Life Cycle Cost Analysis as a Technique to Reduce Project's Cost Overruns of Assets in UAE: A Case Study-Based Research

تحليل تكلفة دورة الحياة كتقنية للحد من تجاوزات تكلفة المشاريع للأصول في الإمارات العربية المتحدة: بحث قائم على أساس دراسة حالة

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Abstract

Infrastructure projects run by two government organisations, Telecom Operator and Water and Electricity Authority, in Abu Dhabi, UAE are suffering from cost overruns during their life cycle. In 13 projects investigated from both organisations, it was found that the cost overruns were approximately estimated as AED27 million. These cost overruns represent 7.7% of the total allocated budget for the 13 projects, and if all the projects were studied, the percentage might increase further. Such percentage is considered high since it contributes to overruns in millions of Dirhams.

Therefore, this study aimed to introduce a technique to reduce project's cost overruns of assets in UAE government organisations. This technique is based on the concept of the life cycle cost analysis (LCCA) which is considered an approach to estimate project's cost and to decide among project's alternatives. Basically, this concept proposes the necessity of including the cost of design and implementation (initial phase), operation and maintenance, and decommissioning during the planning stage of a project. Hence, a considerable amount of money could be saved and a project's cost overruns could be minimised during the life cycle of the asset which can be seen as one of the organisations objectives.

Consequently, a comprehensive literature review was conducted in order to explore the concept of the life cycle cost by studying its phases, methods, models, barriers, and examples. Furthermore, quantitative and qualitative research approaches have been conducted in this study in order to test the literature review findings, and to collect the necessary data from real projects. The quantitative approach was used to check the reliability of the obtained data from the literature review. The qualitative research investigated the current practices in estimating projects life cycle cost at both organisations, and the causes of the cost overruns in their projects life cycle. It was found that both organisations do not consider estimating project's cost from its inception to its disposal which yields to cost overruns during its life cycle as supported by the literature. Finally, based on the literature review findings and the data analysis, several recommendations were proposed to fulfil the gaps of both organisations' estimation process by implementing the life cycle cost analysis.

ملخص

تعاني مشاريع البنية التحتية التي تديرها منظمتين حكوميتين: شركة اتصالات وهيئة المياه والكهرباء في أبو ظبي في الإمارات العربية المتحدة من زيادة في التكاليف خلال دورة حياتها. فقد تبين من خلال التحقيق في ١٣ مشروع لهاتين المنظمتين أن تجاوز التكاليف في هذه المشاريع يقدر بـ٢٧ مليون درهم تقريبا وتمثل تجاوزات التكاليف هذه ٧,٧% من إجمالي الميزانية المخصصة للمشاريع وهي نسبة قد ترتفع إذا ما تمت دراسة جميع المشاريع. تعتبر مثل هذه النسبة عالية جدا نظرا لأنها تساهم في تجاوزات بملايين الدراهم.

ولذلك، فإن هذه الدراسة تهدف إلى إدخال تقنية للحد من تجاوزات تكلفة المشروع للأصول في المؤسسات الحكومية لدولة الإمارات العربية المتحدة. وتستند هذه التقنية على مفهوم تحليل تكلفة دورة الحياة (LCCA) التي تعتبر نهجا لتقدير تكلفة المشروع و الاختيار بين البدائل المنافسة. في الأساس، يقترح هذا المفهوم ضرورة شمل التكاليف المالية للتصميم والتنفيذ (المرحلة الأولى) والتشغيل والصيانة والتفكيك خلال مرحلة التخطيط الأولية للمشروع. وبالتالي يمكن حفظ مبالغ كبيرة من المال ويمكن الحد من تجاوزات تكلفة المشروع خلال دورة حياة الأصول التي يمكن أن ينظر إليها باعتبارها هدفا من أهداف المنظمات الحكومية.

وبناء على ذلك، أجري استعراضا أدبيا شاملا من أجل استكشاف مفهوم تكلفة دورة الحياة من خلال دراسة المراحل، الأساليب، النماذج، الحواجز والأمثلة المرتبطة بها. وعلاوة على ذلك، أجريت المناهج البحثية الكمية والنوعية في هذه الدراسة من أجل استعراض نتائج الاختبار الأدبي وجمع البيانات اللازمة من مشاريع حقيقية. فقد استخدم النهج الكمي للتحقق من دقة البيانات التي تم الحصول عليها من الاستعراض الأدبي. أما النهج النوعي فقد استخدم للتحقيق في الممارسات الحالية في كلتا المنظمتين في تقدير تكاليف دورة حياة المشاريع والأسباب التي أدت إلى تجاوز التكاليف في دورة حياة مشاريعها. فقد تبين أن كلتا المنظمتين لا تأخذان بعين الاعتبار تقدير التكلفة المالية للمشروع من بدايته إلى نهايته مما ينتج عنه تجاوز التكاليف خلال دورة حياتها كما بينه التقرير. وأخيرا، وبناء على نتائج مراجعة التقرير وتحليل البيانات تم تقديم العديد من التوصيات المقترحة لملئ الثغرات الموجودة في عملية تقدير التكاليف في كلتا المنظمتين من خلال تنفيذ تحليل تكلفة دورة الحياة.

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1. Introduction

Many organisations, while planning their projects, depend on estimating the initial cost of design, construction, and implementation to determine the project's cost. In addition, they use such estimate of cost to determine the project's budget, evaluate and select among project's alternatives. There is no significant consideration for other costs associated with the project life cycle such as operation cost, maintenance cost, and disposal cost. According to Taylor (1981, p.32), "in the past there has been a failure to assess adequately the costs arising from the use of the capital asset over the length of its life". During the planning phase, an emphasis is given only to the initial cost of the project to deliver the asset to the concerned stakeholders. Therefore, organisations continuing to use this approach will probably suffer from cost overruns in future that might degrade project's performance. Investment decision-making on projects based on lower initial cost can be considered as an attempt to save money in the short run; however, project managers are expected to have a long-term vision during their investment (Woodward 1997). In other words, it is the total life cycle cost of the project that needs to be minimised and not its initial cost.

Currently, there are many traditional techniques to estimate a project's cost. According to Datta and Roy (2010), such techniques can be classified into qualitative like 'intuitive' and 'analogical' approaches, and quantitative techniques such as 'parametric' and 'analytical' approaches. Moreover, there are new and sophisticated estimation techniques such as 'regression analysis', 'neural networks', and 'case-based reasoning' (Kim et al. 2010). Even though these techniques can be considered as accurate estimation approaches, they are not utilised properly by project managers to estimate the overall project life cost. During the planning phase, only the initial cost is being estimated significantly, and there is no proper consideration to estimate the operation, maintenance, and disposal costs of the project which could yield to cost overruns in future. As stated by Taylor (1981, p.32):

> Consultants in a study of maintenance costs in industry for the Department of Trade and Industry in 1969 concluded that it would be possible to save £500m per year on maintenance in industry in this country if greater care was taken in the design and specification.

This research proposes that if an appropriate attention was given to the maintenance cost during the planning phase, a considerable amount of money could be saved and a project's cost overruns could be minimised.

Therefore, in order to estimate the initial, maintenance, operation, and disposal costs of a project's life, new practises should be introduced and investigated. One approach that can be considered is the Life Cycle Cost Analysis (LCCA) as a technique to estimate the project's cost and to decide among project's alternatives. The LCCA will help to estimate the overall project's cost, choose between competing projects, and evaluate investments among project alternatives (Woodward 1997). The concept of the LCCA method is not that new, and it was used long time ago in the past. For instance, it was utilised by the U.S Department of Defence in 1970s to evaluate new weapon system (Brown 1979; Ahmed 1995). Also, according to MeEachron et al. (1978, p.461), it was "being considered by civilian government agencies to improve the cost-effectiveness and technological quality". However, currently, the LCCA concept is facing some challenges for its implementation in some organisations which limit its use. As stated by Coe (1981), there are barriers to perform LCC such as 'psychological' obstacles which are fear of change and the tendency to select the lowest bid. Furthermore, there are 'structural' barriers represented by the decentralised purchasing systems, and 'procedural' barriers where many organisations are not sophisticated enough to perform an LCCA (Coe 1981). Therefore, management commitment would be needed to overcome such barriers in order to use the potential advantage of the LCCA concept during the planning phase. This paper proposes the use of LCCA to benefit from its advantages mentioned before, and encourages utilising it as a technique to reduce cost overruns during the life cycle of the asset.

1.1. Research Problem

There is evidence that projects in many organisations are subject to cost overruns. There are some drawbacks in the cost estimation process and the selection method among alternatives during the planning phase. This may contribute to cost overruns during the life cycle of the project that includes the initial, operation, maintenance, and decommissioning phases. One or more of the stakeholders are being affected and paying extra money to overcome this problem.

1.2. Aim and Objectives

The aim of this dissertation is to study and investigate how the life cycle cost analysis technique can be used as a method to determine project's initial, operation, maintenance, and decommissioning costs (i.e. project life cycle cost) and to improve the selection process method among project's alternatives in order to reduce project's cost overruns.

The following are the objectives of this dissertation:

- Explore the literature on how LCC analysis can be used to estimate project's cost.
- Identify how to select between project's alternatives based on LCC analysis through the literature review.
- Learn from the literature how organisations from different countries use LCC analysis.
- Investigate the current practices in some U.A.E. organisations, and the causes of the cost overruns in their projects life cycle.
- Check the possibility of implementing the LCCA to U.A.E organisations, and make recommendations as appropriate based on the literature review findings.

1.3. Research Scope

This research concentrates on infrastructure projects established by two U.A.E organisations in Abu Dhabi Emirate which is the capital of the country. Infrastructure projects are becoming one of the most important economic growing sectors in the country. Therefore, both organisations try to invest on such projects. These two organisations are:

- Telecom Operator: It is a semi-government organisation responsible for providing the telecom infrastructure required for mobile, fixed-line voice, data services, and cable TV for individuals as well as business enterprise.

- Water and Electricity Authority: It is a government organisation responsible for providing the infrastructure required for water and electricity distribution inside Abu Dhabi to individuals and enterprise premises.

Implemented and operated projects from both organisations were investigated by collecting data through developed surveys based on the literature review. The aim of the investigation was to study if the LCCA is implemented in both organisations projects, and to explore the relationship between the initial, operation, maintenance, and decommissioning costs and the cost overruns during the project's life cycle. Moreover, interviews were conducted with personnel involved in the projects to study the current practices and the possibility of implementing the LCCA. The name of both organisations, the projects, the stakeholders involved, and the other related information are kept anonymous for confidential aspects.

2. Literature Review

In this section, the concept of the Life Cycle Cost Analysis (LCCA) is studied and explored by conducting a comprehensive literature review. The phases of the project life cycle are identified, and the costs involved in each phase are studied. Also, the LCCA technique is investigated by understanding the basic principles, methods and models associated with it in order to better estimate project's cost and to select among competing project's alternatives. Moreover, the barriers facing the implementation of the LCCA is classified and studied. Finally, some examples about the LCCA implementation in some countries are demonstrated and explained.

2.1. Feasibility Study and Business Case Development

The strategy of most of the organisations is to try and face the complex challenges of today's business environment such as economic crises. Organisations' management have started to plan their investment more carefully in order to be more economical, to minimise their projects' cost, and to evaluate the return on investment. Therefore, project's planning should reflect the organisation's strategy, and for that reason, some organisations tend to prepare a feasibility study for their projects in order to justify the investment and the viability of the project. "There is an area of common ground between strategic planning and project management, and the feasibility study belongs to that intersection" (Caño 1992, p.165). The feasibility study helps the organisation's management to evaluate projects and to make decisions whether to invest in a project or not. As stated by Shen et al. (2010), the feasibility study is implemented by the project client or consultant prior to the initiation of a project and the success of a project will be influenced by the effectiveness of the feasibility study. There are important parameters that should be identified during the feasibility study, such as project execution cost and operation costs, which should be monitored and controlled through the project's life cycle (Caño 1992). Thus, a proper planning for the initial, operation, maintenance, and disposal costs need to be considered in order to allocate the budget for the project. This proper planning can be done by using the Life Cycle Cost Analysis (LCCA) technique to estimate the project's costs which can help minimising the Life Cycle Cost (LCC) of the project, and reducing future cost overruns.

During the different stages of the project life cycle, the organisation strategy differs, and thus for an organisation, it is essential to recognise the importance of the life cycle concept in strategic planning (Tse & Elwood 1990). Therefore, it would be of great value to include the life cycle cost concept in organisation's strategy, and to be considered by management to implement during the business case development. According to Gardiner (2005, p.83), "A business case is prepared to ensure that projects put forward for funding reflect business strategy and will deliver the required benefits to shareholders and stakeholders". Moreover, it is used to get commitment from management to invest in a project and provide a framework for that. It can be noticed that, one of the purposes of feasibility study and business case is to evaluate projects and to ensure that they reflect business strategy. This can be achieved by applying LCCA during these two stages of the project planning which will probably help evaluate the investment among project's alternatives, and ensure the project will yield to the minimum cost which can be seen as one of the organisation strategies. Therefore, understating the concept of the project life cycle cost can help in maintaining organisation strategy. In the coming sections of this dissertation, a detailed explanation of the LCCA concept will be introduced.

2.2. Project and Asset Life Cycle

Before the LCC is analysed, it is important to understand the project life cycle and explore its phases. Project can be defined as "a temporary endeavour undertaken to create a unique product or service" (PMI 2003, p.4). Therefore, the project's life will have a beginning, phases involved, and an end. Project life cycle and asset life cycle are two terms that will be used frequently in this paper. According to Labuschagne and Brent (2005), the project life cycle consists of prefeasibility, feasibility, development, execution and testing, lunch, and post implementation review, while the asset life cycle can be classified into detail design, construction, operations/maintenance, and decommissioning. Figure 2.1 shows the interaction between the project life cycle and the asset life cycle.

