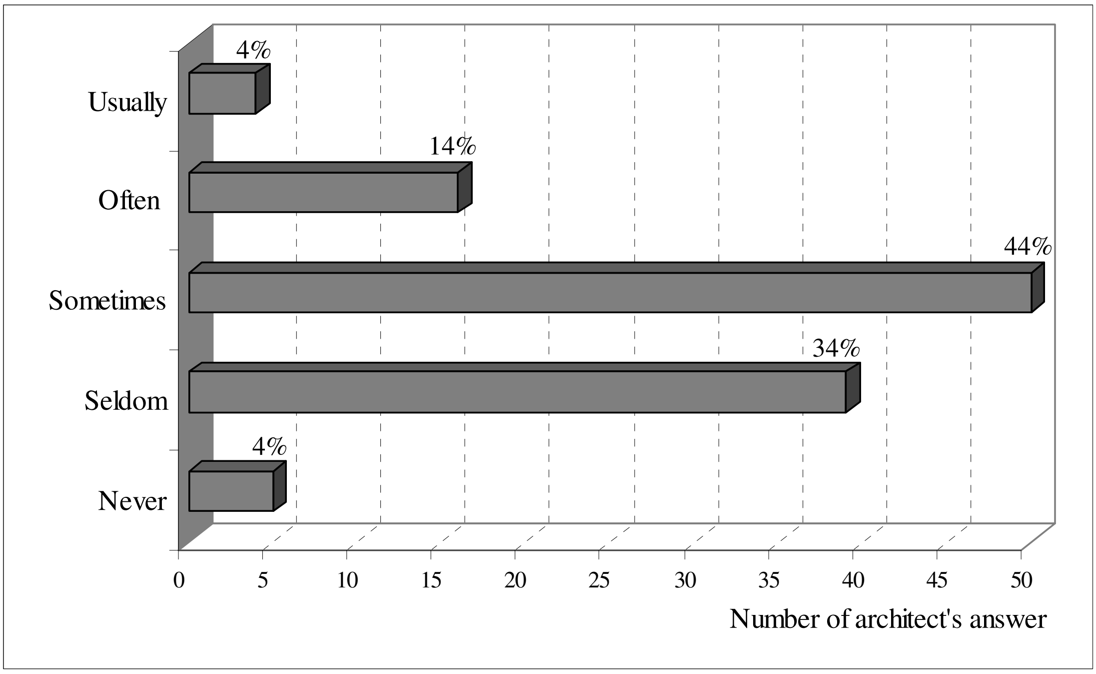
Margin of error = ±0.091

Figure 4.11. Use of LCC by other members of offices



Margin of error = ±0.091

Figure 4.12. Importance of LCC as to participants



Margin of error = ±0.091

Figure 4.13. Importance of LCC as to the other architects surrounding participants

4.2. Summary

The objective of this research is both to define LCC methods in use and its parameters and also find the LCC awareness level of architects in Turkey. There are several important conclusions from the research. This chapter presented the data analysis and documented the results by Figures and Tables. Table 4.7. summarizes the results of data analysis. Chapter 5 will present the conclusions.

Table 4.7. The results of data analysis

COUNTRY / YEAR	FOCUSES	KEY FINDINGS	SAMPLE / KEY INFORMANTS
Turkey 2009	• To outline LCC analysis methods and parameters included LCC calculation in order to identify those that are being employed by architects practicing in Turkey, • To define awareness of life cycle costing among architects in order to establish the importance of LCC, • In which phases they use LCC calculation, • What constraints prevent them to use LCC.	• Component based methods (value-oriented LCC approach and base case approach) are the most employed LCC methods in Turkey, • The parameters that are usually included in LCC calculation are investment, acquisition cost, energy cost and life-cycle, • LCC calculations are usually performed in the idea phase of projects, • The use of LCC and different system solutions for lowest cost is usually important for architects, • In theory, architects have the basic concept but in real practice, they generally do not implement LCC in occupation, • The lack of information and experience appears to be the most important constraints for the usage of LCC analysis.	Survey of 114 Architects

CHAPTER 5

CONCLUSIONS

5.1. Evaluation Review of Research

At the direction of this thesis, it can be said that LCC approach, especially in building industry is considerably new subject of a field of scientific research both in the world and, even more in Turkey. When, the databases are searched, it is seen that there are lots of publishing related to LCC. On the other hand, there is just a few study related to measuring awareness degree of LCC of architects or the members (clients, engineerings etc.) in building industry which is mentioned in Chapter 2. At this study, the degree of awareness of life cycle costing among architects working in building industry and architectural offices in Turkey is investigated. The main findings of this study have been presented in Chapter 4. Taking everything into consideration, acording to questionnaire results, it can be said that there appeared some gaps in the knowledge and understanding of LCC among architects. There are several important conclusions from the research presented in this thesis.

