# Life cycle costing: an alternative selection tool

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**A B S T R A C T**

In today's complex business environment, both raising and application of fund becomes so costly. Thus, business needs to take a wise decision of investing funds in fixed facilities, which at one side consumes a lot of costly fund and on the other, set the value of the business. Net present value (*NPV*), pay back period (*PBP*), internal rate of return (*IRR*) are some widely used and customary tools in such situation most of which are based on projected revenues. In this paper, we have tried to use life cycle costing as a strong alternative, which considers every cost category throughout the life of the assets, from cradle to grave, to represent the effective use of funds in its totality. The theoretical foundation of LCC as a tool comes from literature review but the application of LCC in alternative choosing areas are the development of the authors. The use of mathematical tools and equations is an exemplary one that may be changed or modified to fit it with the typical context, if necessary. The paper can be a guideline which finally concludes that the use of life cycle costing as an alternative selection tool results a better cost structure analysis than others.

**Key Words:** Cost Breakdown Structure (*CBS*), Invisible Costs, Iceberg Effect, Affinity Diagram.

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## 1.0 INTRODUCTION

Automation has already proved as a technique of attaining long-term sustainability. So, most of the manufacturing processes are now being converted from manual to automation or started as automated one from the very beginning that necessitates a huge investment in fixed facilities. And aptly, fund management (*FM*) becomes a part of strategic planning. Life Cycle Costing (*LCC*) is a technique to establish the total costs of facility ownership that requires a lot of funds. It is a structured approach which addresses all the elements of cost related to any facilities and can be used to produce a spend profile of the facility over its anticipated life-span. The results of an *LCC* analysis can be used to assist management in the decision-making process when there is a choice of alternatives.

*LCC* analysis takes all costs of acquiring, owning, and disposing of a facility into account. It is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings or, in other words, minimizes costs. For example, *LCC* analysis will help to determine whether the incorporation of a high-performance *HVAC* or glazing system, which may increase initial cost but results in dramatically reduced operating and maintenance costs, is cost-effective or not. It is not intended to be useful for budget allocation. Lowest *LCC* is the most straightforward and easy-to-interpret measure of economic evaluation. Some other commonly used measures are Net Savings (or Net Benefits), Savings-to-Investment Ratio (or Savings Benefit-to-Cost Ratio), Internal Rate of Return, Payback Period, Net Present Value, Accounting Rate of Return, and Profitability Index etc. They are consistent with the Lowest *LCC* measure of evaluation if they use the same parameters and length of study period. Building economists, certified value specialists, cost engineers, architects, quantity surveyors, operations researchers, and others might use any or several of these techniques to evaluate a project. But, *LCC* is different in the sense that it gives importance on costs rather than benefits as at the very beginning we are assuming that all of the alternatives considered will generate similar or very near to similar benefits.

The article focuses on this important analytical tool for choosing the best economic alternatives. The very objective is to introduce the principles and practices of *LCC* to the purchasing officials and end users so that the maximum 'value for the money' used can be ensured. The methodology applied here is applicable to most purchasing decisions irrespective of complexity and volume of costs. It also explains the implications of *LCC* and how and where it should be applied, the methodology to use and sufficient information for departments to produce tailored instructions for incorporation into their own departmental *LCC* manuals.

## 1.1 Literature Review

Use of *LCC* analysis gets importance in practice than literature. It was strong in the 1960s when *LCC* was the subject of considerable interest and publications. Many original works on *LCC* are out of print. Newer publications are emerging such as: RMS Guidebook (SAE, 1995) for a life cycle cost summary, Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment (SAE, 1999) for introducing details on how equipment survives and how it is restored to operating conditions as a method for decreasing life cycle costs by way of both a strategy and tactics for how reliability tools, used up-front, can reduce costs and Life-Cycle Costing Manual for the Federal Energy Management Program NIST Handbook 135 (US Government, 1995) for background and methodology for US Government calculations along with annual supplements for discount factors (US Government, 2002).

*SAE* advocates reducing life cycle costs for equipment in the automotive sector by showing show/why reliability and maintainability must be included in upfront decisions for strategic and tactical issues of achieving the lowest long-term cost on ownership. *LCC* concepts are resurging with US Government efforts to minimize energy costs. In 1991, the Inter-modal Surface Transportation Equity Act suggested that *LCCA* be considered in the design and engineering of bridges, tunnels, and pavements. In 1995, the National Highway System (*NHS*) Designation Act mandated that States conduct *LCCA* on all high-cost projects (more than $25 million) constructed with Federal funding. In 1996, the Federal Highway Administration (*FHWA*) produced Demonstration Project 115, "Life-Cycle Cost Analysis in Pavement Design, and by July 2002 had brought these techniques to more than 40 State transportation agency pavement design groups. In 1998, the Transportation Equity Act for the 21st Century rescinded the *LCCA* mandate of the 1995 *NHS* Designation Act. States are no longer required to perform *LCCA*, but *FHWA* is directed to further develop the analysis methodology. Thus, in the same year, *FHWA* published its pavement *LCCA* Interim Technical Bulletin, *Life-Cycle Cost Analysis in Pavement Design.* Now, most of the organizations have their tailored *LCC* guidelines for ultimate use and present status of *LCC* analysis becomes stronger due to its legal interest and consideration.

### 1.2 Methodology

The paper highlights both the theory and practice of *LCC*. The basement or foundation of the paper originated from scholarly papers, articles, research works, conference papers, seminars and other published and non-published documents. And for documenting a generalized practice of *LCC* in reality, the authors give importance on critical analysis of some tailored *LCCA* guidelines. Most of the guidelines, as referred to, are from economically advanced countries and are used for such situations where fund involvement is so high. To the best knowledge of the writers, the use of LCC in our country is very rare and so we believe that it will be helpful for anybody who wants to use it. We have used a real life project example to illustrate the applicability of LCC. The methodology applied here will help the readers to design an independent *LCCA* guideline in a customized way to ensure the economic use of owners' funds.