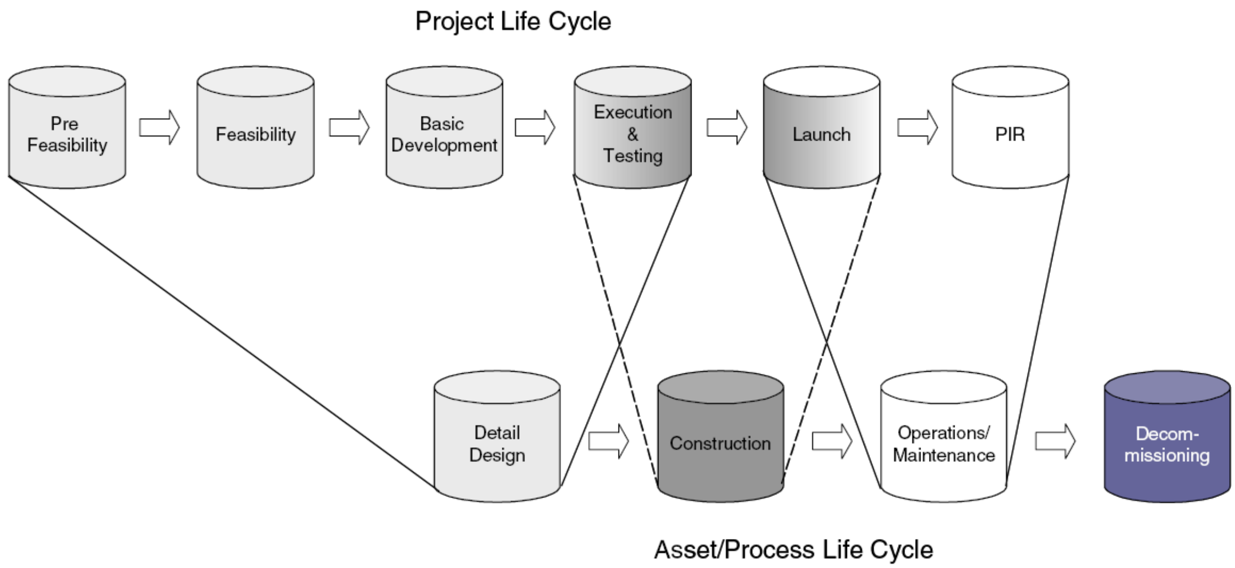

Fig. 2.1 The relation between project and asset life cycle (Labuschagne & Brent 2005, p.164)

From figure 2.1, it can be recognised that the project's life starts at the pre-feasibility study and effectively ends at the delivery of the project to its concerned stakeholders, which is the lunching time of the project. While the asset life cycle ends at the decommissioning of the asset itself. However, in this research, a concentration is given to study both cycles together and to represent them as one full cycle that starts from the project initiation until the asset disposal. As stated by Labuschagne and Brent (2005, p.162), "the project life cycle and asset life cycle are often viewed as one life cycle due to the fact that the two life cycles contribute to the same value chain". Therefore, both life cycles will be analysed and treated the same, and will be referred as project life cycle in this study. Further definitions of the life cycle cost are explained in the coming section.

There is a cost that is associated with each phase or element in the project life cycle. This cost could help during the planning phase to estimate the total cost of the project. For instance, design, construction, commissioning, operation, maintenance, and disposal costs can be categorised as costing elements of a building life cycle (Taylor 1981). In this paper, the project life cycle will be classified into three phases which are design and implementation (initial phase), operation and maintenance, and finally decommissioning as shown in figure 2.2. Each phase will have a cost related to it, and in order to estimate the total life cycle cost, each phase needs to be analysed to determine its cost. Then, the obtained cost will be used in the LCCA technique.

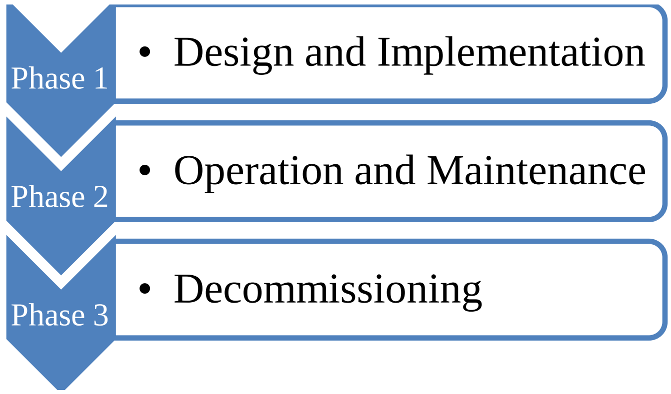

Fig. 2.2 Phases of project life cycle

2.3. Life Cycle Cost Analysis (LCCA) Technique

Many definitions for the LCC can be found in literature. LCC “refers to an analysis technique which encompasses all costs associated with a product from its inception to its disposal” (Sherif 1981, p.287). Also, it can be “described as a forecasting tool used to compare or evaluate alternative planned capital expenditures with the aim of ensuring the optimum value from capital assets" (Taylor 1981, p.33). Thus, according to the above definitions the LCCA can be considered as a technique to estimate the project’s cost through the three stages shown in figure 2.2, and as a tool to evaluate project’s alternatives. In addition, according to the National Institute of Standards and Technology, LCC can be defined as “the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system” over a period of time (Fuller & Petersen 1996, p.2). This means that LCC does not rely only on initial acquisition cost that is used in the traditional planning process, but also rely on the costs of operation, maintenance, and decommissioning which could be a value or a cost.

Life cycle cost analysis is a useful tool that is worth trying by project managers while planning their projects. There are many typical applications where LCC can be used such as “buildings (new constructions or purchases), new product lines, manufacturing plants, commercial aircraft, new automobile models, defence systems, and the like” (Blank & Tarquin 2005, p.190). Applying LCCA to such applications could significantly help minimise their total life cycle cost, evaluate the investment options, and select among project’s alternatives. And thus, it can reduce future projects’ cost overruns.

2.4. Life Cycle Cost Phases

Once a decision is made to start with an investment for a project after conducting a feasibility study, a comprehensive planning for the project and its costs begins. And in order to obtain an accurate cost for the project, the cost of each phase in the project life cycle should be estimated. For instance, as mentioned before, the project life cycle consists of three phases as shown in figure 2.2, and the cost of each phase needs to be defined and estimated. Then, the estimated costs will be used in the LCCA calculations to obtain the life cycle cost of the project. Thus, all the stakeholders involved in the project will be aware of the total cost of the project, as well as of the cost of each phase, and be able to arrange the budget and the cash flows for the project.

2.4.1. Initial Cost

The initial cost of a project represents the cost involved during the basic stages of a project's life starting from the initiation idea to handing over the project to the concerned stakeholder. However, most of the costs result from the design, construction and implementation keeping in mind a cost for the risk that might occur. In most of the cases, the initial cost is well known and planned properly by project mangers compared to other costs. For instance, Wubbenhorst (1986, p.87) stated that "planners, producers, and users of a system perhaps know the initial costs of a system, but they have no idea about the total downstream costs" of the project life. Therefore, in most of the cases, the costing of this phase is planned adequately by managers. However, managers should not depend only on obtaining the cost of this phase, but also need to consider the other costs involved in the other phases of the project life cycle in order to get proper cost estimation.

Work breakdown structure (WBS) is usually used to identify the tasks and the work packages involved in this phase. It can be considered as a tree that illustrates the hierarchy of the required work to be performed in order to complete and deliver a project (Ayas 1996). By creating a detailed WBS based on drawings, specs and old projects, all the tasks, activities and recourses needed to handle the project can be identified. Then, a network diagram can be created for all the activities required for the initial stage of the project. The direct cost of each activity in the network diagram will be estimated as explained in figure 2.3 by defining the resources needed, estimating the duration, and the total cost (Hegazy 2006). Such step will be repeated for the other identified activities in the project network. Then, the obtained costs of the activities will be summed to determine the project’s initial cost that will be used later on for the LCC calculations.

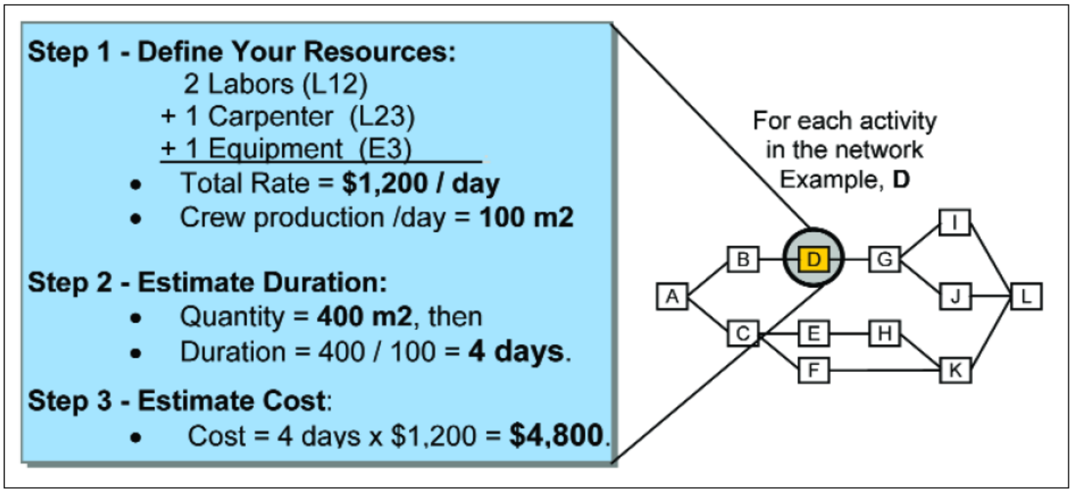

Fig. 2.3 Basic estimation for the work packages (Hegazy 2006, p.21)

2.4.2. Operation and Maintenance Cost

When the project is delivered to its concerned stakeholders, a new phase of the project life cycle starts which is the operation and maintenance (O&M). There are costs involved in this phase that need to be considered carefully during the planning phase in order to minimise project running cost. However, systematic methods to determine operations and maintenance costs during the planning stage of the project are generally not available (Dessouky & Bayer 2002). Therefore, by neglecting the estimate of such costs, the LCC of a project might rise and affect the planned allocated project’s budget and the cash flows. Awareness has been initiated to look after such costs and an emphasis was given to LCC due to the state of economy and budget limitations (Jambulingam & Jardine 1986). For instance, according to Marsh (2007, p.22), “Operation and maintenance costs need to be factored into the project costs of offshore wind farms at an early stage”. Therefore, O&M estimation costs are preferred to be included in the LCCA to obtain the total project cost in order to incorporate it in the project budget and avoid any future cost overruns or variations.

When included in the LCCA, the operation cost can be considered as the “average annual cost of energy, labor, materials, supplies, insurance” (Brown 1979, p.110). The operation cost of an asset includes direct costs such as labour, material, expenses and overheads as well as indirect costs like labour, material, and overheads (Woodward 1997). Also, other costs could be like energy, lease, and insurance. Therefore, it is necessary to incorporate all the costs involved in the operating process of the project to the LCCA during the planning phase. Moreover, the other cost that should be properly planned for in advance stages is the maintenance cost. It can be estimated as the "average annual cost of maintaining the asset as well as any periodic replacement parts" (Brown 1979, p.110). This cost includes the cost of the labour, material, spares, equipments, and energy. Also, the maintenance cost can be classified into regular planned maintenance, unplanned maintenance, and intermittent maintenance (Woodward 1997). Thus, such costs needs to be considered and planned carefully in order to determine the LCC of a project and to avoid future cost overruns. As stated by Moore and Starr (2006), a lot of inherent costs to the organisation can occur like lost production, rework, scrap, labour, spare parts, fines for late orders, and lost orders due to unsatisfied customers if inadequate maintenance planning is made. The ability to estimate the maintenance cost during the planning and design stage could help the organisations to increase their profits. For instance, by using an effective maintenance plan, a Swedish paper-mill's machine could generate extra profit of at least US$0.975 million which is considered as 12.5% of its yearly maintenance budget (Alsyouf 2007). Most of the organisations strategies aim to increase their profits and to save more money. And this could be established by estimating the operation and maintenance costs during the planning stage. The LCCA will use these costs to obtain the LCC of the project and be able to select among project's alternatives based on the determined LCC of the project. The LCC calculations will be explained later in section 2.5 of this dissertation.

2.4.3. Decommissioning Cost

The last stage of the life cycle is the decommissioning phase cost that occurs at the end of the asset life. Decommissioning could be a disposal value like selling the asset or a disposal cost such as demolition, dislocation, and removal (Brown 1979). There are many costs involved in the disposal stage which "covers time of clear transition to new system; removal/recycling of old system" (Blank & Tarquin 2005, p.191). Salvage value is another term found in literature associated with the decommissioning cost phase. According to Monga and Zuo (2001, p.328), "the salvage value is defined as market value of a component/system at the end of its life". For instance, such value can be estimated by creating a depreciation schedule for a system where the depreciation can be categorised as physical and functional depreciation (Monga & Zuo 2001).

The physical depreciation is "a reduction in a system's capacity to perform its intended service due to physical impairment" (Monga & Zuo 2001, p.328). This type of depreciation leads to decline in asset or system performance and high maintenance cost. The other category of depreciation is the functional depreciation. It "occurs as a result of changes in the organization or in technology that decrease or eliminate the need for a system" (Monga & Zuo 2001, p.328). For instance, such depreciation happens when the current system becomes obsolete due to technology enhancements, or the disability of the system to meet the increased demand on quantity or quality.

Therefore, there is a need to incorporate the decommissioning costs of a project to the project's design during the planning phase. This consideration can lead to future saving while disposing the project since the concerned stakeholders will be aware of such cost. Moreover, as stated by Schuman and Brent (2005, p.577), "the system should be designed such that, if required, it can be disposed of at minimum cost in the most environmentally responsible manner". Therefore, not only the costs need to be considered but also the environmental aspects. It is becoming increasingly important during designing a facility to consider environmental issues (Abraham & Dickinson 1998). So, the decommissioning phase should not create any harmful effects to the environment since it will create other unexpected expenses to recover the situation. Therefore, proper considerations need to be established during the decommissioning stage which can include remanufacturing and recycling which are friendly procedures to the environment (Lintona & Yeomans 2002). It could be difficult to obtain the decommissioning cost during the planning phase since it is hard to estimate; however, if obtained, it will be of great value to include in the LCCA. Thus, an overall cost estimate of the whole project can be attained, and the budget can be maintained. According to Abraham and Dickinson (1998, p.146):

> If the disposal phase costs are identified as a significant portion of the facility's overall life-cycle cost, the owner can initiate a balance between functional requirements and disposal requirements early on in the facility's planning and design phase.