First, it seems that the component based methods (value-oriented LCC approach and base case approach) are most employed methods in Turkey during 2009 although present worth cost approach and equivalence annual cost approach are the most employed methods in world. Many architects do not even hear about some LCC methods in advance. On the other hand, most of them know many parameters of LCC calculation. Therefore, like in literature it could be claimed that in theory, architects have the basic concept but in real practice, they generally do not implement LCC.

Second, most of them use LCC when making investment decisions and consider acquisition cost, energy cost and life-cycle. Maintenance cost is really important for LCC calculation, however they do not take maintenance cost into consideration. Besides, especially interest rate should be considered in Turkey, on the other hand, this parameter is almost at the last rank.

Third, it seems that the use of LCC and different system solutions for lowest cost is usually important for participating architects. On the other hand, they thought that the architects do not give enough importance to LCC. This finding is contradictory.

Fourth, the lack of significant information related to input-cost data and lack of experience appears to be the most important problem in this respect. That is why, at architectural education, the subject of LCC may not be emphasized enough or the firms may not promote architects use LCC practically. In order to increase the use of LCC, these two constraints should be addressed.

Finally, it can be said that the results of the present study indicate some architects expand LCC calculations in the design process that this condition is really important. Especially, they evaluate LCC in idea phase which is the first phase of design process. On the other hand, some of architects have still thought that LCC calculations take extra time, however clients may not pay extra costs and design fees. Therefore, they do not apply LCC calculations in design process. They should understand that LCC calculations are the natural part of the design process.

5.2. Implications For Expanded Use

Government

It should be of fundamental interest to adopt a LCC perspective related to building for governments because the total cost for operation and maintenance of existing buildings in Turkey are larger than the investments made on production of new buildings. Therefore, the influence of the government should not be underestimated. Even a very small improvement within the operation phase will have large economic benefits for society as a whole. Buildings that are managed with a rational and long term perspective will also remain attractive during a longer time period and the need for replacement is lessened (Sterner, 2000). Replacing old buildings with new is both economically and environmentally resource demanding and the durability of the building is in this context important. However, buildings are getting more technically complex with an increasing number of installations and equipment. These installations usually have shorter life spans than the building itself. It is suspected that this will increase maintenance costs compared to older buildings due to a faster ageing of components and installations. This implies that components will be replaced although their technological life has not ended. Because of these reasons, governments could promote and encourage that buildings are built and managed over a long term perspective since this would benefit society economy as a whole. It may also be the case that the building is easier to manage and maintain. Lower LCC can also be achieved if the building is prepared for alternative use.

The government also has a major influence on the building industry when creating building codes and regulations. Codes concerning energy use for buildings already include a life-cycle perspective of costs so it would be possible to have such a similar approach for other parts of the building. Minimum requirements stated in codes highly affect development within the building industry. Therefore, it is important that codes are formulated in such a way that further LCC development is encouraged. By putting the life cycle perspective in focus, governments can influence and address the importance of a total cost perspective.

An alternative to voluntary use of LCC is increased regulation through stated requirements. However, most companies within the Turkish building sector are trying to avoid legislation concerning these matters.

Clients

A client is considered to be the sponsoring organization or the initiator, who is directly responsible for the production and development of the project. Clients have several reasons for embracing long term economic models into the different phases of a building project. Most use is in the early stages of design where the possibility to effect costs are the greatest. However, the initial investment cost is of great importance to the overall cost so the potentially increased cost in the design stage can be viewed by clients as barriers. Even if the initial investment can be somewhat higher when performing LCC calculations, it must be placed within the context of cost savings during operation and maintenance. As low operation costs increase the profit, this can be a way for the developer/ client to attract tenants.

For the public client, an extended use of LCC can cause some constraints related to the funding policies used by them, especially if capital costs and operation costs are handled separately. Administrators are usually limited by annual budgets, which limits the time perspective.

By expanding the cost perspective to include LCC in tender evaluation, new and improved construction methods can be encouraged. Clients must be prepared to abstain from forms of construction organization that determines technical solutions since stated technical requirements can prevent development of new and better methods. If the client decides on which technical solutions to be used at the briefing stage, this will both limit the design team's creativity and also the contractor's ability to develop new and better construction methods to carry the work out.