## 2.0 LIFE CYCLE COST (*LCC*) DEFINED

*LCC*is the total cost of ownership of machinery and equipment, including its cost of acquisition, operation, maintenance, conversion, and/or decommission (SAE, 1999). *LC* is the summation of cost estimates from inception to disposal for both equipment and projects as determined by an analytical study and estimate of total costs experienced in annual time increments during the total economic life with consideration for the time value of money. The objective of *LCC*analysis is to choose the most cost effective approach from a series of alternatives to achieve the lowest long-term cost of ownership. *LCC*is an economic model over the project life span. Usually the cost of oper ation, maintenance, and disposal costs exceed initial costs many times over (supporting costs are often 2-20 times greater than the initial procurement costs). The best balance among cost elements is achieved when the total *LCC* is minimized (Landers, 1996) . As with most engineering tools, *LCC* provides best results when both engineering art and science are merged with good judgment to build a sound business case for action.

LCC as a technique takes into account of both initial design and acquisition costs and subsequent running costs and is measured over the asset's "effective life, generally its economic operating life. Although many LCC definitions exist, the majority excludes matters of revenue generated by the asset, other than taxation concessions and salvage value. Perhaps one of the better definitions describes LCC as the *"economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative expressed in equivalent dollars"* (Kirk & Dell'Isola, 1995). The Australian Standard AS/NZS 4536: 1999 provides a more generic definition; *Life Cycle Cost is the sum of the acquisition cost and ownership cost of a product over its life cycle".*

Terotechnology is another term often regarded as synonymous with LCC and comes from the Greek "terein , meaning to look after, and is generally defined as "a combination of management, financial engineering and other practices applied to physical assets in pursuit of economic life cycle costs (British Standards Institution, 1974). It is a "multi-disciplined approach to ensure optimum life cycle costs in the development and use of equipment and facilities and encompasses the management of assets from creation through to disposal or redeployment (British Department of Industry, Committee for Terotechnology, 1978). However, the FMA's Glossary of FM Terms 2nd Ed (Standards Australia reference HB-261: 2001) contains the definition of *Terotechnology as "the* *pursuit of the optimum technical and economic cost of ownership of a facility over its whole life span".*

The National Institute of Standards and Technology (NIST) Handbook 135, 1995 edition, defines *LCC* as "the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time.

The principles of *LCC* can be applied not only to complex items but also to the simplest one. For example, the purchase of pencils might appear a straightforward purchasing decision based on the lowest price offered by a supplier provided the quality requirement is met. However, the requirement is not necessarily for "pencils but a need for a writing implement whose impression can be erased. Therefore there are a number of options: for example, propelling pencils with lead refills which also incorporate an eraser, hence negating the need for a separate purchase of them. The options can be assessed using the principles of *LCC* and the most cost -effective option for a writing implement chosen. Although this may appear a trivial example, it makes the point that LCC principles apply to the majority of purchases.

Thus total *LCC* can be equated in the following manner;

| | | |
|---|---|---|
| Total life cycle cost (*LCC*) | = Initial asset acquisition / capital costs ($C_{ic}$) | *ADD* |
| | Installation and commissioning cost ( $C_{cc}$) | *ADD* |
| | Operating costs ($C_{oc}$) | *ADD* |
| | Maintenance and repair costs ($C_{mc}$) | *ADD* |
| | Downtime cost ($C_{dc}$) | *ADD* |
| | Replacement / disposal / upgrade costs ($C_{rc}$) | *Less* |
| | Tax depreciation entitlements ($R_{tr}$) | *Less* |
| | Residual / salvage value ($R_{sv}$) | |

Typical *LCC* $= Cic + Ccc + Coc + Cmc + Cdc + Crc - R_{tr} - R_{sv}$

## 2.1 The implication of *LCC* analysis

Historically, cost planning and control has focused only on initial capital costs relating to the acquisition or creation or construction of new facilities in terms of machine, building, equipment and product etc, rarely extending beyond the ultimate use and disposing of the facilities. But such costs constitute only the tip of the iceberg where the damaging portion of the iceberg relates to the bulk of other costs associated with life cycle costing for equipment and systems. The visible costs of any purchase represent only a small proportion of the total cost of ownership. Figure 1 gives a graphic representation using the “Iceberg Analogy and highlights the dangers of poor financial management if only the visible portion of costs are considered. If real ‘value for money’ is to be achieved, then today’s management must not only focus on initial capital costs, but also acknowledge the significance of operational costs (which can even exceed the capital costs of some items) and maintain continuous data collection without the inherent information loss over time. The adage, “it is unwise to pay too much, but it is also foolish to spend too little , is the operating principle of *LCC*.

**Insert Figure 1 here**

*LCC* is an important economic risk evaluation technique, for identifying, quantifying and analyzing all costs, initial and ongoing, associated with the ownership of any long-term facilities over its expected economic life. Car fleet operators have, for many years, evaluated total cost of ownership when considering car purchases because running and maintenance costs have a large impact on profitability and have to be budgeted into their total operation. In many departments, the responsibility for acquisition cost and subsequent support funding are held by different areas and, consequently, there is little or no incentive to apply the principles of *LCC* to purchasing policy. Therefore, the application of *LCC* does have a management implication because purchasing units are unlikely to apply the rigors of *LCC* analysis unless they see the benefit resulting from their efforts.

## 2.2 Application of *LCC* Analysis

*LCC* analysis can be used in any areas where the use of fund is required to get the ownership over long-term facilities. It is important that the specification of the facilities under consideration should be presented in performance terms rather than design detail. It should be sufficiently tight so that the facility fits the users' needs but not so explicit that it prevents negotiation and discourages the supplier from using expertise to propose innovation. Often the supplier knows more of the potential of the product than the user.

Additionally, the purchaser of replacement items should consider the *LCC* implications, particularly where the users' experience of operating the product may be relevant. A bad procurement decision in *LCC* terms should not be compounded by the purchase of more of the same purely through administrative inertia or for convenience.

For complex items the application of *LCC* techniques can have a major impact on the contractual negotiation process. For example, an *LCC* analysis should be under-taken to establish the cost-effectiveness of any warranty proposal.

Additionally, an incentive contract might be negotiated to the benefit of the customer if the results of an *LCC* analysis were available. The results allow the purchaser to apply many more imaginative contractual approaches to the benefit of the user.