2.4.4. *Interaction between the Life Cycle Cost Phases*

The interaction between the three phases of the life cycle cost is very important in order to come up with an optimum life cycle cost. As mentioned earlier, there are no significant considerations for the estimation of the operating, maintenance, and decommissioning costs during the planning stage of the project. As shown in figure 2.4 adopted from Taylor (1981, p.37), option 1 represents a normal scenario for a project life cycle cost where it can be noticed that there is a high cost incurred during the O&M phase. On the other hand, option 2 in figure 2.4 shows if a more emphasis is given to the capital cost, which represents the initial cost phase, will lead to a reduction in future running cost. It is basically a trade-off methodology between the three phases.

According to Van Noortwijk and Frangopol (2004), there should be a proper plan and cost considerations for maintaining civil infrastructure systems since such infrastructure is deteriorating with time, and this is recognised as a critical issue worldwide. Therefore, a high increase of the initial cost to include the design of O&M plans during the initial phase will not be a waste; however, it could help in reducing costs in future and optimising the LCC of the project. Also, in order to reach such optimum design, a significant planning, integration, and coordination between the life cycle's phases should be implemented (Ahmed 1995). Hence, the tradition of selecting the project based on lower initial costs needs to be avoided in the organisations. The selection should depend on the cost trade-off among the project life cycle phases. So, if a project has a high initial cost but will lead to a lower O&M cost in the future, it can be considered as a feasible option since it could lead to a cost saving and reduction in future’s cost overruns.

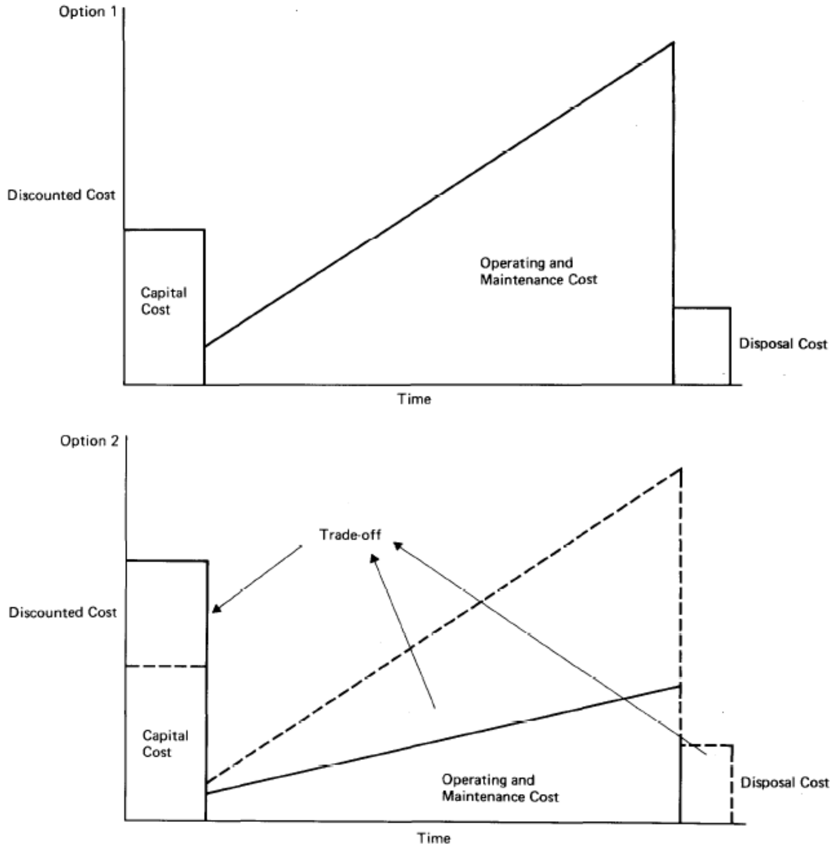

Fig. 2.4 Trade-off between project life cycle cost phases (Taylor 1981, p.37)

2.5. Basic principles and methods for LCC

According to the LCC definition mentioned before, the total cost of the three phases of the project life cycle should be discounted to the present value in order to find the LCC of the project. Therefore, some basic principles should be explained in order to fully understand the LCCA concept and the calculations involved.

2.5.1. Discount Rate

Discounting "is the arithmetical process of converting value statements referring to one moment in time to their equivalent value statement referring to another moment in time" (Snell 1997, p.44). It "is applied to money or to an economic or social value that is expressed in monetary units" (Snell 1997, p.47). Therefore, a discount rate is needed to convert future costs such as O&M and disposal costs to present values. It is a critical parameter in obtaining the present value of a project which is required for the LCC. The discount rate will help in reflecting the inflation rate or the real power of money invested over a period of time (Woodward 1997).

Moreover, it "is especially useful for balancing the initial cost of investment against the future cost" such as the O&M and decommissioning cost (Van Noortwijk & Frangopol 2004, p.356). Furthermore, according to Skipworth et al. (2002, p.33):

> [The discount] rate should not be chosen so that it unduly privileges one set of options over another. Nor should it be so low as to be unrealistic. A sensible approach would be to adopt a mid range estimate and to carry out sensitivity analysis to investigate the impact of the choice of the discount rate on the outcome of the comparison.

Hence, an appropriate discount rate should be determined carefully for example by the help of accountants since it differs from organisation to organisation depending on the scope of the project. For instance, a discount rate of 4% and 6% is used in the United States and the United Kingdom respectively (Van Noortwijk & Frangopol 2004, p.356). In this paper, the symbol 'r' represents the discount rate in the LCC calculations explained in the following section.

2.5.2. Present Value, Average Annual Cost, and Project Selection

The life cycle cost analysis technique, and the life cycle phases have been introduced in earlier sections. In here, the calculations involved in determining the LCC of a project, and the selection among project's alternatives is explored. For instance, once the entire initial, operation, maintenance, and decommissioning costs incorporated in a project are estimated, and the discount rate is determined, the LCC can be obtained. According to Brown (1979), there are two basic life cycle costing techniques that can be considered which are the 'Present Value' and 'Average Annual Cost'. The present value method converts the future costs such as O&M, and decommissioning to present value. However, the initial cost will not be converted and will remain the same since it occurs at the base year of implementing the project. The reason behind obtaining the present value is that £1 invested today has different value in 1 year later due to the interest and inflations rates (Taylor 1981). O&M and decommissioning costs are costs that will occur in the future. Their values differ from the current value of money in the base (first) year of the project initiation. Therefore, there is a need to convert these costs to their present value in order to calculate the LCC.

The basic formula of the present value can be expressed as (Blank & Tarquin 2005, p.51):

$$P = \frac{F}{(1+r)^n} \qquad \text{Eq.1}$$

Where P= present value, F= future value, r=discount rate, and n=life of project in years.

Also, Microsoft Office Excel can be used to obtain the P value using the PV(r%,n,,F) function which will make the calculation of the present value easier and faster (Blank & Tarquin 2005). Moreover, in order to have the present value of uniform annual costs (C) such as operation and maintenance, the following equation can be used (Brown 1979, p.110):

$$P = \sum_{t=1}^{n} \frac{C}{(1+r)^n} \quad \text{Eq.2}$$

However, as stated by Brown (1979, p.110), if the costs are expected to escalate, the present value can be found as:

$$P = \frac{a(a^n - 1)}{a-1} C \quad \text{Eq.3}$$

Where:

$$a = \frac{(1+e)}{(1+r)} \quad \text{Eq.4}$$

e: the rate of escalation.

Once the operation, maintenance, and decommissioning costs are estimated during the planning phase, Eq.1 and Eq.2 can be used to calculate their present values. After obtaining the present values of all the costs involved in the project life cycle phases, the LCC of the project can be determined by summing the initial costs with the present values of the O&M, and decommissioning costs.

The same calculations mentioned before needs to be implemented for the other competing project's alternatives. A decision will then be made in favour of the project that has the lowest LCC. It is the basic idea of the LCC concept, which is to minimise the costs involved in the project life cycle (Sherif 1981), which reflects the strategy of the organisation to reduce future costs (Wubbenhorst 1986). In this case all the costs involved in the project life are considered rather than only considering the initial costs (Woodward 1997). Therefore, the selection among project's alternatives needs to be done based on the lowest LCC and not on the lowest initial cost. According to Coe (1981, p.564):

> The rationale behind LCC is that while the initial cost of a product may be greater than a competing product, the total cost of ownership may be less because over its useful life it is less expensive to operate or maintain.

On the other hand, the average annual cost, which is the second basic method of life cycle costing techniques, converts the future costs to an average annual figure. It is more appropriate to use compared to the present value if project's alternatives have different life periods (Brown

1979). In this method, the average annual cost can be obtained by multiplying the calculated present value by a capital recovery factor ‘A’ (Brown 1979, p.111):

$$A = \frac{r(1+r)^n}{(1+r)^n - 1} \qquad \text{Eq.5}$$

In order to represent the idea of the basic life cycle costing techniques clearly, table 2.1a and table 2.1b represent an example of determining the LCC of a water chillier for two models (A and B) having a 20 year life time using the present value method and the average annual cost method (Brown 1979). The above mentioned equations were used for this example calculation. By using the present value method, it can be noticed that even though the initial cost of model A is higher than model B by $2000, model A LCC is less than model B LCC by $1,607. This can be considered as a saving that will be gained in the long run even though the initial cost is high. This is just an example of selecting water chillier; however, the same can be applied for large investments where potential financial savings could be more. Therefore, by selecting the lowest LCC, organisations can start saving money and try to avoid future cost overruns.

At the same time, in this example, the average annual cost of model A is less than model B by $190. This means that if the two models are selected, the money spent on model A will be less than the money spent on model B by $190 every year. In this case model A will be selected instead of model B since it has the lowest LCC as well as the annual average cost. However, the client may go for model B if he/she realises that the only difference between the two models’ averages cost is $190 only per year and it is worth the additional benefits that model B has.

Both methods of obtaining the LCC are useful since they can provide us with valuable information such as the total LCC of a project and its annual cost. However, the average annual cost method is recommended for the selection among competing projects which has different expected lives (Brown 1979). Therefore, it is the responsibility of planners and managers to select the proper method to use for the LCC calculation depending on the information they want. Furthermore, it would be highly recommended that planners replace the tradition of selecting the project based on lower initial cost by considering the LCCA in order to reduce future cost overruns.

Table 2.1a LCC using the present value method (Brown 1979, p.111)

	Model A	Model B
Initial cost	$28,000	$26,000
Annual K Wh consumption	150,000	165,000
Operation and maintenance (3,000 X 10,87418 X0.52 =)	16,964	16,964
Power (150,000 X 0.03 X 12.81522 X 0.52 =) (165,000 X 0.03 X 12.81522 X 0.52 =)	29,988 ----	---- 32,986
Investment tax credit	(2,800)	(2,600)
Depreciation tax benefit (28,000 ÷ 20 X 0.48 X 8.51355 =) (26,000 ÷ 20 X 0.48 X 8.51355 =)	(5,721) ----	---- (5,312)
Present value of costs	66,431	68,038
Present value differential in favor of A:	$1,607	

Table 2.1b LCC using the average annual cost method (Brown 1979, p.111)

	Model A	Model B
Initial cost (x 0.11746)	3,289	3,054
Operation and maintenance (16,964 X 0.11746)	1,993	1,993
Power (29,988 X 0.11746) (32,986 X 0.11746)	3,522 ----	---- 3,975
Investment tax credit (2800 X0.11746) (2600 X0.11746)	(329) ---	--- (305)
Depreciation tax benefit (1400 X 0.48 =) (1300 X 0.48 =)	(672) ----	---- (624)
Average annual cost	7,803	7,993
Average annual cost differential in favor of A:	$190	

2.6. Life Cycle Cost Models

A concern started to spread among stakeholders about the cost overruns that are occurring in their projects, and how such costs can be minimised. As stated by Durairaj et al. (2002, p.31) “the combination of rising inflation, reduction in purchasing power, budget limitations, increased competition, etc., has created an awareness and interest in the total cost of products, systems, and structures”. This kind of awareness and interest led many scholars to start reviewing the current practices used while estimating the life cycle cost of projects. Thus, several models have been developed for the LCCA such as:

- ‘LCCA model of Fabrycky and Blanchard’ (Durairaj et al. 2002).
- ‘LCCA model of Woodward’ (1997).

- ‘LCCA model of Dahlen and Bolmsjo’ (1996).
- ‘Activity Based Costing (ABC) model’ (Durairaj et al. 2002).

Even though these models are different in their approaches, their aim is still the same which is to reduce the life cycle cost of a project, an asset, or a system (Durairaj et al. 2002). Thus, by reducing the LCC, organisations could avoid today’s life challenges mentioned before such as the rising inflation, budget limitations, increased competition, and cost overruns.

A comparison of the developed LCCA models and their features is shown in table 2.2. Also, a grade is given to each model’s feature in order to evaluate and compare the models. It can be concluded from the table that the mentioned models share some features like the ability to identify alternatives, development of cost breakdown structure, generation of cost estimates, total cost determination, and risk analysis. These features can be considered as critical for the LCCA and can help to come up with an accurate LCC estimate. However, each model serves a specific purpose. For instance, LCCA of Fabrycky and Blanchard is considered as a holistic model, LCCA of Woodward is helpful for assets, LCCA of Dahlen and Bolmsjo considers the labour factor, and the ABC model is used when uncertainty is involved. Therefore, the model to be used by planners needs to be selected effectively. As stated by Durairaj et al., (2002, p.32), “decision makers can understand the various LCCA methodologies and possibly select the respective method which is the most suitable for their company on basis of the elemental features”. To better understand these LCCA models, a brief explanation of each model is provided in the following sections.

Table 2.2 Comparison of existing LCCA Models (Durairaj et al. 2002)

No	Features	LCCA (Fab. & bla.)	LCCA (Wood.)	LCCA (Dahlen)	ABC Model
1	Objective	Cost Alternates	LCC of assets	Cost labor	Cost Redn.
2	Identifications of alternatives	A	A	A	A
3	Development of CBS & CBRs	E	E	E	E
4	Identification of suitable cost model	E	G	G	E
5	Generation of cost estimates	E	E	E	E
6	Availability of cost profiles	G	A	A	A
7	Break Even Analysis	A	A	A	A
8	Determination of High Cost contributors	A	NA	NA	A
9	Total Cost Determination	A	A	A	A
10	Incorporation of Eco-costs	NA	NA	NA	NA
11	Correlation with Design changes	NA	NA	NA	A
12	Implementation of a Design solution	NA	NA	NA	A
13	Quality Aspects	NA	NA	NA	NA
14	Inclusion of Supplier Relationships	NA	NA	NA	NA
15	Trade – offs	NA	E	NA	A
16	Employment cycles	NA	NA	E	NA
17	Sensitivity Analysis	A	A	A	A
18	Risk Analysis	A	A	A	A
19	De-manufacture concept	NA	NA	NA	A
20	Any special feature	Holistic model	Asset model	Human factor	Uncertainty
A, available; NA, not available; G, good; E, excellent.					

