BRIDGE LIFE CYCLE COST ANALYSIS

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Abstract : The paper presents a methodology of life cycle cost analysis (LCCA) , which is used for the best economic design for both structural integrity and durability , comparison of alternative design approaches , Comparison of alternative strategies , Identification of cost effective improvement , Project's budget cum economic viability assessment and Long term financial planning. Structural deterioration increases with the age of the bridge structure due to concrete spalling, rebar rusting, corrosion, fatigue, wear and tear and other methods of material deterioration. Traffic volume, vehicles number and legal load limits increases with time in future. When the ageing bridge structures are subjected to these kinds of excessive loads, then the structural capability of it reduces. Therefore, LCCA method is best suited to maintain the bridge in good condition index, for the ever-increasing loads and traffic on deteriorated bridge. All types of cost like initial, maintenance, repair, rehabilitation, aesthetical, cultural value, environmental impact etc. associated with the bridge during its service whole life. Currently, almost only functional performance and conventional financial costing guides the design of a new bridge. A new life cycle framework to integrate all cost to keep the bridge in good service condition like maintenance, user cost, the aesthetical; cultural value and the environmental impact with the economic issues become very essential for achieving sustainable infrastructure.

Keywords: Bridge , Service, Life, Cycle, Cost, Analysis

1. Introduction

Structural deterioration increases with the age of the bridge structure due to corrosion, fatigue, wear and tear and other methods of material deterioration. At the same time loads, vehicles and legal load limits for bridges have been increasing. When the ageing bridge structures are subjected to these kinds of excessive loads, then the structural capability reduces. The ability of a bridge to provide service successfully during service life is predicated although it is being maintained appropriately in future by the agency. Bridges are required to provide service for many years i.e. 100 years as per IRC: 112-2011. Thus the investment decision should consider not only the initial activity that creates a public good, but also all future activities that will be required to keep that investment available to the public. It is important to note that the lowest agency cost option may not necessarily be implemented when other considerations such as aesthetical and cultural value, user cost and environmental concerns are taken into account.

The paper empathies the principles of Life Cycle Cost Analysis (LCCA) with Service Life Design (SLD) of bridges. The primary focus of this brief is on the application of the LCCA during bridge design. It (LCCA) is a process of evaluating the total costs over the life of a bridge. Total costs include initial costs and projected future costs such as maintenance, repair, rehabilitation and reconstruction (discounted to today's money value). Life Cycle Cost (LCC) analysis and Total Cost incurred from construction to the end of service life evaluation are the basis for decision making for project selection among various alternative. LCCA is also used to evaluate two potential design features of a bridge for their best option selection among alternatives.

2. Literature Review

When making funding decisions under constrained budgets, it is tempting for decision-makers and elected officials to think in the short-term. In an effort to construct projects within limited capital budgets, high importance is placed on the up-front costs, with little attention to costs incurred in the future. In order to improve our long-term decision-making, planners and policy-makers need to begin thinking more strategically about how we maintain and operate our transportation network and manage its assets. With the focus of funding shifting toward system preservation, greater use of analysis that looks at both upfront and long-term costs can ensure the sustainability of future budgets and better management of our vital infrastructure.

Decisions related to implementation of a transportation improvement generally require that several alternatives be considered. Many factors contribute to an agency's decision to select a particular option, although initial project costs may dominate this decision. Initial agency costs, however, tell only part of the story. The idea behind this study is that, bridges investment decisions should consider all of the costs and considerations incurred during the service life period over which the alternatives are being compared.

2.1 Background

The life cycle of a bridge involves the following phases in the life of the structure:

- Design
- Construction
- Maintenance , repair , rehabilitation
- Demolition , Landscaping

2.2 Life Cycle Cost analysis

The optimized cost analysis depends upon following factors.

- Evaluation and comparison of alternative design approaches
- Comparison of alternative strategies
- Identification of cost effective improvements
- Project's budget and economic viability assessment
- Long term financial planning

The first life cycle phase is design for both structural integrity and durability. The latter phase is also known as SLD, a rational engineering approach to specify and provide durable structural materials and component details to resist deterioration resulting from the prevailing environmental exposure conditions.

LCCA is an engineering economic analysis tool that allows transportation officials to quantify the differential costs of alternative options for a given bridge project. At a project level, LCCA of alternative new bridge designs seeks to quantify the differential costs associated with differing design features to allow optimization of costs.