For departments involved in the purchase of items designed specifically to meet their requirement, decisions in the design process should be evaluated in terms of *LCC* Trade -

offs between performance, cost and timescale involve many complex and related parameters, e.g. material cost, production rate, reliability and maintainability. It is only through the use of LCC techniques that meaningful trade-off decisions can be made. This provides designers and managers with a systematic approach to assessing the relevant design parameters. It has been shown that the greatest opportunity to reduce costs and improve performance is during the initial development phases. Funds spent during this time are relatively small in comparison with total system life costs. Nevertheless, decisions made at this time can have profound cost implications on procurement, operation and support costs.

### 2.3 Constituents of *LCC*

*LCC* simply stands for all costs related to any facilities from cradle to grave to facilitate the strategic decision making processes. In defining the costs in such a scenario, careful attention is required, at least, over the different cost categories as jotted down in Table 1.

**Insert Table 1 here**

Successful implementation of *LCC* analysis depends on the identificati on and groupings of all costs related to the facilities under consideration accurately. It is important to appreciate the difference between these cost groupings because one-off costs at t = 0 are sunk once the acquisition is made whereas recurring costs are time dependent and continue to be incurred throughout the life of the ownership of facilities. Furthermore, recurring costs can increase with time if the facility is liable to wear incurring subsequent increased maintenance costs.

Timing of incurrence of costs will affect the decision due to time value of money, inflation, cost of capital and other macro economic variables. Thus, *LCC* analysis presumes that the constituents (in terms of cost categories) are rightly identified with other relevant factors and macro economic variables.

## 3.0 THE METHODOLOGY OF CALCULATION OF *LCC*

*LCC* is based on the premise that to arrive at meaningful purchasing decisions, full account must be taken of each available option. All significant expenditure of resources, which is likely to arise as a result of any purchase decision, must be addressed. Explicit consideration must be given to all relevant costs for each of the options from initial consideration through to disposal. Here, we have tried to propose a 5-step process to decide over best alternative in a typical *LCC* environment.

### 3.1 Step 1: Cost Breakdown Structure (*CBS*)

*CBS* is central to *LCC* analysis. It will vary in complexity depending on the decision criteria. Its' aim is to identify all the relevant cost elements and it must have well defined boundaries to avoid omission or duplication. Figure 2 is an example of a *CBS* for a major acquisition and consists of many cost categories each with a variety of constituent parts. This can be simplified for a minor purchase as shown in Figure 3. If the cost categories are seems to be numerous and vague, the concept of affinity diagram may be used to categorize the costs as per different categories.

**Insert Figure 2 here** **Insert Figure 3 here**

However, whatever may be the degree of complexity, any *CBS* should have the following basic characteristics:

1. It must include all cost elements that are relevant to the option under consideration;

2. Each cost element must be well defined so that all involved have a clear understanding of what is to be included in that element;
3. Each cost element should be identifiable with a significant level of activity or major item of hardware or software;
4. The cost breakdown should be structured in such a way as to allow analysis of specific areas. For example, the purchaser might need to compare spares costs for each option; these costs should therefore be identified within the structure;
5. The *CBS* should be compatible, through cross-indexing, with the management accounting procedures used in collecting costs. This will allow costs to be fed directly to the *LCC* analysis;
6. For programs with subcontractors, these costs should have separate cost categories to allow close control and monitoring; and
7. The *CBS* should be designed to allow different levels of data within various cost categories. For example, the analyst may wish to examine in considerable detail the operator manpower cost whilst only roughly estimating the maintenance manpower contribution. The *CBS* should be sufficiently flexible to allow cost allocation both horizontally and vertically.

### 3.2 Step 2: Estimation of Costs

Having produced a *CBS*, it is necessary to determine the costs of each category as accurate as possible. These may be determined by using any one of the following methods:

**Known factors or rates:** These are inputs to the *LCC* analysis that have a known accuracy as per the accounting records of the entity. For example, if the unit production cost (*UPC*) and quantity are known, then the manufacturing cost can be calculated. Equally, if staff costs and equipment utilization are known, then the operator manpower cost (*OMC*) can be calculated [i.e. staff cost (per hour) × hours used per month].

**Cost estimating relationships (*CERs*):** These are derived from historical or empirical data. For example, if experience had shown that for similar items the cost of initial spares was 20 per cent of the *UPC*, this could be used as a *CER* for the new purchase. *CERs* can become very complex but, in general, the simpler the relationship the more effective the *CER*. The results produced by *CERs* must be treated with caution as incorrect relationships can lead to large *LCC* errors.

**Expert opinion:** Although open to debate, it is often the only method available when real data is not available. When expert opinion is used in an *LCC* analysis it should include the assumptions and rationale supporting the opinion.

### 3.3 Step 3: Set other macro economic variables

*LCC* analysis needs careful consideration of some other critical variables for taking the most accurate decision like discounting rate, inflation etc. The money expensed today and the money that will be expensed 1 year later is not the same. The value depends on some factors that are embedded in national and international economic structure. In literature these issues are discussed in terms of time value of money where the value of money is adjusted with time period. For such adjustment, we use a rate that is called discount rate. At this point, we have to set such rates considering other factors that affect the rate.

**Discounting**

Discounting relates to the value of money over time. When comparing two or more options, a common base is necessary to ensure fair evaluation. As the present is the most suitable time reference, all future costs must be adjusted to their present value. To make cash flows time-equivalent, the *LCC* method converts them to present values by discounting them to a common point in time, usually the base date. Discounting refers to the application of a selected discount rate such that each future cost is adjusted to present time i.e. the time when the decision is made. Discounting ensures a level playing field for all available alternatives so that the best alternative can be chosen in an unbiased economic situation irrespective of economic status. The interest rate used for discounting is a rate that reflects an investor's opportunity cost of money over time, meaning that an investor wants to achieve a return at least as high as that of her next best investment.

The procedure for discounting is straightforward and discount rates for government purchases are published. Discount rates used by industry will vary considerably and care must be taken when comparing *LCC* analyses, which are commercially prepared to ensure a common discount rate, is used. In *OMB* and *FEMP* studies, all annually recurring cash flows (e.g., operational costs) are discounted from the end of the year in which they are incurred; in MILCON studies they are discounted from the middle of the year. All single amounts (e.g., replacement costs, residual values) are discounted from their dates of occurrence. The rate, in most of the times, reflects the cost of capital of the respective entity for which the decision is going to be taken. It may be the bank rate, may be the call money rate, and may be the bank deposit or advance rate, which depends on the type of funds used.