2.6.1. LCCA Model of Fabrycky and Blanchard

As reviewed by Durairaj et al. (2002), this model depends on a detailed cost break-down structure (CBS) for a product where its total cost will be divided into four categories which are research and development, productions and construction, operation and maintenance, and disposal costs. It can be considered as a sophisticated model since it considers all the costs involved in the life cycle. Based on this, the cost of each category is sub-divided into relevant incremental cost. The essential steps of this model are shown in figure 2.5. This model is considered as a holistic model to determine the total cost of a project, and can be used to include environmental costs to the CBS because of its generality (Durairaj et al. 2002). Moreover, the steps of this model are general and can be applied to any application.

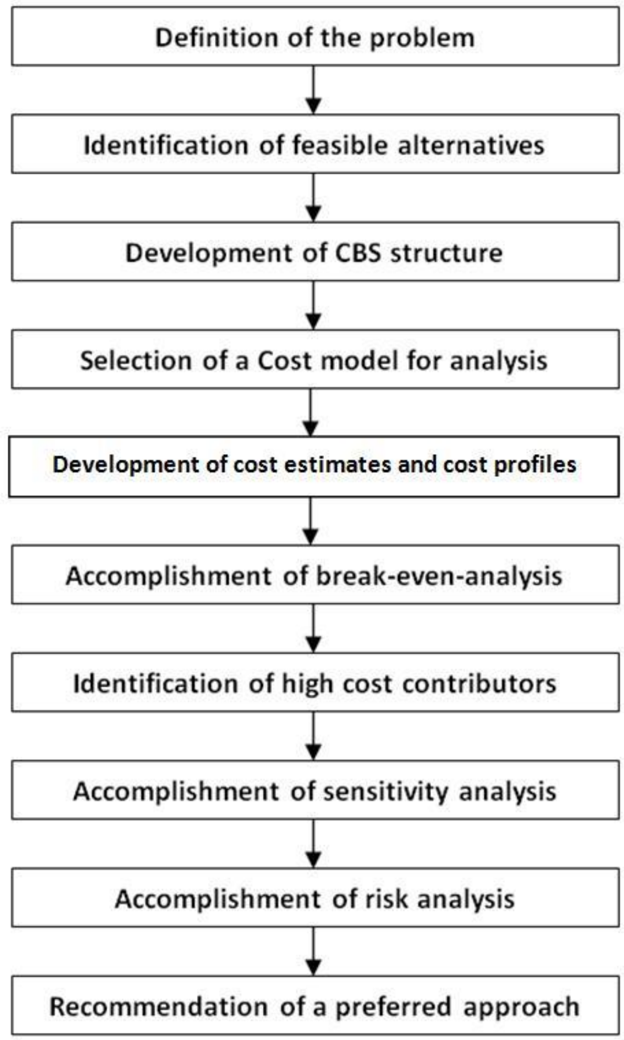

Fig. 2.5 LCCA Model of Fabrycky and Blanchard (Durairaj et al. 2002, p.34)

2.6.2. LCCA Model of Woodward

This model targets the asset's life cycle starting from the development stage of the asset until the disposal stage. Woodward (1997, p.335) summarises the aim of this model to optimise the:

> value for money in the ownership of physical assets by taking into consideration all the cost factors relating to the assets during their operational life. Optimizing the trade-off between these cost factors will give the minimum life cycle cost of the asset. This process involves an estimation of costs on a whole life basis before making a choice to purchase an asset from the various alternatives available. This approach encourages a long-term outlook to the investment decision-making process.

Therefore, it is very useful to use this model for the asset's planning and decision making among project alternatives. In this model, Woodward (1997) has adopted Kaufman eight step approach, illustrated in figure 2.6, which is establishing the operating profile, establishing utilisation factors, indentifying all the cost elements, determining the critical cost parameters, calculating all costs at current prices, escalating current costs, discounting all the costs, and finally summing the discounted costs to establish the net present value. The significance of this model lies behind the aim to optimise the LCC of an asset by including all the costs involved rather than the initial costs only. This makes the evaluation of the investment more reliable since it could include future savings because most of the costs involved are considered in the planning phase.

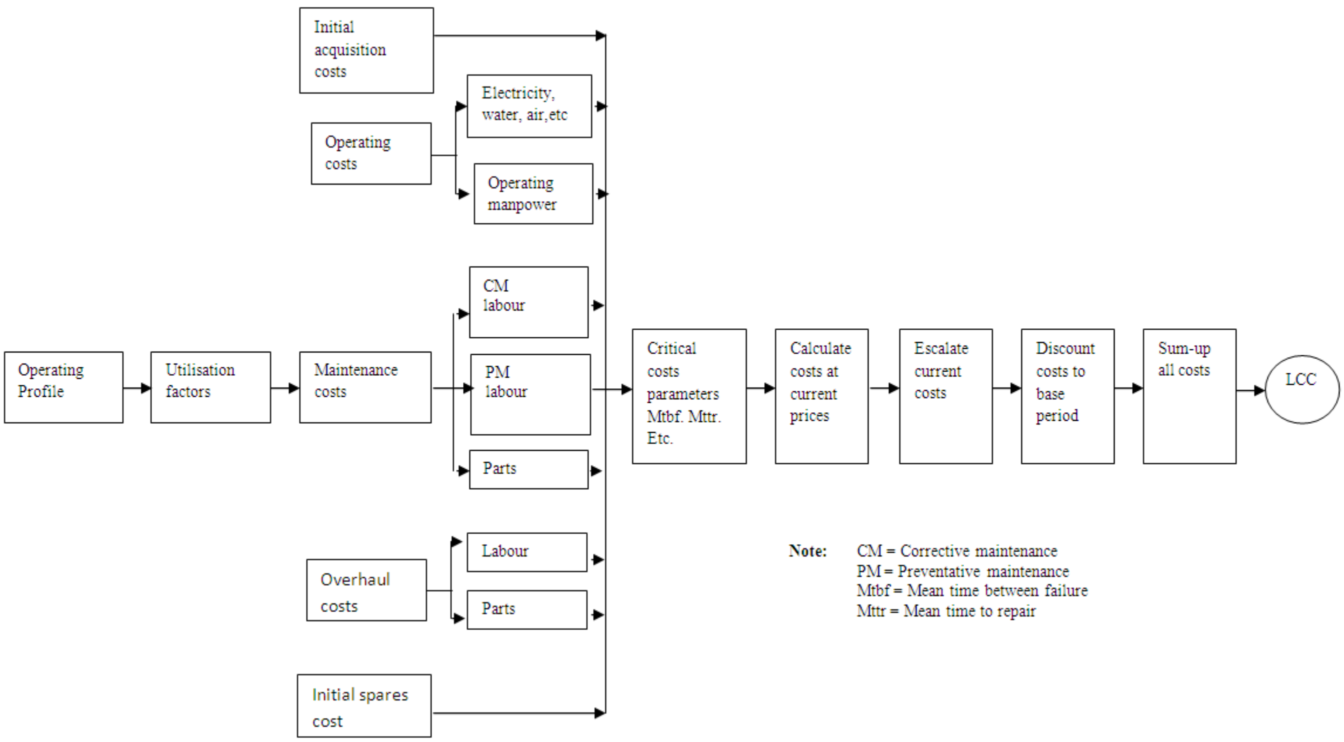

Fig. 2.6. Kaufman's LCC formulation (Woodward 1997, p.337)

2.6.3. LCCA Model of Dahlen and Bolmsjo

In most of the discussions of this paper, the LCCA was used to analyse the costs involved in the life cycle of a project, a product, or a system. However, the purpose of Dahlen and Bolmsjo model according to Dahlen and Bolmsjo (1996, p.459) is to "widen the field of application for life-cycle costing and carry through an analysis of investments done when raising the production factor labor”. The model covers the cost of labour from recruitment until retirement, and the costs are categorised to three stages:

i. Employment costs that include costs of recruiting, and training.
ii. Operation costs which include costs of wages, and labour overheads.
iii. Work environmental costs that include cost of absence, rehabilitation and pensions.

This model aims to use the LCC technique to carry through an analysis of the costs for an employee over the whole employment cycle (Dahlen & Bolmsjo 1996). Moreover, it is suggested that the labour costs should be treated in a similar way as the life cycle cost of production equipment (Durairaj et al. 2002).

2.6.4. Activity Based Costing(ABC)Model

“In order to provide an efficient and effective decision support in life cycle design, costing methods should have the capability to handle uncertainty” (Durairaj et al. 2002, p.36). Therefore, ABC model could be considered as an effective way for cost assessment of the life cycle, and to be used in uncertain situations that lack information. For instance, it is relevant to deal with environmental issues since uncertainty is involved and its conditions need to be considered in this model. Bras and Emblemsvag cited in Durairaj et al. (2002, p.36) have developed a six step ABC model which is:

1. Creation of an activity hierarchy and network that will ensure that all the activities in the part of the life cycle are considered.
2. Identification and ordering of all the necessary cost drivers and consumption intensities.
3. Identification of relationships between cost drivers and design changes.
4. Determination and minimization of the cost of the consumption activities, that use an optimization algorithm where the design parameters serve as the source variable and the total cost as the response variable.
5. Evaluating the solution.
6. Iterations, if necessary.

2.7. Cost Monitoring and Control

Selecting the project from different alternatives using the LCCA can probably help saving cost in the long run even if it is not observed in the short run. However, in order to make sure that project’s cost is according to the budget allocated by the organisation, cost monitoring and control techniques should be implemented while running the project. In addition, to achieve the planned cost objectives, the actual costs should be compared to the planned cost assumptions, and any deviations from the planned forecasts should be corrected by taking necessary actions

(Taylor 1981). Hence, there is a need to have a monitoring and control system to compare activities' progress and cost to the plans by generating reports, tracking of critical success factors, and establishing an incentive scheme (Ahmed 1995). The monitoring and control technique involves many steps that need to be accomplished. For example, in construction projects, the steps include making the plan, implementing the plan, monitoring actual output, recording it, report actual and planned parameters and their variations, and finally taking action (Al-Jibouri 2003). The monitoring involves gathering the useful information and comparing it to the plans to check project progress, while the control involves using the obtained information from the monitoring to take necessary actions to achieve project objectives.

There are many techniques or methods used by project management for monitoring and control purposes. This paper proposes the use of the earned value management (analysis) which is considered by Anbari (2003, p. 12) as "a powerful tool that supports the management of project scope, time, and cost". It helps to detect if project is suffering from 'over-costs' and delays during the project life cycle (Pajares & López-Paredes 2010). Also, according to Waehoe (2004, p.1), earned value management (analysis) is considered as:

> a system that incorporates the organized components of the project's schedule, budget estimate and scope of work into a process by which the project's forecasted costs at the end of the project can be more reliably determined.

In other words, such method could help monitor the actual project's costs during its life cycle and compare them to the planned costs determined during the planning phase of the project. Thus, necessary actions will be taken in case a deviation occurs between the actual costs and the planned costs. These necessary actions would try to maintain the project within its specified budget and avoid, if possible, any costs overruns.

According to Gardiner (2005), the earned value analysis uses the planned cost, planned schedule, actual cost, and actual progress to determine the variables needed to evaluate project performance in terms of cost and schedule. These variables are the value of planned work, the actual cost of work performed, and value of actual work which is known as the earned value (Gardiner 2005). The planned value of work refers to "the approved budget for the accomplishing the activity, work package, or project related to the schedule" (Anbari 2003, p. 13). Also, it was previously known as the budgeted cost of work scheduled (BCWS). However, the actual cost (AC) "is the cumulative AC spent to a given point in time to accomplish an activity, work package, or project and to earn the related value" (Anbari 2003, p. 13). It was known as the actual cost of work performed (ACWP). The earned value "represents the amount budgeted for performing the work that was accomplished by a given point in time" (Anbari 2003, p. 13). The budgeted cost of work performed (BCWP) was the name given previously to the earned value.

Management could use this method at each stage of the life cycle that was shown in figure 2.2 to monitor and control the costs of design and implementation, operation and maintenance, and decommissioning. They would be able to determine the actual cost of work performed (ACWP) and compare it to the budgeted cost of work scheduled (BCWS) and budgeted cost of work performed (BCWP) as shown in figure 2.7. Such variables will help to determine the cost variance (CV) and the cost performance index (CPI). The cost variance "is the difference between actual expenditure and the earned value" while the cost performance index is "the ratio of BCWP to ACWP" (Gardiner 2005, p.292). If the CV has a negative value or the CPI is less than 1, this indicates that there is a cost overruns occurring. From figure 2.7, it can be noticed that the CV= -20 and the CPI=0.67. Both values indicate that the project is running over budget at that moment of time during the life cycle of the project. Therefore, management need to take the necessary actions to maintain the project's costs within the allocated budget of the project in order to avoid any future cost overruns or time delays. Hence, cost monitoring and control techniques needs to be considered and implemented by project mangers during the project's life cycle in order to achieve the LCCA objectives.