Figure No- 1 shows a graphical representation of the events making up the life cycle of a bridge. The horizontal axis represents time and identifies activities occurring in each phase. The vertical axis represents the condition of the structure. A design condition is planned that may be exceeded, achieved, or not achieved during construction. The condition changes with time during service, as assessed through a schedule of necessary inspections and/or monitoring (indicated as 'Inspection' on Figure No- 1) and periodic monetary investments are made to help preserve the structure (that is, maintain or improve the condition) through cyclical and condition-based maintenance or replacement of replaceable components. LCCA may be used to schedule and quantify these activities and investments to help owners make decisions throughout the life of the structure.

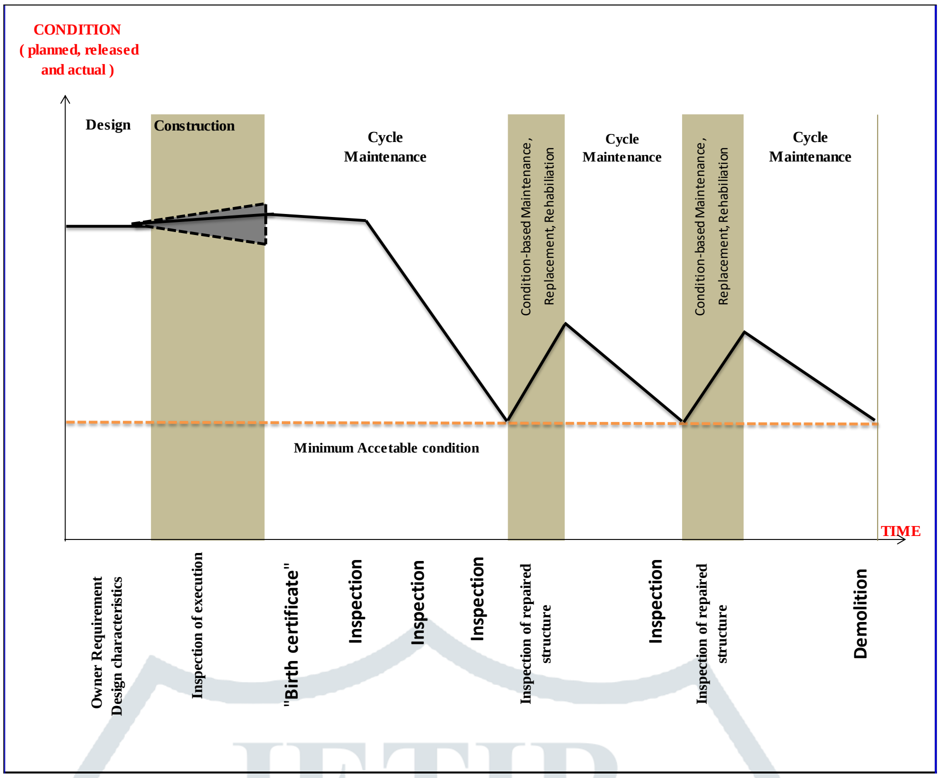

Figure No- 1: Complete Service Life (adapted from Gehlen, 2006, [19])

LCCA can consider all agency expenditures and user costs throughout the life of an alternative, not only initial investments. As it is generally the transportation official's policy decision to include user costs in decision-making, comparisons may be made both with and without consideration of user costs.

2.3 LCCA Methodology

The following steps define the LCCA Methodology:

I. **Establish alternative design and preservation strategies**. Project teams using the LCCA process first define reasonable design and preservation strategy alternatives. For each proposed alternative, they identify initial construction activities, the necessary future maintenance activities and the timing of those activities. At least two mutually exclusive options must be considered and the economic difference between alternatives is assumed to be attributable to the total cost of each.

II. **Determine activity timing**. From this information, a schedule of activities is constructed for each project alternative. After the component activities for each competing project alternative have been identified, each alternative's maintenance plans are developed. Effectively, this plan results in a schedule of when the future maintenance activities will occur, when agency funds will be expended, and when and for how long the agency will establish work zones.

III. **Estimate agency costs**. Next, activity costs are preparation of estimate in details. Best practice LCCA calls for including direct agency expenditures (for example, construction or maintenance activities). LCCA does not require that all costs associated with each alternative be calculated. Only costs that demonstrate the differences between alternatives need be explored.