**Inflation**

It is important not to confuse discounting and inflation. The Discount Rate is **not** the inflation rate but is the investment “premium  over and above inflation. Provided inflation for all costs is approximately equal, it is normal practice to exclude inflation effects when undertaking *LCC* analysis.

However, if the analysis is estimating the costs of two very different facilities with differing inflation rates, for example oil price and labor-hour rates, then inflation would have to be considered. However, one should be extremely careful to avoid double counting of the effects of inflation. For example, a vendor's proposal may already include a provision for inflation and, unless this is noted, there is a strong possibility that an additional estimate for inflation might be included.

An *LCCA* can be performed in constant dollars or current dollars. Constant-dollar analyses exclude the rate of general inflation, and current-dollar analyses include the rate of general inflation in all dollar amounts, discount rates, and price escalation rates. Both types of calculation result in identical present-value life-cycle costs.

**Cost Period(s)**

Period refers to the time period for which the intended assets or facilities are going to be used. In other words, period may be traced in relation to the incurrence of costs. Simply, period is the total life span. It is a combination of study period and service period.

**Study period**: The study period begins with the base date, the date to which all cash flows are discounted. The study period includes a planning/ construction/ implementation period and the service or occupancy period. The study period has to be the same for all alternatives considered.

**Service period**: The service period begins when the completed building is occupied or when a system is taken into service. This is the period over which operational costs and benefits are evaluated.

### 3.4 Step 4: Computation of *LCC* through *LCC* equation

As defined earlier, *LCC* is the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system or any other facilities over a period of time. Keeping this definition in mind, one can breakdown the *LCC* equation into the following three variables: the pertinent **costs** of ownership, the period of **time** over which these costs are incurred, and the **discount rate** that is applied to future costs to equate them with present day costs.

The first component in a *LCC* equation is cost. There are two major cost categories by which projects are to be evaluated in a *LCCA*. They are initial expenses and future recurring expenses. **Initial Expenses** are all costs incurred prior to occupation of the facilty at t = 0. **Future Expenses** are all costs incurred after occupation of the facility.

Defining the exact costs of each expense category can be somewhat difficult since, at the time of the *LCC* study, nearly all costs are unknown. However, through the use o f reasonable, consistent, and well-documented assumptions, a credible *LCCA* can be undertaken.

One should also note that not all of the cost categories are relevant to all projects. The analyst is responsible for the inclusion of the pertinent cost categories that will produce a realistic *LCC* comparison of project alternatives. If costs in a particular cost category are equal in all project alternatives, they can be documented as such and removed from consideration in the LCC comparison.

The second component of the *LCC* equation is time, which is a combination of study and service period as defined earlier. The third component in the *LCC* equation is the discount rate. The **discount rate**, as defined by Life Cycle Costing for Design Professionals, 2nd Edition, is "the rate of interest reflecting the investor's time value of money. Basically, it is the interest rate that would make an investor indifferent as to whether he received a payment now or a greater payment at some time in the future.

The discount rate may be real or nominal one. The difference between the two is that the **real discount rate** *excludes* the rate of inflation and the **nominal discount rate** *includes* the rate of inflation. This is not to say that real discount rates ignore inflation, their use simply eliminates the complexity of accounting for inflation within the present value equation. The use of either discount rate in its corresponding present value calculation derives the same result.

The equation that we have derived here for computing the total *LCC,* considering maximum factors, is

$$Total\ LCC = One - Off_{t=0} + \int_0^T (\mathrm{Re}curring\ Cost)dt - Disposal\ Cost_{t=T} \ \ldots\ldots\ldots\ldots\ldots \text{(eq. 1)}$$

Equation 1 can further be simplified if recurring cost is classified into fixed and variable portion as follows:

$$Total\ LCC = One - Off_{t=0} + \int_0^T (Fixed + Variable)dt - Disposal\ Cost_{t=T} \ \ldots\ldots\ldots\ldots\ldots \text{(eq. 2)}$$

Equation 2 will only be useful if recurring cost can be classified into fixed and variable portion. If this is not possible due to the complexity of cost behavior, equation 1 will be applicable. The equations have three elements. First element considers one-off cost expensed at the time of acquisition (at t = 0) of the facility. Second element deals with recurring cost, may be total or classified, that are accumulated throughout the economic life of the facility without considering the time value of money. If information required for discounting is not available or if it reveals that the use of such information will not produce different result, then this cost element will be considered in this simple way. Because, this will retain the usability of *LCC* so simple and may increase the s cope of using it. And the final component focuses on disposal cost that in most of the cases results savings of costs in the form of salvage value (at t = T, where T represents the last year of using the facility). Thus, the equation will consider the total costs of holding a facility from cradle to grave.

The results that equation 2 derives can again be considered for discounting if the application of time value of money becomes mandatory. One-off cost in our case represents the current cost which requires no discounting. But, we need to discount the recurring and disposal costs, as these costs will incur in future. If we have data regarding the time of occurrence and the discount rate we can easily use equation 4 to discount a future amount to the current period costs. Equation 4 is derived as follows:

1. Let present value = P, interest rate i = 5%, time = t years, future value F =?

To compute the future value (F), we have go for a differential equation. To this end, please note that the rate of increase, Tk. 5 per year, has (Taka / year) as its unit of measurement. If this rate continued for *dt* years, where *dt* therefore has (years) as its unit of measurement,

Then, 5(Taka / year). *dt* years = 5 *dt* Taka.

So *5 dt* Taka represents the change in the amount in time *dt* years. Calling this change in amount in to the account is *dy*, and we write the differential equation as follows:

$$\frac{dy}{dt} = 5 \text{ (Constant), Which is the slope of a straight line.}$$

Implies $\quad dy = 5\, dt$

Now to derive the general solution of the differential equation;

$dy = (Interest\ Rate)(Present\ Value).\, dt$ $\quad$ [$dy$ = change of amount after t years]

$\Rightarrow dy = 0.05\,(P).\, dt$ $\quad$ [Assuming 5% interest rate and present value is P]

$\Rightarrow \int dy = \int 0.05\,(P).dt$

$\Rightarrow y = 0.05(P)\, t + C$ ……………………………………………………(eq. 3)

As (Interest rate).(Principal Amount) is a constant term, it will not effect the integration. The mode of thinking just illustrated is precisely only when the rate functions is linear. This is the general solution.