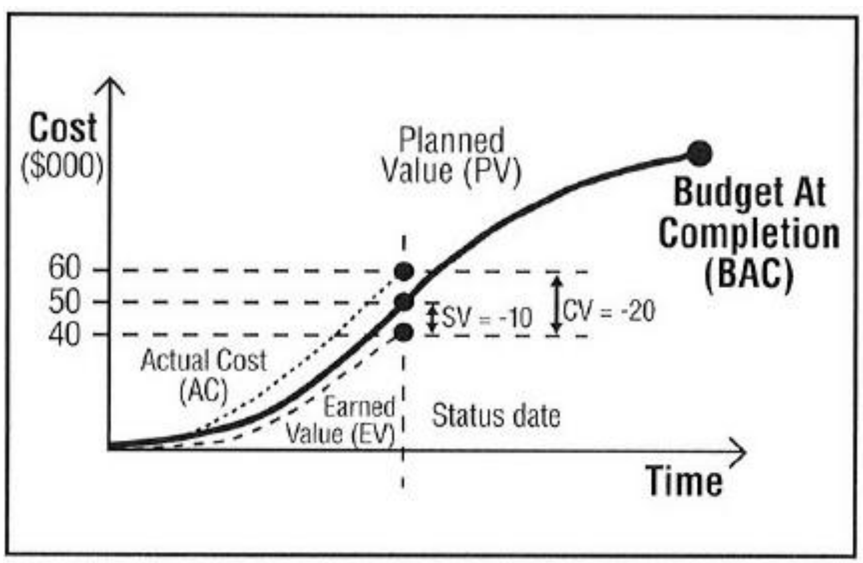

Fig. 2.7. Planned value, actual cost, and earned value (Anbari 2003, p. 13)

2.8. LCCA Implementation Barriers.

Although LCCA technique is generally seen as useful, there are some barriers or obstacles facing the implementation of the LCCA concept in some organisations which limit the use of its benefits. For instance, there are psychological barriers represented by the fear of change and the tendency to select the lowest bid from competing alternatives (Coe 1981). It is considered easier to select the lowest cost rather than performing a comprehensive LCCA. According to Wubbenhorst (1986, p.94), “higher cost in initiating, planning, and realization of a system are regarded as unattractive in comparison to only potential savings in operation and disposal/salvage”. Usually, it is the current savings that managers are looking for not the uncertain future savings that might occur. Based on the current performance and the money saved on an immediate basis, managers are judged and rewarded (Ahmed 1995). To overcome such attitude, a cultural change is needed where the acceptance of higher initial costs should be accepted and communicated to project’s members and decision hierarchy (Wubbenhorst 1986). And by applying such approach, long term saving can be attained.

According to Coe (1981), another obstacle to perform the LCC is the structural barriers that occur in some organisations from the existence of decentralised purchasing systems. In some cases, the procurement funds are supervised from a department other than the operation and maintenance departments (Wubbenhorst 1986). For example, in this case, there is no significant consideration given by the procurement department to pay higher initial costs in order to save money for the system’s operation or maintenance in future. Management is required to break such kind of behaviour of the insular thinking of separate departments and to promote the objective of reducing the LCC. The procedural barriers are considered as another problem facing the LCCA execution in some organisations where they “are not sophisticated enough to carry out LCC” (Coe 1981, p. 567). This might be due to the organisation lacks of tools, skills and experts who are aware of the LCCA concept. Moreover, it is not easy to have a clear sight about the incurred future cost elements (Ahmed 1995). This could be referred to the doubts about the accuracy and reliability of the obtained data due to the contractors being “reluctant to guarantee estimates” (Wubbenhorst 1986, p.94).

Even though there are some problems facing the implementation of the LCCA, it is still useful to keep in mind its potential advantages mentioned in earlier sections of this paper. For example, the LCCA can help to estimate the overall project’s cost starting from the initial phase up to the disposal stage, choose between competing projects to reduce future cost overruns, and evaluate investments among project alternatives which might help achieving long term benefits. Therefore, management's commitment is needed to overcome the LCCA barriers and to make an effort implementing the LCCA concept in their organisation during the planning phase of the project initiation. Thus, organisations can benefit from the LCCA advantages in the long-run.

2.9. Examples of Applied LCCA in Different Countries and in UAE

The life cycle costing technique is not a recent concept. It was utilised by the U.S Department of Defence in 1970s to evaluate new weapon system (Brown 1979; Ahmed 1995), and also was used by the Norwegian defence procurement projects (Tysseland 2008). Hence, this concept is not that new since it was known for some sectors. Moreover, it was used in many states in the US for systems such as copying machines, air conditioners, lighting, etc (Coe 1981). However, the implementation of the LCCA is not limited to the previous mentioned applications. Organisations started to implement the LCCA in projects to accomplish their strategies that call for minimising projects' costs. For example, in Europe, a Sweden study had investigated the LCCA of a car, a city bus and an intercity bus 'powertrain' for the year 2005 and 2020. According to Hellgren (2007), it is required to have a cost effective design for a powertrain because there are cheap vehicles with high operating cost and there are also expensive vehicles with low operating cost. Therefore, there should be a tradeoff between these two cases and a development of alternative powertrains. The use of the LCCA was necessary since the aim of that study was to assess the choices of the powertrain for different applications. A computer tool called THEPS was developed and used in order to come up with accurate results since this tool is able to evaluate a large number of powertrain designs. It was concluded that it is cost effective, in 2005, to provide a city bus with a hybrid powertrain in countries that have high fuel price (Hellgren 2007). Moreover, it was noticed from the analysis that "pure electric, hybrid and/or fuel cell cars will probably be a more cost effective choice than conventional cars in year 2020"(Hellgren 2007, p.39). From this example, it can be noticed how the LCCA helped to evaluate cost effective developed vehicles with alternative powertrains, and developing a computer tool to assist in the evaluation to make it easy on the stakeholders involved in the study.

Another example of executing the LCCA is in Myanmar, Asia. The LCCA was used in high way bridges development projects (Singh & Tiong 2005, p.38). There was a need to renovate the old bridges and construct new ones due to the rapid increase of traffic volumes. An efficient plan needed to be executed in order to rehabilitate the bridges even though the funds were limited. Therefore, the planners had used the LCCA to optimise "the whole life cost of structures rather than just initial cost of construction only" (Singh & Tiong 2005, p.38). A detailed LCCA framework was developed for the highway bridges. Basically, it included a range of cost components and statistical factors involved in the life cycle of the bridges that are needed for the LCC calculations. Also, a sensitivity analysis was performed to demonstrate the uncertainties involved in such project. This project has proved that even if the initial cost is high for the construction of the bridges, a lower LCC will be achieved. Also, with such design, the total cost of the highway bridges was minimized "without compromising the functional requirements while maximizing the utility of the structure to the users in particular and to the society in general" (Singh & Tiong 2005, p.37). This project has proved the finding obtained in previous section about the necessity of using the LCCA to the project's life rather than considering the initial costs only. Therefore, the total cost of the project would be minimised which could lead to future saving and avoiding cost overruns.

Pumping systems is considered as another example where the LCCA can be applied. Discflo Corporation (1998) which is a US organisation tries to analyse the costs of the pumping systems over their life cycle. The purchasing cost of the pumping systems is considered insignificant compared to the costs of the running, maintenance, spare parts, and unplanned down time of the system. Therefore, Discflo Corporation realised the importance of the LCCA in order to study the costs involved in the pumping systems during their life time. The corporation has defined a simple theory to develop the LCCA which is to sum all the money spent on direct and indirect way to a pumping system from its initiation to its dissolution including the acquisition, ownership and disposal costs. According to Discflo Corporation (1998, p.28), it is found that the benefits of implementing LCCA are to:

- provide justification for "spend to save" decisions
- enable competing systems to be compared
- allow alternative systems (e.g. pumping rather than conveying) to be evaluated
- enable decisions to be better informed
- enable a program or process to be monitored more effectively

- assess different levels of reliability and maintainability, to facilitate potential trade-offs against other priorities.

The above benefits of the LCCA lead the management at Discflo Corporation to end an era of basing investment decisions solely on capital cost alone without considering other costs involved during the life of the pumping systems. As stated by Discflo Corporation (1998, p.32), “it is no longer a question of whether you can afford to carry out LCC analysis, but whether you can afford not to”.

The previous mentioned examples are only few ones, and there are many of them available in books and journal articles. As illustrated in these examples, many countries and organisations started implementing the LCCA in their projects. For instance, by knowing the advantages of the LCCA, some organisations have developed different frameworks, approaches, and software programs to implement the LCCA into their projects. Even though these approaches or software programs are different, their aim is still the same which is to reduce the life cycle cost of the project, and avoid or reduce cost variations that might occur during the project’s life. However; through the conducted literature review, there are unavailable papers in literature that discuss the implementation of the LCCA concept in the United Arab Emirates (U.A.E). There are many projects that are being developed in U.A.E especially in Abu Dhabi and Dubai emirates. The country took “huge steps toward achieving a solid and sustainable economic growth as well as urban development” (Kazim 2010, p.2257). According to Zaneldin (2006), in order to improve the infrastructure of the country, the government in U.A.E is investing billions of dollars every year in new facilities. Such investments include projects’ developments of houses, malls, hospitals, high rise buildings, telecommunication infrastructure, and water and electricity infrastructures (Zaneldin 2006). Therefore, it would be recommended to study the life cycle cost of such projects in order to better estimate the costs involved in their life cycle. Moreover, the LCCA could help evaluate the investments options in order to select the one that could achieve long-term benefits, and to reduce future costs overruns on the government’s allocated budget for such projects. Hence, UAE government can try applying and integrating the LCCA concept to some of its organisations’ estimation and evaluation process in order to test the validity and the advantages of the LCCA concept.

2.10. Summary

In the previous sections, the concept of life cycle cost analysis was introduced and studied through conducting a literature review supported by references from journal articles and books. At the beginning, the relation between the organisation's strategy and the LCCA had been identified through the feasibility study and the business case development stages. Applying the LCCA during these two stages of the project planning could help evaluating the investment among project's alternatives, and ensure project will yield to the minimum cost which can be seen as one of the organisation strategies. Then, the project life cycle cost technique had been defined and explained. The phases involved in the project life cycle have been identified as three phases which are the design and implementation, operation and maintenance (O&M), and decommissioning. The costs involved in each phase had been introduced. It was found that in order to estimate the project's cost in a better way, the initial, O&M, decommissioning costs need to be included in the LCCA and investigated during the planning phase of the project. Including such costs can provide the concerned stakeholders awareness about the total cost required for a project. So, the adequate budget can be allocated and the cash flows can be maintained during the project life cycle.

Moreover, by providing the necessary equations, the calculations involved in determining the LCC of a project, and the selection among project's alternatives had been studied. Two basic methods of determining the LCC had been introduced which are the 'Present Value' and 'Average Annual Cost'. Both methods help determining the LCC of a project and selecting the project among competing alternatives. The selection should be done by considering all the costs involved in the project's phases. So, the traditional way of selecting the project based on lower initial cost need to be avoided. It is the total life cycle cost of the project that needs to be minimised not its initial cost. Thus, future saving can happen and cost overruns can be reduced. Furthermore, in order for the LCCA to achieve its objectives and to make sure that project's costs is according to the budget allocated by the organisation, cost monitoring and control techniques should be implemented while running the project.

In addition, the LCC implementation barriers which limit the use of its benefits had be summarised as 'psychological', 'structural', and 'procedural' barriers. In order to overcome such obstacles, management commitment would be needed in order to use the potential advantages of the LCCA technique during the planning phase. Finally, examples about the LCCA implementation in some countries and organisations had been provided. Also, different frameworks and software programs to implement the LCCA have been developed by these organisations into their projects in order to benefit from its advantages.

3. Methodology

This part of the dissertation tries to set a methodology framework in order to study and investigate the role of LCCA in improving projects' performance in the organisations mentioned in the research scope in terms of cost overruns and selecting the best alternative. In this research, the concept of the life cycle cost analysis have been introduced and studied through conducting a literature review supported by references from journal articles and books. The literature review focused on how the LCCA can be used to estimate project's cost, the selection among competing alternatives, and the use of the LCCA in organisations from different countries. It should be noted that the concentration of this study is to reduce project's cost overruns of the assets in the Telecom Operator and the Water and Electricity Authority organisations mentioned in the research scope. Therefore, there is a need to investigate the current practices in both organisations, and the causes of the cost overruns in their projects life cycle. In addition, since this study proposes the use of the LCCA, there is a need to check the possibility of implementing the LCCA to both organisations.

Both quantitative as well as qualitative research approaches have been used in this study in order to test the literature review findings, and to collect the necessary data from the real projects implemented by both organisations. According to Westerman (2006, p. 273), "both types of research are aimed at learning about concretely meaningful practices and both are pursued by investigators who are themselves participants in the world of practices". In this study, the quantitative approach was studied at the beginning. The aim of the quantitative analysis" is to measure and determine the relationships among variables" (Forman et al. 2008, p.765). For instance, the relationship between the initial cost, O&M cost, decommissioning cost, and the project selection with the project's cost overruns was studied. As a start for the quantitative analysis, a survey approach was used as a method for collecting the required data through specific questions that was distributed to personnel involved in projects from both organisations. The significance of using the survey is that it can be managed by using phone calls and emails to distribute them to remote locations.

As shown in appendix 1, two surveys have been developed based on the literature review conducted earlier. For instance, survey 1 'Project General Information' was utilised to obtain general information about the projects in both organisations like project location, type, lifetime, budget, and percentage of the cost overruns. On the other hand, survey 2 'Investigated Variables' was used to collect data about the main variables that could influence the project life cost. These variables are the initial costs, operation costs, maintenance costs, decommissioning costs, and the selection among alternatives in both organisations' projects. In addition, measures were developed based on the literature review, and attributed to each variable in a form of questionnaire. As shown in appendix 1, this survey includes 41 questions about each measure for each studied variable. The 'Likert' format was used in the questionnaire which consists of a five-point scale where the lowest scale is 1 which represents the strongly disagree option, while the highest scale is 5 which represents the strongly agree option. Furthermore, the target was to collect data from at least 30 projects from both organisations. However, a pilot study consisted of 13 projects was recommended to start with in order to test the validity and the easiness of both surveys.

As a continuation for the quantitative approach, a statistical analysis was performed on the obtained data from the pilot study. The collected data was analysed statistically using the Statistical Package for the Social Sciences (SPSS) software. In the SPSS software, two statistical methods were performed on the obtained data which are the reliability test and the correlation test. In both tests, the initial costs, O&M costs, decommissioning costs, and the selection among alternatives were considered as independent variables. In contrast, the percentage of the cost overruns was considered as a dependent variable.

In the reliability test, the measures of the independent variables were used in the survey's questionnaire, and the reliability test was performed in order to confirm if these measures can be considered as reliable representations of the independent variables. In this test, the Cronbach's alpha value was used to evaluate if the measures used to represent the independent variables are reliable. In such type of test, "[t]he values 0.7 or 0.75 are often used as cutoff value for Cronbach's alpha and thus for the reliability of the test" (Christmann & Van Aelst 2006, p.1661). For example, the measures used to represent the independent variable 'Initial Costs' was tested by using a 0.7 Cronbach's alpha value. Therefore, by using the SPSS, if the result of the Cronbach's alpha value was greater than or equal to 0.7, the initial costs independent variable can be represented by averaging its measures. Also, this means that the measures obtained from the literature are valid and reliable. However, if the Cronbach's alpha value obtained from the SPSS is less than 0.7, the SPSS has a function called "Scale if item deleted" to check which measure or measures are insignificant and if removed will increase the Cronbach's alpha value.