Instead, requirements should be stated on functions, quality and costs. The contractor must have the possibility to find the best available methods for carrying out the construction work. Today, the design team is usually represented by several groups as architects, structural, mechanical and electrical consultants, etc. the building is considered as different parts rather than as a whole, resulting in each group's decision casting costs onto the others. Increased co-operation between clients, design team and contractors could lead to lower costs and higher quality. For this research, especially the role of architects was really important for LCC calculation in early phases of design.

Architects

If a LCC perspective is to be used, the largest benefits are made in early stages of design. This usually implies that it is up to the consultant to perform the analysis. These consultants are mostly architects who play a major role for cost reduction in early stages of design. Unfortunately LCC analyses can be time demanding which may translate into higher professional costs and design fees. The encouragements for the architects, in terms of payment, to perform such analyses is often limited. The driver for change is that clients should recognise the added value being provided and, as a result, pay for this service. Until this is done, architects will provide the largest resistance to use LCC techniques.

Architects must also, in procurement documentation, clearly specify how the evaluation is going to be performed (which parameters are included and how they are evaluated). If this is not done in an accurate way, there is a possibility to come in conflict with laws associated to the procurement process.

More prominent architects might use a LCC perspective to confirm a more complex and sophisticated design with a higher initial cost, provided that the long term costs are equal or less than competing alternatives. Architects who are interested in environmental progressive building design will also have an excellent opportunity to contribute their designs since `green' building often translates into lower operation costs.

Environmental aspects

Operation of a building is cost demanding and the environmental impact caused, due to energy use amongst other factors, is large. If economics and ecology are considered together from a lifecycle perspective, another implication for expanded use of LCC models is found. By looking at life cycle costs, an environmentally progressive building design, which might have a higher initial cost, can be motivated since these types of buildings often have low operation costs. These lower costs are due to utilization of natural ventilation, effective use of day lighting and passive solar energy use. If the initial and operation costs are not seen through a long term perspective, the true economic benefits of green building design will not be displayed.

5.3. Directions for Further Research

An interesting area for further research would be to use the survey instrument developed in this research, including some modifications based on region, to sample a larger population. A larger population would allow for data analysis and statistical tools to be used to analyze the survey responses. Regional and cultural differences can impact and may change the results of the architects' degree of awareness of life cycle costing and consraints which prevent architects' usage of LCC. Because of this, if this study is implemented in other regions, consraints can be defined for all country. By this way, it can be tried to deal with this problems. Additionally, future works may explore some questions:

- How can national regulations be organized to increase the use of LCC?
- How are the effects of education systems on use of LCC and what can be changed?
- What can the firms do to increase employees' use of LCC?

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APPENDIX A

THE ORIGINAL QUESTIONNAIRE IN TURKISH

İYTE

İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ
MİMARLIK BÖLÜMÜ

YAŞAM DÖNGÜSÜ MALİYETİ ANKET ÇALIŞMASI

A. AŞAĞIDAKİ KENDİNİZ VE BÜRONUZ HAKKINDAKİ BİLGİLERİ LÜTFEN DOLDURUNUZ.

1. Yaş aralığınız hangi kategoriye girmektedir?						
☐ 21-25	☐ 26-30	☐ 31-40	☐ 41-45	☐ 45-50	☐ 51-60	☐ 60 ve üzeri
2. Cinsiyetiniz nedir?						
☐ Kadın	☐ Erkek					
3. Yıllık iş hacminiz hangi kategoriye girmektedir?						
☐ 0-3000m²	☐ 3000-6000m²	☐ 6000-9000m²	☐ 9000-12000m²	☐ 12000m² ve üzeri		
4. Aşağıdaki proje tiplerinden en çok uyguladığınız 2 tanesini seçiniz.						
☐ Konut & İşyeri	☐ Turizm Tesisi	☐ Sosyal Tesis	☐ Sağlık & Kamu Binası	☐ İç Tasarım		