2. To derive the particular solution;

Let the present value of the amount when t = 0 be

$y = P$

$\therefore P = 0.05(P).0 + C$

$\Rightarrow C = P$

Hence, the particular solution is;

F= $y(t) = 0.05(P)\, t + P$ ……………………………………………………(eq. 4)

### 3.5 Step 5: Select the Alternative

The decision rule in *LCCA* is very simple. The alternative that results the lowest amount as LCC in step 4 will be chosen. If more than one alternative produces same results, then indifferent situation comes when other qualitative factors may be used for final decision.

## 4.0 A HYPOTHETICAL EXAMPLE OF LIFE-CYCLE COST ANALYSIS (*LCCA*): DETERMINISTIC APPROACH

Presented here is an example of a deterministic LCCA comparing two alternative project strategies.

Alternative 1: Purchasing of a new Hi-Lux pick up van.

Alternative 2: Hiring of a Hi-Lux pick up van.

**Assumptions:** To make the example suitable for LCCA, let us assume the following issues:

1. Each alternative will supply the same level of performance or benefits;
2. The vans will run for 100 miles a day during the project work throughout the country;
3. The project lasts for 5 years and both of the vans will serve for these periods when the company enjoys the full authority over the equipment and develop their own facilities for smooth operation;
4. Discount rate in this case is assumed to be minimum, say 5 percents.

### 4.1 Step One: Cost Breakdown Structure

As per our discussion, *LCCA* starts with a detailed cost break down structure. Here, we have accumulated all costs relating to the alternatives under consideration and classified accordingly (Table 2).

**Insert Table 2 here**

One-off costs are sunk (except disposal costs) once the acquisition is made. But recurring Costs are time dependent and continue to be incurred throughout the life of the project. Also, recurring costs contain two types of cost: fixed cost for the year and variable cost.

Fixed costs are fixed charges like salary, insurance premium etc. But, variable costs vary on mileage covered in this case like fuel & consumables, spares etc.

### 4.2 Step Two: Estimation of Costs

In this stage, costs are attached as per the identified cost categories in step one. Disposal cost category is the exceptional one, which generates revenue in terms of salvage value. Thus, disposal cost shows a negative value (revenue) that reduces the total life cycle costs.

**Insert Table 3 here**

### 4.3 Step Three: Other macro economic Variables- Time value of money.

Most of the macro economic variables are identified in the form of assumptions. The life of the project will be 5 years with a discount rate of 5%. It is assumed that the project is independent of inflation. So, inflation rate is not considered here at all.

### 4.4 Step Four: Computation of LCC through LCC equation

**Total LCC calculation for Alternative 1:** *Puchasing of a New Hi -Lux Pickup Van*

Let us find out the required information for alternative 1 to fit into equation 2 for computing total LCC. One-off cost amounts to Taka ***2,582,700.00*** as per computation. Taka is the local currency of Bangladesh. Now, we need to classify the recurring costs into fixed and variable. As per the computation in Table 4 Recurring cost (fixed + variable per year) is expected to be at the rate of 314 + 339t thousand taka per year at time t year. The expected disposal value (resale value) of the van after 5 years is supposed to be Taka 1,250,000.

**Insert Table 4 here**

Now, we have all required information for putting into the *LCC* equation. So, let us calculate the total amount of LCC by solving the equation.

$$Total\ LCC = One - Off_{t=0} + \int_{0}^{T} (Fixed + Variable)dt - Disposal\ Cost_{t=T}$$
$$= 2{,}582{,}700 + \int_0^5 (314 + 339\,t)\,dt - 1{,}250{,}000$$
$$= 2{,}582{,}700 + \left[ 314\,t + \frac{339\,t^2}{2} \right]_0^5 - 1{,}250{,}000$$
$$= 2{,}582{,}700 + \left[ 314\,(5) + \frac{339\,(5)^2}{2} - 0 \right] - 1{,}250{,}000$$
$$= 2{,}582{,}700 + [1570 + 4237.5] - 1{,}250{,}000$$
$$= 2{,}582{,}700 + [5807.5] - 1{,}250{,}000$$

Now recurring and disposal costs can be discounted by using the equation as derived for the purpose (equation 4).

$y(t) = 0.05(P)\,t + P$ , Where t = 5 years and y = 5807.5 for discounting recurring costs

5807.5 = 0.05 (P) 5 + P

5807.5 = P(0.25 + 1)

P = Taka 4646 thousand

And for discounting disposal costs, we may again use the same equation by changing the information only. Then,

1250 = 0.05 (P) 5 + P

1250 = P (0.25 + 1)

P = Taka 1000 thousand.

Thus total LCC at present value will be,

Taka (2,582,700 + 4,646,000 – 1,000,000) = Taka 6,228,700

**Total LCC calculation for Alternative 2:** *Hiring of a Hi-Lux Pickup Van*

Let us find out the required information for alternative 2 to fit into equation 2 for computing total LCC as we have done for alternative 1. Total one-off cost amounts to Taka ***507,700*** as per computation. Now, we need to classify the recurring costs into fixed and variable. As per the computation in Table 5, recurring cost (fixed + variable per year) is expected to be at the rate of 852 + 291.84t thousand taka per year at time t year. The van will run for 5 years and will have no disposal value, as the van was a hired one.

**Insert Table 5 here**

Now, we have all required information for putting into the *LCC* equation. So, let us calculate the total amount of LCC by solving the equation.

$$Total\ LCC = One - Off_{t=0} + \int_0^T (Fixed + Variable)dt - Disposal\ Cost_{t=T}$$

$$= 507{,}700 + \int_0^5 (852 + 291.84t)\,dt$$

$$= 507{,}700 + \left[852t + \frac{291.84t^2}{2}\right]_0^5$$

$$= 507{,}700 + \left[852(5) + \frac{291.84(5)^2}{2} - 0\right]$$

$$= 507{,}700 + [4260 + 3648]$$

$$= 507{,}700 + [7908]$$

Now recurring costs can be discounted by using the equation as derived for the purpose (equation 4).