Moreover, the same procedure was repeated to test the reliability of the other independent variables. The measures that failed in the reliability test were not included in the independent variable's averaged value.

After that, the correlation test was implemented in order to test the relationship between the dependant variable, the percentage of the cost overruns, with each of the previously mentioned independent variables separately. The levels of significance (α) that are typically used in such test are 0.1%, 1%, and 5% (Thompson 2004). In this study, the significance level is considered to be 5% which means 95% confidence level. Moreover, the observed level of significance, p-value, was used to check the correlation validity. For example, if the p value of the initial cost independent variable obtained from the SPSS was greater than 0.05, there would be no statistical evidence of any correlation of the initial costs variable with the percentage of the cost overruns variable. Due to the results obtained from this test, the data collected from both organisations was limited to the pilot study only. The reasons behind that are explained in the coming data findings and discussion chapter.

After obtaining the quantitative approach results, the qualitative research approach was conducted. As stated by Forman et al. (2008, p.765), the goal of the qualitative analysis is "discover-oriented and holistic to understand processes and question underlying assumptions". Basically, it helps exploring the causes of a process and making predictions (Thompson & Walker 1998). Therefore, this approach was used in order to understand how both organisations estimate the costs involved in the project life cycle phases, and explore the causes of the cost overruns in their projects life. An interview approach was used to achieve this approach where an open and closed type of questions was used. Personnel from both organisations involved in infrastructure projects were interviewed such as project managers and engineers. The interviews helped in answering questions that require more than yes/no answers where an explanation is required. The questions that were asked to both organisations' personnel were mainly about the following but not limited to them:

- The process of estimating the project's initial costs.
- The process of estimating the project's operation and maintenance costs.
- The process of estimating the project's decommissioning costs.
- The causes of the cost overruns during the project life cycle.
- The possibility of implementing the LCCA to their organisations.

Consequently, the output findings of the qualitative approach is represented and discussed in the following data findings and discussion chapter. Finally, based on the literature review, the quantitative analysis outputs, and the qualitative analysis findings, a recommendation section is developed in order to implement the LCCA in both organisations to reduce their projects' cost overruns during their life cycle.

4. Data Findings and Discussion

In this part of the dissertation, the collected data from the authorities mentioned within the research scope, and the data findings for the quantitative approach explained in the methodology section are presented. The outputs of survey 1 'Project General Information' and survey 2 'Investigated Variables' are shown and discussed by incorporating the outputs obtained from the SPSS program. In addition, the findings from the qualitative approach from the authorities' personnel involved in the research scope are presented and discussed too.

4.1. Quantitative Analysis Findings and Discussion

The output findings of the first survey shown in appendix 1 that involved obtaining general information about 13 projects conducted in the authorities mentioned in the research scope are summarised and shown in table 4.1. From this table, some important information that is beneficial for the purpose of the LCC studied in this research can be attained such as the life time of the asset, its allocated budget, and the cost overruns which occurred. It can be noticed that the life time of most of the assets is less than 30 years, and if their average is taken, the average life time of the projects involved can be considered as 15.2 years. Moreover, the budgets invested and allocated for these projects are huge and in millions. For instance, if the 13 projects' budget averages are summed, the total allocated budget of these projects can be estimated as AED349 million.

In addition, by doing further calculations, the cost overruns in these 13 projects can be obtained approximately. For example, by multiplying the percentage of the cost overrun of each project with its allocated budget, the amount of the project's cost overrun is found. Based on this, the project's cost overrun for each of the 13 projects is summed and the total cost overruns is estimated as AED27 million. From this, a note should be taken which is that the projects conducted in the authorities mentioned in the research scope are suffering from cost overruns where one or more of the involved stakeholders are being affected and paying extra money to overcome this problem. The percentage of the cost overruns of these projects is 7.7% (AED27 million) from the total allocated budget (AED349 million) which can be considered as high and contribute to cost overruns in millions since the investments of these authorities are in millions too. These authorities can use and invest the cost overruns that are estimated in millions of Dirhams in other future development projects.

Table 4.1 Summery of Project General Information

	Authorities Participated	Project Type	Asset Life time	Allocated Budget	Cost Overruns %	LCCA Applied	Estimation Includes
Telecom Operator	7						
Water and Electricity Authority	6						
Satellite		2					
Radio		3					
Infrastructure		8					
Less than 10 years			4				
10 - 20 years			5				
21 - 30 years			4				
More than 30 years			-				
Less than 10 million AED				2			
10 - 20 million AED				3			
21 - 30 million AED				1			
31 - 40 million AED				5			
More than 40 million AED				2			
0%					-		
< 5%					3		
5% - 10%					6		
11% - 15%					3		
More than 15%					1		
Yes						-	
No						13	
Initial costs							10
Initial, and Operation Costs							1
Initial, O&M Costs							2
Initial, O&M and Decommissioning Costs							-

Therefore, from the results presented in table 4.1 and the above mentioned analysis, both organisations studied in this research need to investigate the causes that contribute to the cost overruns in their projects. Questions need to be asked to the departments or personnel who planned and estimated the project life cycle cost of these projects such as (questions are not limited to the below only):

- Why did such costs occur?
- Why not the project's allocated budget cover such costs?
- How the costs involved in the project life cycle were estimated?

- Which phases of the project life cycle were included in the cost estimation during the planning phase of the project?

Some answers to the above questions can be found in table 4.1. For example, during the planning stage of these projects, the cost in most of the projects was estimated up to the initial phase of the project life cycle which includes only the design and implementation costs. This means that a significant attention and considerations are given to the project initial stage in these organisations. However, in few projects, the operation and maintenance costs were included in the project estimate. Based on that, it can be noted that one of the cost overruns' causes that occur in these organisations could be from the lack of estimating the project's costs involved in all the project life cycle phases shown in figure 2.2 (design and implementation, O&M, and decommissioning).

Consequently, in order to minimise the cost overruns, the management in both organisations needs to look for approaches to solve such problem and better methods to estimate the project's cost. Considering the LCCA, explained in the literature review, can be seen as a solution to reduce the cost overruns in the investigated organisations projects. From table 4.1, it was found that both organisations are not aware of the LCCA concept and did not use it in any of the projects. The LCCA helps to obtain the project's cost a long its life cycle. This could give awareness to the stakeholders about the costs involved in the project so they can allocate the budget, arrange the cash flows, and reduce the cost overruns during the project life cycle.

4.1.1. SPSS Tests' Results

As a continuation for the quantitative analysis, the project's initial cost, operation cost, maintenance cost, decommissioning cost, and the selection among the competing alternatives, as called in the second survey 'Investigated Variables', were investigated in the studied organisations. They were studied as independent variables in order to check if the dependent variable, percentage of cost overruns, depends or has a relation with them according to the literature review of the LCCA. As explained in the methodology section, the findings of the data obtained from the second survey where analysed using the SPSS software by conducting two tests which are the reliability and the correlation tests.

4.1.1.1 Reliability Test Results

In the reliability test, the questions, statements, or measures extracted from the literature to measure the studied independent variables such as the initial cost, operation cost, maintenance cost, decommissioning cost, and the project selection are examined. Mainly, the test is used to check if the determined measures can be set as representations of the independent variable. The Cronbach's alpha value is used in this test to evaluate if the measures used to represent the independent variable are valid and reliable as mentioned in the methodology section. As a start, the value of the Cronbach's alpha used in this test is set to 0.7. Then, the test is implemented to examine the reliability of the different measures representing the first independent variable 'Initial Cost'. These measures are the questions used for the initial cost part in the second survey shown in appendix 1. The obtained data from the survey for the measures related to the initial cost variable was analysed using the SPSS. The Cronbach's alpha value for these measures was found as shown in table 4.2 extracted from the SPSS. The value found is 0.811 which is an acceptable result since it is greater than 0.7. This means that the measures used to represent the initial cost variable is reliable and valid measures. In other words, the questions or the statements used to investigate the initial cost variable are significant and reliable.

Table 4.2 Reliability Statistics: Cronbach's alpha Value for the Initial Cost Measures

Cronbach's Alpha	N of Items
.811	11

After that, the same test was applied to examine the data findings of the measures of the second independent variable 'Operation Cost'. As can be seen from table 4.3 extracted from the SPSS, the obtained Cronbach's alpha value is 0.638. This result is considered unacceptable since it is less than 0.7.

Table 4.3 Reliability Statistics: Cronbach's alpha Value for the Operation Cost Measures

Cronbach's Alpha	N of Items
.638	6

However, the SPSS has a function called "Scale if item deleted" to check which measure or measures are insignificant and if removed will increase the Cronbach's alpha value. Hence, this function was used and the result obtained is shown in table 4.4. It can be noticed that if the OC3 measure, which is the indirect cost, is removed the value of the Cronbach's alpha will be 0.673. Still, this value is unacceptable; therefore, another measure should be excluded. The next measure which can increase the Cronbach’s alpha if deleted is OC4 which is the inflation rate. Table 4.5 shows the Cronbach’s alpha value result after excluding the OC3 and OC4 measures which is 0.702. Now, this result is acceptable since it is greater than 0.7. Consequently, the indirect cost and the inflation rate cannot be considered as measures for the overall operation cost independent variable in this research. Excluding both measures can be reasonable since in most of the tested projects the responses of considering the indirect cost and inflation rate in the projects were neutral and disagree respectively.

Table 4.4 Item-Total Statistics when Scale if Item Deleted Function is Used

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
OC1	14.3077	6.897	.410	.579
OC2	14.2308	6.692	.513	.534
OC3	14.3846	9.590	.060	.673
OC4	15.3077	7.064	.271	.653
OC5	14.8462	7.974	.369	.597
OC6	14.6154	6.923	.651	.500

Table 4.5 Reliability Statistics: Cronbach’s alpha Value for the Operation Cost Measures after Excluding OC3 and OC4

Cronbach's Alpha	N of Items
.702	4

Similarly, the same reliability test was performed on the rest of the independent variables maintenance cost, decommissioning cost, and the project selection in order to examine the validity of their measures. The Cronbach’s alpha value for each variable was determined and their results obtained from the SPSS are shown in tables 4.6, 4.7, and 4.8 respectively. It can be noticed that the Cronbach’s alpha value for all of the variables is greater than 0.7. Thus, the measures used to refer to these independent variables are considered as reliable representations and valid scales.

Table 4.6 Reliability Statistics: Cronbach’s Alpha Value for the Maintenance Cost Measures

Cronbach's Alpha	N of Items
.778	10

Table 4.7 Reliability Statistics: Cronbach's Alpha Value for the Decommissioning Cost Measures

Cronbach's Alpha	N of Items
.843	6

Table 4.8 Reliability Statistics: Cronbach's Alpha Value for the Project Selection Measures

Cronbach's Alpha	N of Items
.900	8

Consequently, from the reliability test, it was noticed that the measures used to represent the independent variables initial cost, operation cost, maintenance cost, decommissioning cost, and the project selection were considered accurate. Basically, these variables are considered the pillars used to determine the LCC of a project and help while selecting between competing projects. Their tested measures were obtained and extracted from the literature review conducted earlier. And since most of the obtained measures were reliable, the literature review conducted earlier can be considered reliable too since its findings were supported by the outcomes obtained from the SPSS reliability test. Furthermore, in order to further test the literature findings, a correlation test was performed.

4.1.1.2 Correlation Test Results

In this test, the relation between the dependant variable, which is the percentage of the cost overrun, with each of the independent variables separately is determined. For instance, it was found in the literature review that by considering the independent variables at an early stage of the project planning, the cost overruns can be reduced. Therefore, this test examined if the projects cost overrun's percentage in the organisations mentioned in the research scope rely on the independent variables. As stated in the methodology section, the significance level α is considered to be 0.05 in this test which means 95% confidence level. Moreover, the p value was used to check the correlation validity. For instance, if the p value of the independent variable test was greater than 0.05, there would be no statistical evidence of any correlation of the independent variable with the dependant variable. However, before conducting this test, each independent variable is represented by averaging its all measures except the operational cost variable. It is averaged after excluding the non reliable measures determined by the reliability test which were the indirect costs and the inflation rate.

Then, the correlation test was performed to measure the correlation of each independent variable separately with the percentage of the cost overruns as a dependent variable. The p value of each independent variable was found using the SPSS and the results are shown in table 4.9 at the Sig. (2-tailed) row. It can be noticed that the p values of all the independent variables, the initial cost, operation cost, maintenance cost, decommissioning cost, and the project selection, are greater than 0.05. This result means that there is no statistical evidence of any correlation between each of these independent variables with the percentage of the cost overruns. Due to this result, the data collection for other projects was stopped, and the study was limited to the pilot study (13 projects only) since the nature of the projects conducted in both organisations are similar. Therefore, there was no point to continue investigating other projects since the correlation test result will stay the same due to the similarity between the projects and some other reasons that will be explained shortly.

Table 4.9 Correlations Test Result

		% of the Cost Overruns	Initial Cost IndV	Operation Cost IndV	Maintenance Cost IndV	Decommissioning Cost IndV	Selection among Project's Alternatives
% of the Cost Overruns	Pearson Correlation	1	.061	.289	.425	-.407	.481
	Sig. (2-tailed)		.844	.338	.147	.168	.096
	N	13	13	13	13	13	13

***. Correlation is significant at the 0.05 level (2-tailed).**

**. Correlation is significant at the 0.01 level (2-tailed).

Basically, it was found that there is no correlation between the independent variables and the percentage of the cost overruns. This result could be contradicting with what was mentioned in the literature review section. For instance, in the LCCA, taking into consideration the independent variables during the estimation and planning stage of the project initiation would help reduce project cost overruns. Also, the reduction in cost overruns could occur if projects were selected based on LCCA. Therefore, there is a kind of correlations between these variables. However, the result obtained from the SPSS correlation test is contradicting due to the following reasons that can be considered reasonable:

- The studied projects were limited only to the two organisations mentioned in the research scope. Some of these projects were not disposed yet, and they are still running and operating. And, some of them were already disposed. This is due to the nature of the projects involved in these two organisations which is mainly infrastructure projects that require long life time to be disposed. Therefore, the obtained data might not be appropriate for the correlation test since the LCCA covers the period from initiating the project until disposing it.
- Most of the personnel involved in these projects, while filling the survey, stressed that they do not significantly consider the estimation of the operation, maintenance, and decommissioning costs. This would be an obvious reason that there was no correlation with the percentage of the cost overruns in these projects. Thus, the SPSS correlation test result was affected and been apposite to the literature finding.
- The project management concept is considered new to these organisations since they are not that old where they were formed in the 1980s. Also, the concept of the LCCA started in the 1970 where it was used for military purposes. The LCCA concept took some time until it proved its validity, and used as an approach in project management. As obtained from the survey results, both organisations do not consider the LCCA during the planning stage of the project. So, the LCCA concept is new to both organisations and they are not aware of it.