IV. **Estimate user costs**. User costs are costs to the public resulting from work zone activities, including lost time and vehicle expenses during in any construction activities. In LCCA, user costs of primary interest include vehicle operating costs, travel time costs and crash costs. Such user costs typically arise from the timing, duration, scope and number of construction, preservation, and replacement work zones characterizing each project alternative. Because work zones typically restrict the normal capacity of the facility and reduce traffic flow, work zone user costs are caused by speed changes, stops, delays, detours, and incidents.

V. **Determine LCC**. Once the expenditure streams have been determined for the different competing alternatives, the objective is to calculate the total LCCs for each alternative.

2.4 Purpose

LCCA can be used as a supporting tool in bridge SLD to assess alternatives and optimize, based on minimum cost or maximum service life durations. The purpose of a project-level LCCA is to quantify and identify the least cost alternative option. The project evaluation team concentrate on optimizing alternatives by minimum cost for the same service life duration. LCC strategies and findings are used as a decision-making tool for the selection of materials and details for durability.

2.5 Scope

Based on the background and purpose identified, the following items are expanded upon herein:

Summarization of the full life-cycle considerations required to achieve the desired service life duration for a bridge. Summarise all necessary schedule i.e. inspection, special durability monitoring, cyclical and condition-based maintenance, and component replacement activities.

- Anticipated maintenance activities to be incorporated during the specified service life, and associated agency costs.

Component wise cost is obtained through LCCA and needful tool for comparison of alternative components in a bridge. This will compare only the costs that demonstrate the difference between the alternatives. For any future activities requiring lane closures or detours, Work zones and associated user costs will be developed. User Costs will include delay costs too (vehicle operating costs, travel time costs) based on available national data and assumed values (for example, detour distance).

3. Bridge Life Cycle Cost Analysis (BLCCA)

3.1 Necessity of BLCCA : BLCCA is needed for following reasons

- Larger bridge inventories and aging bridge population
- Increasing bridge rehabilitation and replacement needs
- Large percentage of these for all types of minor and bridges to reduce the failure; collapse
- Never enough money to spend at the time of planning for any client/ government
- Increasing public demands and scrutiny by knowing the condition index of bridge
- Need to make cost-effective comparisons of alternatives (bridge activity and type)
- Public expectation of longer bridge life (100 years) at optimum life-time costs
- Increasing focus on longer term planning for the network/groups of bridges

3.2 Principle in life cycle cost analysis

3.2.1 Terminology and definition used in LCCA

I. Service Life
II. Design service life
III. Analysis Period
IV. Discount Rate
V. Present Value
VI. Sensitivity Analysis

➢ **Service Life**: The term 'service life' generally relates to the period of time that the bridge is expected to be in operation and the structure performs its design function without unforeseen maintenance or repair. The estimated number of years the bridge will be serviceable in their service life. Service life beyond the end of analysis period must be accounted for through inclusion of a "Residual Value" for the bridge.

- **Design service life** – assumed period for which a structure or a part of it is to be used for its intended purpose with anticipated maintenance, but without major repair being necessary. Bridges are designed for 100 year life and, therefore, analysis is done for 100 years for either rehabilitation or partial / full replacement of some components of bridges (like bearing , expansion joints , drainage spouts , wearing coat , coating systems , crash barrier , footpath , railing , approach slab , wearing coat etc.)

Design Life is focused on structural loading and strength properties remaining the same throughout the 100-year duration as per IRC 112-2011. Load and resistance factors for structural design in IRC 6-2017 were calibrated to the 100-year period, but deterioration of the structure over time was not explicitly considered. Service Life Design is a durability related concept associated with preventing excessive deterioration that directly affects the ability of the structure to remain in use and recognizing that its condition changes over time. All structural components of a bridge are designed to equations calibrated to the 100-year Design Life. Ideally, all components would also be designed to achieve a service life of 100 years, as a minimum. It is generally possible for the major structural components like piles, footings, columns, pier caps, girders, and decks to achieve a desired Service Life of 100 years. However, it is not always feasible for other components like bearing , expansion joints , drainage spouts , wearing coat , coating systems , crash barrier , footpath , railing , approach slab , wearing coat etc. Fortunately, these components can often be replaced with minimal effects to traffic, and thus a shorter life can be specified. Therefore, all components need not have the same Service Life.