B. AŞAĞIDAKİ BİR BİNANIN YAŞAM DÖNGÜSÜ MALİYET ANALİZİNE YÖNELİK YÖNTEMLER HAKKINDAKİ BİLGİ-KULLANIM DURUMUNUZU LÜTFEN BELİRTİNİZ.	Duymadım	Duydum	Biliyorum	Bazen Kullanıyorum	Sık sık Kullanıyorum
1. Yıllık ödemeleri baz alan "yıllık maliyet analizi yaklaşımı" hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐
2. Başlangıç ve gelecekteki maliyeti, enflasyon ve faiz oranlarını da baz alarak detaylı bir şekilde inceleyen "mevcut (şimdiki) değer maliyet analizi yaklaşımı" hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐
3. Projenin herbir öğe ya da fonksiyonunun maliyetini ayrı ayrı hesaba katan "değere yönelik maliyet analizi yaklaşımı" hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐
4. Bilgisayar desteğiyle yapay sinir ağından yararlanan "uygun maliyet analizi yaklaşımı" hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐
5. Önceden yapılmış benzer projelerle "kıyasa dayalı maliyet analizi yaklaşımı" hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐
6. Maliyet analizi doğruluğunun algoritmik hesaplarla, hassas bir şekilde incelenmesine dayalı olan yaklaşım hakkındaki bilginiz ne konumdadır?	☐	☐	☐	☐	☐

Figure A.1. The original questionnaire

(cont. on next page)

C. AŞAĞIDAKİ YAŞAM DÖNGÜSÜ MALİYET HESABINDA KULLANILAN PARAMETRELERİ KULLANIM DURUMUNUZU LÜTFEN BELİRTİNİZ.	Kesinlikle Kullanıyorum	Kısmen Kullanıyorum	Kararsızım	Kısmen Kullanmıyorum	Kesinlikle Kullanmıyorum
1. Bina yatırım maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
2. Bina enerji maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
3. Bina bakım maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
4. Malzeme ve ya bina kullanım fonksiyonu değişim maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
5. Kazanç maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
6. Hurda maliyetini hesaba katıyor musunuz?	☐	☐	☐	☐	☐
7. Çevresel maliyetleri hesaba katıyor musunuz?	☐	☐	☐	☐	☐
8. Faiz oranlarını hesaba katıyor musunuz?	☐	☐	☐	☐	☐
9. Binanın yaşam süresini hesaba katıyor musunuz?	☐	☐	☐	☐	☐

D. AŞAĞIDAKİ YAŞAM DÖNGÜSÜ MALİYET ANALİZİ KULLANIMI İLE İLGİLİ SEÇENEKLERİ LÜTFEN İŞARETLEYİNİZ.	Her zaman	Sıkça	Bazen	Nadir	Hiçbir zaman
1. Projede düşük maliyet sağlayacak teknik çözümler geliştiriyor musunuz?	☐	☐	☐	☐	☐
2. Projede farklı çözümler geliştirerek, binanın bakım ve uygulama (inşa) maliyetlerini alt seviyelere çekebileceğinize inanıyor musunuz?	☐	☐	☐	☐	☐
3. Bina maliyeti analizi, büronuzdaki diğer çalışanlar tarafından yapılabiliyor mu?	☐	☐	☐	☐	☐
4. Binaların maliyet performansını hesaplayarak, binanın yaşam boyu maliyetini minimuma düşürme yaklaşımının önemli olduğunu düşünüyor musunuz?	☐	☐	☐	☐	☐
5. Çevrenizdeki diğer mimarların bu konuya önem verdiklerini düşünüyor musunuz?	☐	☐	☐	☐	☐

6. Aşağıdaki aşamalardan yaşam döngüsü maliyet analizini kullandığınız aşamaları öncelik sırasına göre 1' den başlayarak numaralandırınız (sadece kullandığınız aşamaları!).

☐ Fikir aşaması ☐ Planlama ☐ Tasarım ☐ Malzeme tedarik

7. Aşağıdaki kısıtlamalardan hangileri yaşam döngüsü maliyet analizini uygulamanıza engel oluyor? Size uyan nedenleri öncelik sırasına göre 1' den başlayarak numaralandırıp işaretleyiniz. İlave etmek istediğiniz kısıtlamalar varsa yazınız.

☐ Deneyim ve bilgi eksikliği
☐ Yeni malzeme ve uygulama sistemleri ile ilgili veri eksikliği
☐ Çok fazla parametre ile hesaplama yapıldığında oluşan karmaşık modeller
☐ Diğerleri:……………………………………………………………………………

Anketimize katıldığınız için teşekkür ederiz.
Anket sonuçlarıyla ilgili bilgilendirme için e-mail adresinizi yazınız…………………………………………………..