In addition, it can be noted from the correlation test that there was no correlation between the initial cost of the design and implementation and the cost overruns occurring in these projects. Even though both organisations do consider the initial cost adequately during the planning phase as shown in table 4.1, there are cost overruns that still occur. As supported by the literature review, this means that not only the proper planning of the initial cost can help to reduce cost overruns, but also the trade off with the other costs such as the operation, maintenance and disposal needs to be considered in order to reduce the overruns through the implementation of the LCCA. Therefore, there was no point to continue with the quantitative analysis due to the nature of the obtained results. Hence, there was a need to investigate the process of estimating projects' cost in these two organisations through conducting a qualitative analysis to tackle the issue. Also, this approach was required in order to check the possibility of implementing and integrating the LCCA into their planning and estimation process.

4.2. Qualitative Analysis Findings and Discussion

The results obtained by the correlation test from the quantitative approach were kind of disappointing since they were contradicting with the literature review findings about the relation between the LCC and the cost overruns. Therefore, in order to better understand how the LCC can help reduce projects' cost overruns in the Telecom Operator and the Water and Electricity Authority, a qualitative analysis was conducted. The aim of this approach was to understand how both organisations estimate the costs involved in the project life cycle phases illustrated in figure 2.2 which includes the design and implementation, operation and maintenance, and decommissioning. Personnel working and involved in projects from both organisations were interviewed to understand how projects were estimated. However, it was difficult to meet project's decision makers to evaluate how the selection among project alternatives was accomplished.

In the Telecom Operator Organisation, based on the conducted interviews, a development section is available which takes the responsibility of the first phase of the project life cycle; the design and implementation. Telecom cable infrastructure, radio, and satellite are types of the projects involved in this organisation. For instance, in these projects, a bottom-up estimation method is used to estimate the first phase of the project life cycle. The project team prepares a detailed design based on the project's requirements, then; all the activities involved in the project up to handing it over to the operation department are defined. Based on the defined activities, an initial estimate of the first phase could be established based on old records and similar previous projects that share the same activities if available. Moreover, a return on investment (ROI) is estimated based on a pre-defined rate and the number of users who will benefit from the project. After that, the initial estimate is presented to the management, and based on the validity of the project requirements, the initial estimate, and the ROI, a decision is made whether to invest in the project or not. Once the project is approved from the management, a tender is established to allow the bidders to quote for the project execution. Then, an evaluation is made to select the bidder who can satisfy the project's requirements based on the lowest cost.

The process in the other organisation, Water and Electricity Authority, can be considered similar to the Telecom Operator. Water pipes and electricity cables infrastructure are mainly the projects carried in this organisation. For instance, there is a department called projects which looks after the first phase of the project life cycle. This department receive the requirements from the asset section. Based on the requirements provided, the projects section calculates what is called ‘a rough estimate’ for the project based on, for example, the length and capacity of the pipes in order to get an idea about how much it will cost. Then, the project’s requirements are passed to a consultant who works for the projects section. The consultant prepares a detailed design for the concerned project, and makes a comparison about which type of piping and materials will suit the project environment. Then, in order to get a better estimate than the obtained earlier about the project cost, a Bill of Quantity (BOQ) rate list is used which are available from past records which includes the costing rates for all the material types and installation charges. After that, a tender is made to invite the bidders to apply for the tender. After conducting a ‘techno commercial evaluation’ for the bidders, a contractor is selected based on satisfying the technical requirements of the project and based on the lowest cost.

It can be noticed from the above findings of the interviews conducted in both organisations that both of them share the followings:

- A dedicated department or section exists which takes the responsibility of executing the project starting from the project initial requirements until delivering it ready for operation to the concerned stakeholder which is the operation and maintenance section.
- A detailed design, tasks, and activities are established to satisfy all project requirements. Also, an initial estimate is found by using old records of similar projects, however; the accurate estimate is obtained after the tendering stage. This estimate includes only the costs required for the project’s design and implementation (i.e. the first phase of the project life cycle)
- Based on a technical evaluation and the lowest cost among the bidders, the contractor is selected to execute the project.

It seems that both organisations are spending significant efforts on the first phase of the project life cycle (design and implementation). Also, the costs associated with this phase are estimated adequately by obtaining direct quotes from the contractors who are involved in the job. However, according to the interviews, even thought the initial estimate is found and the project budget is allocated based on that, there are still cost overruns affecting the allocated budget that occur during the project execution phase. The reasons behind the overruns were referred to the change in project requirements, resources allocation, uncertainties, underestimating some technical aspects, and unforeseen technical challenges.

In Addition, from the interviews discussion, both organisations have a department called operation and maintenance which look after the second phase (O&M) of the project life cycle shown in figure 2.2. Even though the personnel know that this phase is different from the first phase of the project life cycle, the costs of the O&M are not included during the planning stage for any specific project. There is a budget allocated for this department from the organisation in a yearly basis regardless of any project. In terms of operation, most of the executed projects are infrastructures which do not acquire a lot of efforts and costs to operate since most of the heavy works and costs are incurred during the first phase. Basically, the budget includes the cost of the engineers, workers, offices, IT services and the energy required at the stations. Also, the same staffs who are involved in operating one project might work for other projects depending on the work load.

Regarding the maintenance, it is also run by the O&M section, and its budget is treated in the same manner as the operation. The costs required for the maintenance phase for any project are not included while designing and planning that specific project. However, in most of the projects, there is a maintenance contract which handles the responsibility of maintaining the project from any defects to the contractor who implemented the project. Usually, these types of maintenance contracts are established for one year or more depending on the singed agreement between the organisation and the contractor. After the maintenance contract is over, the O&M handle the project by implementing corrective maintenance and planned periodic maintenance upon staff availability. If the project is kind of sophisticated and the section does not have the skills and expertise to handle it, the maintenance contract can be renewed for the contractor for additional period of time.

When the personnel of the O&M section were asked about their involvement during the planning stage of the project, it was found that in some cases they are involved in selecting the material type which can contribute to low maintenance during its life. However, they stressed that if the costs of the O&M could be included during the planning phase of the project, this can help giving them an idea about the costs and resources required for the implemented projects. The same can be forwarded to the organisation in order to include in the yearly budget since they are facing sometimes lack in the budget assigned for their section by the organisation.

Furthermore, the personnel referred to some points that could contribute to cost overruns such as, which not limited to the below:

- Due to the increasing number of the projects handled to the operation team, there is a shortage in the number of staff and other resources. This makes the team to work in double shifts and increase the overtime hours for them. Costs, which were not considered before, arise due to the increase in shifts and overtime to pay for the staff. Sometimes, extra costs are required to outsource operating the project when the work load on the O&M staff is to the maximum.
- Contractors are not being penalised if many faults occur in their system. For example, in the Water and Electricity Authority, contractors are allowed to apply for new projects tenders even though these contractors have some faults in previous completed projects. This happens because the projects section has no records about such contactors.
- Renewal of maintenance contracts since the contractors or suppliers keep asking for higher cost once they feel that O&M section is in need for them.
- In some cases, it is difficult to renew the maintenance contract due to technology discontinuity which shortens the operation of the project. For example, in the Telecom Operator, an access control system which connects most of the old premises of the operator is left to die.
- Few extra costs occur due to the currency exchange rate with foreign suppliers when ordering spare parts since the exchange rate cannot be fixed and guaranteed.

By keeping the situation the way it is in the O&M section in both organisations, cost overruns could continue contributing to a lack in the budget assigned for this section. In the Water and Electricity Authority, whenever the budget allocated for the O&M section is consumed, the section can ask the management for extra budget and they obtain it. This can be considered as impractical way since the overall organisation budget can be affected. Therefore, in order for the O&M section not to face or reduce the cost overruns, the costs involved in the O&M phase need to be included while planning the project from the beginning through implementing the LCCA.

The last phase of the project life cycle is the decommissioning stage. When the personnel at both organisations were asked about the cost estimation of this phase, the answer was negative. It was found that none of the organisations consider estimating the decommissioning costs of any project and they do not even think about it. Basically, the life of the assets in both organisations is very long since they are mainly infrastructure; therefore, the management do not bother itself to calculate such costs. However, in case of project disposal, the material (pipes or cables) used for that project is removed and kept in the store if it is still valid and can be used as spare parts in other projects. The costs associated with the removal of the material such as transportation, heavy equipments, engineers, workers, and energy are drawn directly from the organisation and they are not related to the project life cycle cost.

From the above findings of the qualitative approach, it can be noticed that there is no cost estimation associated with any conducted project from its initial phase until decommissioning it (i.e. there is no single record to track the project cost). The cost estimation is mainly done for the first phase of the project life (design and implementation) without considering the other two phases of the project life cycle (O&M and decommissioning). There is a yearly budget for the O&M section in both organisations regardless of the conducted projects. Assigning a yearly budget without considering the implemented projects could affect organisation budget by consuming more money due to cost overruns that keep occurring. Also, keeping doing that, the personnel involved in projects can be careless about the O&M of the projects since they can draw money from the organisation whenever they need to support their section needs. Therefore, in order to solve such problem, the management in both organisations need to create a record for each project separately in order to track how much each project requires in terms of money and resources. In the current scenario, the cost of each project is known up to the initial phase only and the O&M costs are not defined per project. Such record can be established by implementing LCCA from the start of any project, so the cost of each project can be estimated and included in the budget rather than asking the organisation each year for further funds to support the O&M phase every year. The LCCA concept and its benefits mentioned in the literature review section was proposed and explained to the personnel at both organisations. The concept was welcomed by most of the interviewed personnel; however, they stressed that management commitment is required to achieve such concept by integrating it to the current practises.

4.3. Summery

In this chapter of the research paper, the findings and discussion of the quantitative and qualitative approaches were presented. First, the quantitative approach was analysed by distributing survey 1 and 2 shown in appendix 1 to the organisations mentioned in the research scope: Telecom Operator and Water and Electricity Authority. The data for 13 projects was obtained and analysed. The findings from the first survey 'Project General Information' helped to give us a figure about:

- The average life time of the projects involved which is approximately 15.2 years.
- The total allocated budget for the 13 projects can be estimated as AED349 million.
- The project's cost overrun for each of the 13 projects was summed and the total cost overruns was estimated as AED27 million.

The projects conducted in the authorities mentioned in the research scope are suffering from cost overruns where one or more of the involved stakeholders are being affected and paying extra money to overcome this problem.

Next, the findings of the second survey 'Investigated Variables' were analysed using the SPSS by conducting two tests: the reliability test and the correlations test. In both tests, the initial cost, operation cost, maintenance cost, decommissioning cost, and the project selection were considered as independent variables while the cost overruns was considered as dependent variable. From the reliability test, it was noticed that the measures used to represent the independent variables were considered reliable. These measures were extracted from the conducted literature review. And since most of the obtained measures were reliable as obtained from the SPSS, the literature review conducted earlier can be considered as reliable. However, the result of the correlation test was not as the expected from the literature review. For instance, it was found in the literature review that by considering the independent variables at an early stage of the project planning, the cost overruns can be reduced. But, the result obtained from the SPSS showed that there is no statistical evidence of any correlation between each of the independent variables with the percentage of the cost overruns. The contradiction, between the literature review findings and the SPSS output, was attributed to some reasons associated to the studied organisations.

In addition, due to the result of the correlation test, there was a need to conduct a qualitative approach. The aim of this approach was to understand how the Telecom Operator and the Water and Electricity Authority estimate the costs involved in their project life cycle phases. It was noticed that the approach used by both organisations looks similar. A significant consideration is given to estimate the initial phase of the project (design and implementation) by establishing a detailed design, tasks, and activities. Then, the contractor who will be on charge for conducting the project is selected based on technical evaluation as well as based on the lowest cost. Even thought the initial estimate is found and the project budget is allocated based on that, there are still cost overruns affecting the allocated budget. Moreover, the other costs involved in the project life cycle such as the O&M and decommissioning are not considered during the estimation process. There is a section called O&M which has a yearly budget from the organisation regardless of any project. Therefore, there is no single record available to track the costs involved for a project from its initiation to its disposal. This could cause cost overruns during the O&M phase even though the O&M section can ask for more funds whenever they have a lack in their yearly budget. As expressed by the personnel involved in the projects, it is could be more practical to have a complete record for each project separately in order to evaluate which project yield to cost overruns in the O&M budget. The LCCA concept was proposed to the interviewed personnel, and they welcomed the idea. By implementing the LCCA, there will be a proper coordination between the development and projects sections in both organisations with the O&M section. This coordination could help establish a cost estimate for a project from its inception to its disposal. So, the organisation can maintain a budget for that project instead of creating yearly budgets for the sections. Thus, the cost overruns that may occur during the project life cycle could be reduced.

5. Conclusions and Recommendations

This part of the paper attempts to draw conclusions for the conducted research. The conclusions try to cover and summarise the main sections of the study and relate them to the objectives of the dissertation. Moreover, based on the study findings, a recommendations section is established in order to overcome the research problem.

5.1. Introduction

There is evidence that projects in some organisations are subject to cost overruns. Hence, this study aimed to reduce project's cost overruns of assets in U.A.E during its life cycle. The occurrence of the cost overruns affects the project's planned allocated budget by the organisation. And in order to solve such problem, one or more of the involved stakeholders are paying extra money to maintain the project. However, this study proposed a better solution in order to overcome the problem and to reduce project's cost overruns by adopting the life cycle cost analysis (LCCA) concept.

Therefore, a comprehensive literature review was conducted in order to explore how the LCCA can be used to estimate project's cost in order to reduce the overruns. It was found that the costs involved at each phase of the asset life cycle should be considered. For instance, the initial, O&M, decommissioning costs need to be included during the estimation process and to be investigated during the planning phase of the project. By indentifying such costs from the beginning, the organisation can allocate the adequate budget and maintain the cash flows during the project life cycle.

In addition, through the literature review, the selection among project's alternatives was identified based on the LCCA using two basic methods: 'Present Value' and 'Average Annual Cost'. Basically, the selection should be based on the lowest LCC of the project not on the lowest initial cost. It is the total life cycle cost of the project that needs to be minimised not its initial cost. Therefore, cost overruns can be reduced and future savings can be established.