$y(t) = 0.05(P)t + P$ , Where t = 5 years and y = 7908 for discounting recurring costs

7908 = 0.05 (P) 5 + P

7908 = P (0.25 + 1)

P = Taka 6326.4 thousand

Thus total LCC at present value will be, Taka (507,700 + 6,326,400) = Taka 6,834,100

## 4.5 Step Five: Analyse the result

The results of both alternatives at present value are presented in Table 6 below for a comparative view.

**Insert Table 6 here**

Alternative 1 has more one-off cost (purchase equipment and purchase activities cost) compared to alternative 2. On the other hand, alternative 2 has more recurring costs compared to alternative 1. Total LCC for alternative 1 is less than alternative 2 but consists more management activities and close supervision. In contrast, alternative 2 has less management activities, which indicates that the company if it wants to avoid purchase activities cost may go for alternative 2 and hired not only the car but also the tension free operation. Thus LCC gives us a total picture of costs of owning a facility. We can forecast the involvement of costs throughout the life in advance. We also enjoy the option of subjective or qualitative judgements when most of the alternative produces very close results.

## 5.0 CONCLUSION

The acquisition cost of a facility can often represent only a small proportion of the total cost of ownership. Generally, operating and maintaining the facility will form the major part of the total cost. However, purchasing decisions are normally made on the acquisition price - the longer-term costs being ignored. True value for money can only be achieved when the total cost of ownership is known and considered at the very beginning. Whilst *LCC* certainly has its limitations, its benefits in terms of greater certainty in the formulation of optimal design solutions, materials selection, budgetary planning, long term cost control and a framework for functional performance measurement cannot be overlooked. *LCC* assists procurement managers to identify the most cost effective whole of life decision for new and existing facilities, and combined with the potential savings can pay for itself. A structured *LCC* framework utilizing proper research, sensitivity analyses and probity audits provides an invaluable fund management (*FM*) tool for the facility design, delivery and operational decisions and achievement of long-term sustainability.

**REFERENCES**


American Society for Testing and Materials, 1994. Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems. Philadelphia: ASTM.

Alphonse, J. D., 1997. Value Engineering: Practical Applications for Design, Construction, Maintenance & Operations. Kingston MA: R.S. Means Company, Inc.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. 1989. Energy efficient design of new buildings except low-rise residential buildings. United States: ASHRAE.

Ballesty, S., Orlovic, M., 2004. Lifecycle costing and facility management. Facility Management 12 (2), 28-32.

Ballesty, S., Orlovic, M., 2004. Life Cycle Costing and Facility Management. FM Magazine 12 (2).

British Department of Industry. (1978). Terotechnology Handbook. Her majesty's Stationery Office.

Dell'Isola, A. J., 1997. Value Engineering: Practical Applications for Design, Construction, Maintenance & Operations, Kingston MA: R.S. Means Company, Inc.

Department of Sport and Recreation, 2004. Asset management guide: a guide for sport and recreation facility owners and managers. Perth, Western Australia: Department of Sport and Recreation.

Harold, E. M., Rosalie, T. R., 1980. Simplified Energy Design Economics. NBS SP 544. Washington, DC: National Bureau of Standards.

ISO 14040, 1998. Environmental Management-Life Cycle Assessment Framework.

Kirk, S. J., Dell'Isola, A. J., 1995. Life Cycle Costing for Design Professionals. McGraw Hill, Inc. (USA).

Landers, R. R., 1996. Product Assurance Dictionary, Marlton Publishers, 169 Vista Drive, Marlton, NJ 08053.

NSW Department of Public Works, 1992. Total Asset Management Manual.

Rosalie, T. R., Harold, E. M., 1990. Building Economics: Theory and Practice. New York: Van Nostrand Reinhold.

Sieglinde, K. F., Stephen, R. P., 1996. Life Cycle Costing Manual for the Federal Energy Management Program. NIST Handbook 135.Washington: U.S. Government Printing Office.

Stephen, J. K., Alphonse, J. D., 1995. Life Cycle Costing for Design Professionals. McGraw- Hill, Inc.

U.S. General Services Administration, 2003. Facilities Standard for the Public Buildings Service.

United States Government: Sieglinde, K. F., Stephen R. P., 1995. Life-Cycle Costing Manual for the Federal Energy Management Program, NIST Handbook 135, available on the internet at http://www.bfrl.nist.gov/oae/publications/handbooks/135.pdf.

United States Government: Sieglinde, K. F., Stephen, R. P., 2002. Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – April 2002 [Annual Supplement to NST Handbook 135 and NBS Special Publication 709], available on the internet at http://fire.nist.gov/bfrlpubs/build02/PDF/b02017.pdf.

Society of Automotive Engineers (SAE), 1999. Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment, M-110.2Warrendale, PA.

Society of Automotive Engineers (SAE), 1995. *"Life Cycle Cost"*, Reliability, Maintainability, and Supportability Guidebook, 3rd edition. Warrendale, PA.

Standards Australia, 1999. Life cycle costing: an application guide. (ANZS & NZS 4536: 1999). Sydney, New South Wales: Standards Australia.

Sieglinde, F., Petersen, S. R., 1995. *Life-Cycle Costing Manual for the Federal Energy Management Program*. NIST Handbook 135. National Institute of Standards and Technology.

Wolter, J. F., Benjamin, S. B., 1991. Life-Cycle Cost and Economic Analysis. Englewood Cliffs. NJ: Prentice Hall.

Whitestone Research, 2004. *Building Maintenance and Repair Cost Reference*.

Sieglinde, K. F., Amy, S. R., Laura, I. S., 2005. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis, Annual Supplement to Handbook 135*.

NISTIR 85-3273-19. Gaithersburg, MD: National Institute of Standards and Technology.

Thuesen, G. J., Fabrycky, W. J., 1993. Engineering Economy. Prentice Hall.