Figure A.1. (cont.) The original questionnaire

APPENDIX B

ENGLISH TRANSLATION OF THE QUESTIONNAIRE

İZMİR INSTITUTE OF TECHNOLOGY
DEPARTMENT OF ARCHITECTURE

THE STUDY OF LIFE CYCLE COSTING SURVEY

İYTE

A. PLEASE SELECT THE APPROPRIATE INFORMATION ABOUT YOU AND YOUR OFFICE.

1. Which category does your age take place?						
☐ 21-25	☐ 26-30	☐ 31-40	☐ 41-45	☐ 45-50	☐ 51-60	☐ 60 and over
2. What is your gender?						
☐ Female	☐ Male					
3. What is your annual work capacity?						
☐ 0-3000m²	☐ 3000-6000m²	☐ 6000-9000m²	☐ 9000-12000m²	☐ 12000m² and over		
4. Please select 2 types of project most implemented in your office.						
☐ House & Business	☐ Tourism Facility	☐ Social Facility	☐ Health & Public Building	☐ Interior Design		

B. PLEASE SELECT THE APPROPRIATE CHOICE ABOUT THE METHODS OF LIFE-CYCLE COSTING.

	Never Hear	Hear	Know	Sometimes Use	Often Use
1. Which condition does correspond to your knowledge about "equivalence annual cost approach" which is in the case of regular annual series of disbursements?	☐	☐	☐	☐	☐
2. Which condition does correspond to your knowledge about "present worth cost approach" which allows for a more detailed evaluation of future costs using inflation-interest rate?	☐	☐	☐	☐	☐
3. Which condition does correspond to your knowledge about "value-oriented life-cycle cost approach" which assesses the function costs for both the whole product as well as for its components?	☐	☐	☐	☐	☐
4. Which condition does correspond to your knowledge about "the approximate life-cycle costing method" which benefits the artificial neural network?	☐	☐	☐	☐	☐
5. Which condition does correspond to your knowledge about "base case approach"?	☐	☐	☐	☐	☐
6. Which condition does correspond to your knowledge about "rigorous method" which calculates life cycle costingsensitively with algorithmic checking of correctness?	☐	☐	☐	☐	☐

Figure A.2. English translation of the questionnaire

(cont. on next page)

C. PLEASE SELECT THE APPROPRIATE CHOICE ABOUT THE PARAMETERS THAT ARE USUALLY INCLUDED IN A LIFE-CYCLE COSTING CALCULATION.

	Certainly Use	Partially Use	Uncertain	Partially Disuse	Certainly Disuse
1.Do you take into account building investment cost?	☐	☐	☐	☐	☐
2.Do you take into account building energy cost?	☐	☐	☐	☐	☐
3.Do you take into account building maintenance cost?	☐	☐	☐	☐	☐
4.Do you take into account building alteration cost?	☐	☐	☐	☐	☐
5.Do you take into account building acquisition cost?	☐	☐	☐	☐	☐
6.Do you take into account building salvage value?	☐	☐	☐	☐	☐
7.Do you take into account building environmental cost?	☐	☐	☐	☐	☐
8.Do you take into account building interest rate?	☐	☐	☐	☐	☐
9.Do you take into account building life-cycle?	☐	☐	☐	☐	☐

D. PLEASE SELECT THE APPROPRIATE CHOICE ABOUT USE OF LIFE-CYCLE COSTING.

	Usually	Often	Sometimes	Seldom	Never
1. Do you evaluate which technical solution will give the lowest costs?	☐	☐	☐	☐	☐
2. Do you believe how different system solutions will affect and minimize the operations- and maintenance costs?	☐	☐	☐	☐	☐
3. Is life-cycle costing calculation done by other members of your office?	☐	☐	☐	☐	☐
4. Do you consider important approach which account cost performance of building for lowest cost in life-cycle?	☐	☐	☐	☐	☐
5. Do you think that the other architects surrounding you attach importance to life-cycle costing?	☐	☐	☐	☐	☐

6. Put below phases of projects where you use life-cycle costing in priority order with the most important as first (only phases used by you!).

☐ Idea ☐ Planning ☐ Design ☐ Procurement

7. Which constraints do prevent you to use life-cycle costing? Put them in priority order. Add any supplementary information you find necessary.

☐ Lack of experience
☐ Lack of significant input data related to new metarials or new operating systems
☐ Complex models included too many parameters
☐ Others:……………………………………………………………………………………
……………………………………………………………………………………………

Thank you to join this survey.
Please write your e-mail in order to get info about survey results:………………………………………

Figure A.2. (cont.) English translation of the questionnaire