Furthermore, the 'psychological', 'structural', and 'procedural' barriers facing the implementation of the LCCA were demonstrated. It was found that management commitment would be needed in order to overcome such barriers. For instance, some organisations used the LCCA have developed frameworks and software programs to implement the LCCA in their projects in order to benefit from its advantages.

In order to tackle the problem of project's cost overruns in U.A.E, two government organisations, Telecom Operator and Water and Electricity Authority, were investigated as mentioned in the research scope. The investigation was based on quantitative and qualitative research approaches as explained in the methodology. The aim of both approaches was to test the literature review findings, and to collect the necessary data from 13 real projects from both organisations.

By developing questionnaires based on the literature review findings, the quantitative approach helped to collect general information about the studied projects, and to conduct the reliability and correlation tests. It was found that in 13 projects only, the cost overruns were approximately estimated as AED27 million. Hence, there is a need to introduce new practices to both organisations such as the LCCA in order to reduce the cost overruns. Moreover, from the reliability test, it was noted that the measures, extracted from the literature, used to represent the initial cost, O&M cost, decommissioning cost, and the project selection independent variables were considered reliable. However, the correlation test failed where there was no statistical evidence of any correlation between each of the independent variables with the percentage of the cost overruns. The failure of this test was attributed to some reasons associated to the nature of studied projects as explained in chapter 4.

Consequently, a qualitative approach was needed in order to investigate the current practices at both organisations while estimating project's cost. It was observed that a significant consideration is given to estimate the cost of the initial phase only of the project. As supported by the literature, keeping the process the way it is at both organisations will contribute to cost overruns during projects life cycle. Moreover, the interviews used in the qualitative approach helped to identify some causes of the cost overruns in both organisations' projects life cycle such as:

- The Existence of decentralised departments.
- The selection among competing alternatives is based on the lowest initial cost.
- There is no complete record about any project's costs.
- The excess use of the O&M resources.
- There is no consideration for decommissioning costs.

Based on the literature review findings and the quantitative and qualitative research results, the possibility of implementing the LCCA to the Telecom Operator and Water and Electricity Authority is investigated in the following section by proposing a set of recommendations.

5.2. Conclusions

From the data findings and discussion chapter, it was noticed that the Telecom Operator and the Water and Electricity Authority organisations are facing cost overruns in their assets. The cost overruns occur through all the project life cycle: design and implementation, O&M, and decommissioning. For instance, the cost overruns in 13 projects only at both organisations were approximately estimated as AED27 million. Such amount could be simply invested in another project or used as a bonus (incentive) for the employees in both organisations. Based on the conducted qualitative study, the reasons behind the occurrence of the cost overruns in both organisations can be attributed to the following:

- The existence of decentralised departments. For instance, there is no single department that look after a project from its initial planning to its disposal. There exists a separate department for planning, and O&M. Also, there is no proper coordination between these two departments which could contribute to cost overruns during the life of the asset.
- The selection among competing projects is based on technical evaluation and the lowest initial cost. The technical evaluation is an important step; however, the selection needs to be based on the lowest LCC not on the lowest initial cost. For example, a low initial cost for an alternative even though it satisfies the project requirements could have higher costs over the asset’s life cycle especially during the O&M phase.
- There is no complete record about any project’s costs from its inception to its disposal. The budget of the O&M section is shared among all the organisation’s projects. This makes it difficult to track which project consumes more money and resources compared to others.
- The excess use of the O&M resources since there is no clear identification for the required resources of each project from the beginning of the project’s planning. For example, staff keeps asking for overtime, double shifts, or outsourcing.
- There is no consideration for the costs related to the decommissioning of an asset.

According to the above reasons, it seems that both organisations are suffering from cost overruns in their projects life cycle due to the improper considerations of the total project LCC during the planning phase of any project. In order to overcome such problem, there is a need to include the initial cost of the design and implementation, the cost of the O&M, and the decommissioning cost while planning any project. Including such costs can provide the concerned stakeholders awareness about the total cost required for a project. So, the adequate budget can be allocated and the cash flows can be maintained during the project life cycle. By achieving that, a complete record for each project's cost could be established.

5.3. Recommendations

Therefore, new practises should be introduced to both organisations in order for them to better estimate project life cycle cost, and to allocate its budget separately rather than sharing it with other projects which may yield to excess in the consumption of the organisation's budget. This research paper proposed the use of the life cycle cost analysis as a technique to estimate the project's cost and to decide among project's alternatives for both organisations. As supported by the literature review, the LCCA will help to estimate the overall project's cost, choose between competing projects, and evaluate investments among project alternatives (Woodward 1997).

By applying the LCCA to both organisations, the traditional way of selecting the project based on the lowest initial cost could be avoided. It is the total life cycle cost of the project that needs to be minimised not its initial cost. Moreover, the LCCA can help in achieving the trade-off between the three phases of the project life cycle. Even though both organisations consider significantly estimating the initial cost, there are cost overruns that still occur. As supported by the literature review, this means that not only the proper planning of the initial cost can help to reduce cost overruns, but also the other costs such as the O&M and disposal need to be considered in order to reduce the overruns through the implementation of the LCCA. The trade-off between the costs of the three phases could ensure that the project will yield to the minimum cost which can be seen as one of the organisation objectives. Based on the literature review findings, the reasons mentioned above behind the cost overruns in both organisations could be reduced by using the LCCA as shown in table 5.1.

Table 5.1. The main causes of the cost overruns in the Telecom Operator and the Water and Electricity Authority projects vs. the proposed LCCA technique solution

Cost Overruns Causes	How the LCCA could help reducing cost overruns causes
Existence of decentralised departments for the project development and the O&M.	- The LCCA will encourage the coordination between the project development section and the O&M section. - All the tasks and activities required for each phase of the project life cycle will be incorporated during the planning phase of the project. - The cost required for each phase of the project life cycle will be included during the planning stage of the project by converting the future costs to present value. - A budget will be allocated from the organisation based on the project LCC to cover the project's cost from inception to disposal.
Selection among competing alternatives or contractors is based on the lowest initial cost.	- The LCCA will ensure that project is selected based on the lowest LCC among the competing alternatives. - A long-term vision is established while investing in projects. - Ability to achieve organisation strategy by minimising the incurred costs throughout the project life cycle.
No complete record about any project's costs.	- LCCA could help creating a complete record for each project costs from its initiation to its decommissioning. - Cost overruns can be tracked easily for each project through the monitoring and comparison to the LCC established during the planning stage.
Excess use of the O&M resources.	- The recourses required during the O&M phase could be planned in advance during the planning stage of the project. - The direct and indirect costs of the O&M required recourses will be included in the LCC of the project during the planning stage.
There is no consideration for decommissioning costs.	- The decommissioning cost of the asset will be considered during the planning stage by converting its future costs to present value

Applying the LCCA concept to both organisations is not hard to implement. Most of the information required for such analysis is available. By using the past records of previous projects, the majority of the costing elements of the project life cycle could be obtained. However, one of the stakeholders needs to take the initiative to gather, coordinate, and distribute it to the other parties. For instance, the initial cost of any project can still be obtained in the same way it is done in both organisations, and by including some enhancements such as:

- Developing a detailed design, tasks, and activities to satisfy project requirements.
- Establishing a work break down structure that was not adopted before by both organisations based on the developed design.
- Obtaining direct quotes for the implementation of the initial phase from the different alternative bidders.
- Summing the cost of developing the design and the cost of implementation to represent the initial cost.

Moreover, the cost of the O&M phase can be established by:

- Identifying the recourses required for the project during that phase.
- Calculating the direct and indirect costs of the O&M resources. Both organisations need to allocate the costs of the recourses required for each project separately. It might sound difficult to obtain such cost; however, it is available. For example, the salaries and wages of the engineers and workers are known. Also, the cost of energy, stations, and IT services can be obtained from previous operated projects since most of the projects in these organisations look similar (infrastructure).
- Obtaining the cost of the spare parts required for maintenance from the applying bidders. Furthermore, training cost for staff can be obtained from the bidders instead of having maintenance contract every year. Basically, it is a matter of collecting the costs of the O&M phase dedicated for each individual project.
- Converting the O&M phase’s cost to present value using equation 2 mentioned earlier in the literature review. The discount rate can be obtained by the help of the organisation’s finance and accounting department under the consultancy of the Ministry of Economy in the country.

Finally, the cost of the decommissioning phase can be obtained based on:

- Previous disposed projects since almost most of the projects in both organisation are similar.
- Converting the decommissioning phase's cost to present value using equation 1 mentioned earlier in the literature review section.

After obtaining the initial cost, the present value of the O&M, and decommissioning phases' costs, all these costs are summed to give us the LCC of the project. The same above procedures needs to be done to obtain the LCC of the other competing alternatives. Then, based on the literature review findings, the alternative which has the lowest LCC should be selected which will contribute to the minimum cost during the asset life cycle. Based on the LCC, the asset budget can be allocated and maintained during its life cycle.

In order to implement such concept, management commitment would be needed in order to use the potential advantages of the LCCA technique during the planning phase. They can test the LCCA concept by implementing it on projects which last for less than 5 years to check the validity of the concept about reducing the cost overruns. If the concept gained their acceptance, it can be implemented to all the conducted projects. Furthermore, in order for the LCCA to achieve its objectives and to make sure that project's costs is according to the budget allocated by the organisation, cost monitoring and control techniques such as the earned value management discussed earlier should be implemented while running the project.

6. References

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7. <u>Appendix 1: Surveys</u>

Dear Sir/Madam,

I am a student in the Project Management Programme at the British University in Dubai, and I would gratefully appreciate your participation by filling in the enclosed questionnaires with your views. The aim of this questionnaire is to collect data required for an MSc dissertation titled "Life Cycle Cost Analysis as a Technique to Reduce Project's Cost Overruns of Assets in UAE: A Case Study-Based Research".

It has been observed that projects in many organisations are subject to cost overruns. There are some drawbacks in the cost estimation process and the selection method among alternatives during the planning phase. This may contribute to cost overruns during the life cycle of the project. This research tries to study and investigate how the life cycle cost analysis technique can be used as a method to better determine project's initial, operation, maintenance, and decommissioning costs (i.e. project life cycle cost) and to improve the selection method among project alternatives in order to reduce future cost overruns.

All the data provided from your side will be kept confidential and will be used and analysed for the purpose of the research investigation only. Your valuable response is highly appreciated and we are thankful for the time and effort you will spend to complete the survey.

Thanks and Regards,

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Survey 1: Project General Information

Please select one option only with respect to each particular project.

A) Authorities Participated:	
1) Telecom Operator	
2) Water and Electricity Authority	
B) Project Location:	
1) Abu Dhabi	
2) Dubai	
3) Northern Emirates	
C) Project Type:	
1) Satellite	
2) Radio	
3) Infrastructure	
D) Life Time of the Asset:	
1) Less than 10 years	
2) 10 - 20 years	
3) 21 - 30 years	
4) More than 30 years	
E) Allocated Budget for the Project:	
1) Less than 10 million AED	
2) 10 - 20 million AED	
3) 21 - 30 million AED	
4) 31 - 40 million AED	
5) More than 40 million AED	
F) The Percentage of the Cost Overruns:	
1) 0 %	
2) < 5%	
3) 5% - 10%	
4) 11% - 15%	
5) More than 15%	
G) Life Cycle Cost Analysis (LCCA) was used to estimate the Project's Costs	
1) Yes	
2) No	
H) The Estimated Cost of the Project Included:	
1) The initial costs [design, implementation and installation]	
2) The initial, and operation costs	
3) The initial, operation, and maintenance costs	
4) The initial, operation, maintenance and decommissioning cost	
I) What was the Estimation Method Used to Calculate the Project's Cost?	

Survey 2: Investigated Variables

Please select one option only with respect to each particular project.

Investigated Variables	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
A) Initial Costs					
1) The design cost had been estimated					
2) The implementation cost had been estimated					
3) The installation cost had been estimated					
4) The risk had been considered while estimating the project cost					
5) The life of the asset was identified					
6) The degree of information about costs involved was high					
7) Past records were used to estimate the project					
8) The quotes provided by contractors were guaranteed					
9) The stakeholders were aware of the estimated cost of the project					
10) The initial costs were monitored during execution & compared to the planned costs					
11) The procurement estimation was supervised by the operation and maintenance departments					
B) Operation Costs					
1) The cost of operation was estimated in the planning stage of the project					
2) The direct costs of labours, materials, expenses and overheads were included					
3) The indirect costs of the project were considered					
4) The inflation rate was considered while estimating the operation cost					
5) The operation costs were guaranteed by the supplier					
6) The operation estimation was supervised by the procurement and maintenance departments					

Investigated Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
C) Maintenance Costs					
1) The cost of maintenance was estimated in the planning stage of the project					
2) Preventive maintenance cost was considered in the estimate					
3) Corrective maintenance cost was included in the estimate					
4) Planned maintenance cost was considered in the estimate					
5) Direct costs of labour, material, power, and equipments were estimated					
6) Indirect costs of the project were estimated					
7) The inflation rate was considered while estimating the maintenance cost					
8) The maintenance costs were guaranteed by the supplier					
9) The initial costs were monitored during execution & compared to the planned costs					
10) The maintenance estimation was supervised by the procurement and operation departments					
D) Decommissioning Costs					
1) The cost of decommissioning was included in the estimate during the planning stage of the project					
2) The cost of discontinuing the service while decommissioning was considered					
3) The inflation rate was considered while estimating the decommission cost					
4) The decommissioning cost resulting from demolition, dislocation, or scrapping was considered					
5) The decommissioning value resulting from selling the asset was considered					
6) The decommissioning costs were monitored during execution & compared to the planned costs					

Investigated Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
E) Selection among Project's Alternatives					
1) The organisation had the skilled & experienced personnel to select among project's alternatives					
2) The organisation had the fundamental systems & tools to select among project's alternatives					
3) A trade-off was considered among the initial, operation, maintenance, & disposal costs					
4) The selection was based on the lowest estimated cost for the total costs of the initial, operation, maintenance, & decommissioning costs					
5) There was consideration of long term benefits among project's alternatives					
6) The selected project was considered the most valuable option among the project's alternatives					
7) Life cycle cost analysis (LCCA) was used in the process of evaluating different alternatives					
8) Present-value and/or average annual-cost methods was used to select among project's alternatives					