**List of Tables and Figures**

**Figure 1: Total Cost Visibility – the iceberg effect**

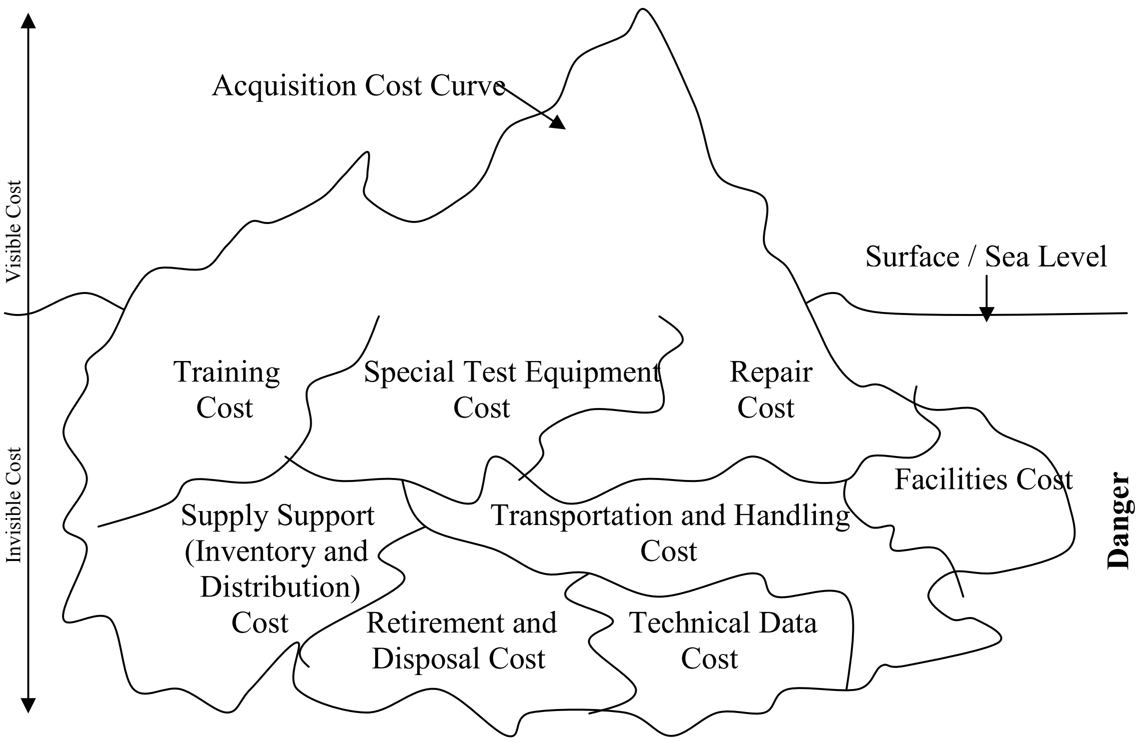
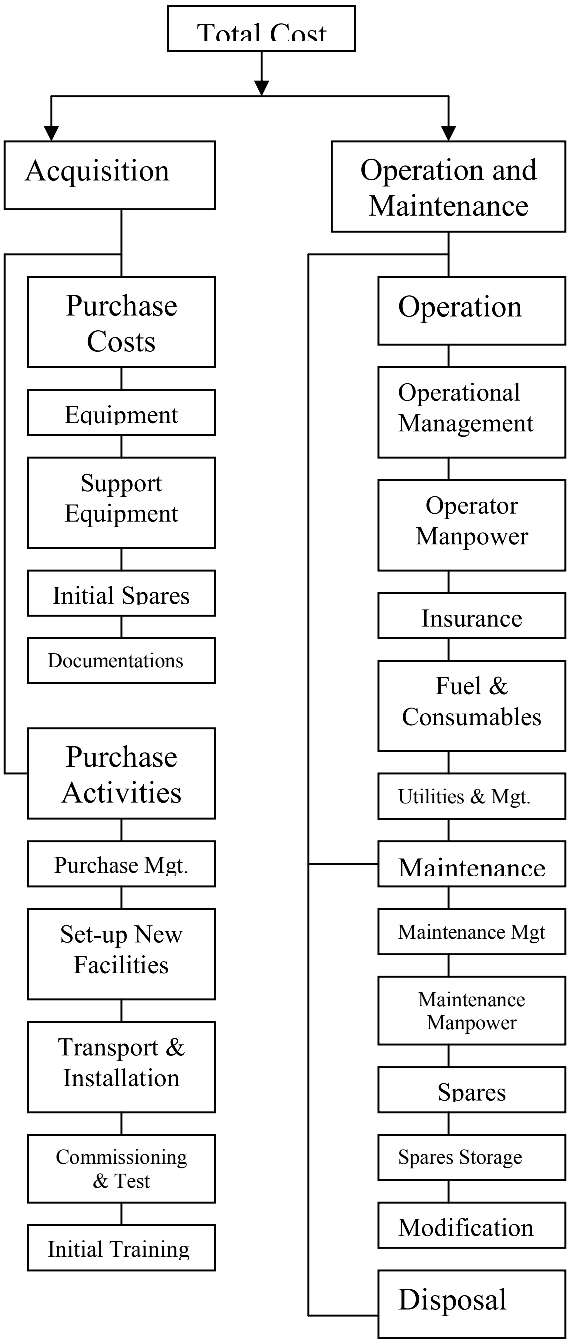



**Figure 2:**

**Major Project Cost Breakdown Structure**

**Figure 3:**

**Minor Project Cost Breakdown Structure**



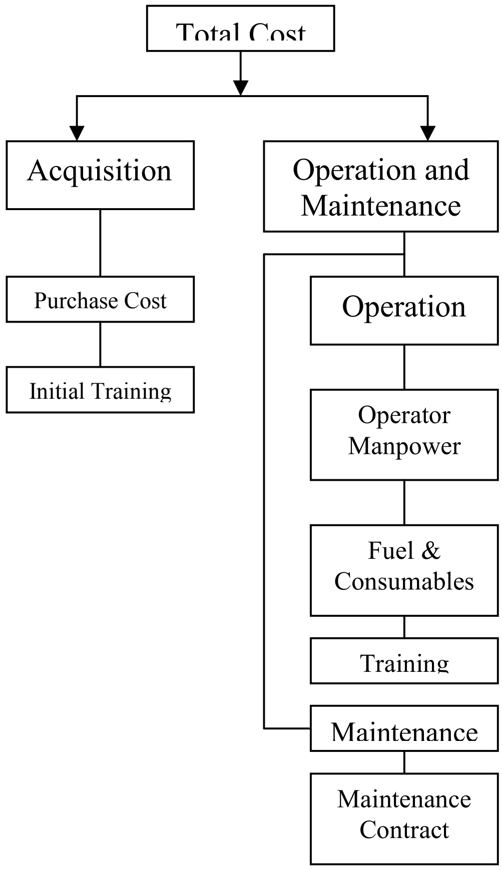




**Table 1: Cost Components as per Categories**

| **Categories** | **Period** | **Cost Components** | **Sub Categories** | **Cycle Cost** |
|---|---|---|---|---|
| One-Off | t = 0 | Purchase management + set up + documentation + transportation & installation + commissioning + initial training **ADD** | Purchase Activities Costs | |

| | | | | |
|---|---|---|---|---|
| | | Equipment + Support Equipment + Initial Spares | Purchase Costs | |
| | t = n | Cost of Disposal – scrap or salvage value realized | Disposal Costs | |
| Recurring | t = 1–n | Operational management + operator manpower + insurance + fuel and consumables + utilities **ADD** | Operational Costs | |
| | | Maintenance management + maintenance manpower + spares + spares storage + modification | Maintenance Costs | |

**Table 2: Cost Break Down Structure**

| | | | | |
|---|---|---|---|---|
| **Total LCC** | Purchase Mgt. + Set up new Facilities + Documentation + Transportation & Installation | = | **Purchase Activities Cost** | **One – Off Costs** |
| | Equipment + Support Equipment + Initial Spares | = | **Purchase Cost** | |
| | Salvage Value (net -ve) | = | **Disposal Cost** | |
| | Operational Mgt + Operator Manpower + Insurance + Fuel & Consumable + Utilities | = | **Operational Cost** | **Recurring Costs** |
| | Maintenance Mgt + Maintenance manpower + Spares + Spares Storage + Modification | = | **Maintenance Cost** | |

**Table 3: Estimation of Costs as per CBS**

| Elements of Costs as per CBS | | | | **Alternative 1** *Purchasing of a New Hi-Lux Pickup Van* | **Alternative2** *Hiring of a Hi-Lux Pickup Van* |
|---|---|---|---|---|---|
| **Total LCC** | **One-off Cost** | Purchase Activities Cost | Purchase Mgt | 2,700.00 | 2,700.00 |
| | | | Set up new facilities | 500,000.00 | 500,000.00 |
| | | | Documentation | 105,000.00 | - |
| | | | Transportation & Installation | 5,000.00 | - |
| | | | | | |
| | | Purchase Cost | Equipment | 1,950,000.00 | - |
| | | | Support Equipment | 15,000.00 | 5,000.00 |
| | | | Initial Spares | 5,000.00 | - |
| | | | | | |
| | | Disposal Cost | Salvage Value (-ve) | (1,250,000.00) | - |
| | | **Total One-off Cost (excluding disposal cost)** | | **2,582,700.00** | **507,700.00** |
| | | | | | |
| | **Recurri** | Operational Cost (Per year) | Operational Mgt | - | 720,000.00 |
| | | | Operator Manpower | 132,000.00 | 132,000.00 |
| | | | Insurance @1st 3 years | 75,000.00 | - |
| | | | Insurance @ last 2 years | 20,000.00 | - |

| | | | | | |
|---|---|---|---|---|---|
| | | | Fuel & Consumable | 272,250.00 | 272,250.00 |
| | | | Utilities | 18,600.00 | 18,600.00 |
| | | | | | |
| | | Maintenance Cost (Per year) | Maintenance Mgt | 15,000.00 | - |
| | | | Maintenance Manpower | 120,000.00 | - |
| | | | Spares @ 1st 3 year | 25,500.00 | - |
| | | | Spares @ 2nd 2 year | 50,00000 | - |
| | | | Spares Storage | - | - |
| | | | Modification | 3,000.00 | - |

**Table 4: Break down of recurring costs into fixed and variable for alternative 1**

| | |
|---|---|
| **Fixed Costs** | |
| Driver Salary (per month)- for 26 working days, 8 hours per day | 5,000 |
| Overtime - normal day (@ Taka 36 per hour x 4 hours per day x 26 working days) | 3,744 |
| Overtime - holiday (@ 36 per hour x 10 hours per day x 4 holidays per month) | 1,440 |
| Total Salary per month | 10,184 |
| Total Salary per year (Taka 10,184 x 12 months) | 122,208 |
| Others (expenditure for breakfast or dinner, at site hotel cost etc per year) | 10,000 |
| **Total Expenditure Per year (operating manpower)** | **132,208** |
| Insurance per year (average) | 53,000 |
| Maintenance manpower salary (Taka 10,000 per month x 12 months) | 120,000 |
| Tax-token, road permit and others (per year) (fixed part of maintenance management) | 9,000 |
| **Total Fixed Costs** | **314,304** |
| **Variable Costs** | |
| 3000-3200 cc Hi-lux pickup van runs 100 km per day (4.25- 4.50 km / liter) | |
| Fuels required 22-23 liter per day @ Taka 33 per liter = Taka 759 per day | |
| Thus, Fuels cost for the year (Taka 759 per day x 360 days in a year) | 273,240 |
| Utilities (Light for garage, water for wash, tissue box, fan for the car, window shade, mobil and others) | 18,600 |
| Servicing (6 servicing per year @ Taka 1000 per servicing) (variable part of maintenance mgt) | 6,000 |
| Spares (average) (Tire, Engine oil, Battery, Break shoe, class plate , fan belt etc) | 35,300 |
| Modification (preparing rack for carrying equipment or prepare shelter etc. per year) | 3,000 |
| Others | 3,000 |
| **Total Variable Costs** | **339,140** |

**Table 5: Break down of recurring costs into fixed and variable for alternative 2**

| | |
|---|---|
| **Fixed Costs** | |
| Rent (Taka 60,000 per month x 12 months) | 720,000 |
| Driver salary and overtime (as computed in alternative 1) | 132,208 |
| **Total Fixed Costs** | **852,000** |

| **Variable Costs** | |
|---|---|
| Fuel & Consumables (as computed in alternative 1) | 273,240 |
| Utilities (as computed in alternative 1) | 18,600 |
| **Total Variable Costs** | **291,840** |

**Table 6: Status of Alternatives in terms of LCC at Present Value**

| Cost Category / Alternatives | One – off | Recurring | Disposal | Total |
|---|---|---|---|---|
| Alternative 1 | 2,582,700 | 4,646,000 | (1,000,000) | 6,228,700 |
| Alternative 2 | 507,700 | 6,326,400 | - | 6,834,100 |