- **Analysis Period** - The time period, typically measured in years, over which costs of a bridge-management strategy are evaluated; same as time horizon, planning horizon, but not necessarily the same as service life.

- **Discount rate**: This rate is used to calculate present value for incurred cost in future to maintain the serviceability of bridge. In cases where borrowed funds are used to fund initial construction, preservation or maintenance activities, the real discount rate would represent the borrowing rate of the borrowed funds. The *real* discount rate does not include inflation. Thus, by using the real discount rate in equation, estimates of future costs can be made in current money value.

The term $\left[\frac{1}{(1+r)^{n_k}}\right]$ is called the discount factor.

Where r – Discount rate, n_k – year in which maintenance work will be done

- **Present Value**: Present value Since constructing and managing a bridge covers service life of 100 or more years, those costs need to be converted to a form that allows them to be compared. Time value of money is different in future. Economists distinguish the value between a fund today and one in the future through a process called discounting. The net present value concept in LCCA is an economic method for combining initial costs and present currency (rupees / dollar) values of future expected costs so that lifetime costs for various alternatives can be directly compared. Rupees / Dollars spent at different phases of time within a structures life have different present values, so the projected activity costs for an alternative cannot simply be added together to calculate the total life cycle cost for that alternative. A rupee or dollar value nowadays is worth more than a rupee or dollar five years from now, even if there is no inflation because today's dollar can be used productively in the ensuing five years, yielding a value greater than the initial dollar. Future benefits and costs are discounted to reflect this fact.

The relationship between the amount of a future expenditure and its equivalent present value, (PV) is calculated from the following expression using a real discount rate (r).

$$Pv = \text{Initial cost} + \Sigma C_n * 1/(1+r)^{n}{}_{k}$$

Where:

C_n	=	Cost of expenditure at year n_k, (in today's money)
r	=	Real discount rate
n_k	=	year in the future when the cost will be incurred

- **Sensitivity analysis:** LCCA estimations should be investigated to establish sensitivity to the uncertain parameters of the analysis such as analysis period, discount rate, traffic growth rates, traffic speeds, capital costs and accident predictions. Alternatively, in case of high uncertainty for a specific unit cost, a sensitivity analysis may be completed using minimum, average, and maximum expected unit cost values so that this uncertainty is considered in deciding which solution is most cost-effective.

3.2.2 Necessity of Life Cycle Cost Analysis for bridges

Life-Cycle Cost Analysis (LCCA): -LCCA is a cost-centric approach used to select the most cost-effective alternative that accomplishes a preselected project at a specific level of benefits that is assumed to be equal among project alternatives being considered. All of the relevant costs that incurred throughout the life of an alternative, including the original expenditures, are taken to obtain accurate cost. The Service Life of different bridge components depends on their rate of deterioration, which again depends on their environmental exposure. Pier shaft and foundation is more vulnerable to deteriorate due to environmental or collision impacts. For steel components, the environmental exposure of the component influences how fast the steel deteriorates due to corrosion.

Throughout the Service Life of the bridge, bridge components need preservation and maintenance actions to counter the effects of deterioration and restore components to an acceptable condition. Certain bridge components might even need replacement if their Service Life is less than that of the bridge. Thus, a bridge represents a long-term, multi-year investment and the cost to an agency for a bridge is never a one-time expenditure because expenses to preserve and maintain the desired performance levels must be expected throughout its life cycle. LCCA is a process of identifying the least cost alternative and associated preservation and maintenance strategy of competing design alternatives to achieve a specific Service Life. Thus, an LCCA can assist decision makers in comparing alternative strategies for managing a bridge in good condition.

LCCA may also be used to evaluate competing design alternatives. In such cases, the bridge's service life is typically used as the analysis period. The competing design alternatives should first be benchmarked for suitability (that is, each design alternative must first show it reliably achieves project requirements such as service life, structural stability, and desired level of maintenance) before consideration in an LCCA. Further, it is important to understand the risk and reliability associated with each design alternative and that these may likely differ amongst the design alternatives. These vital considerations shall not be overlooked in the completion of an LCCA.

4. Cost calculation for BLCCA

4.1 Costs by the Entity that Bears the Cost (Level 1)

In this level, the costs can be divided as shown in Figure No--2 below, and will discuss in the following subsections.

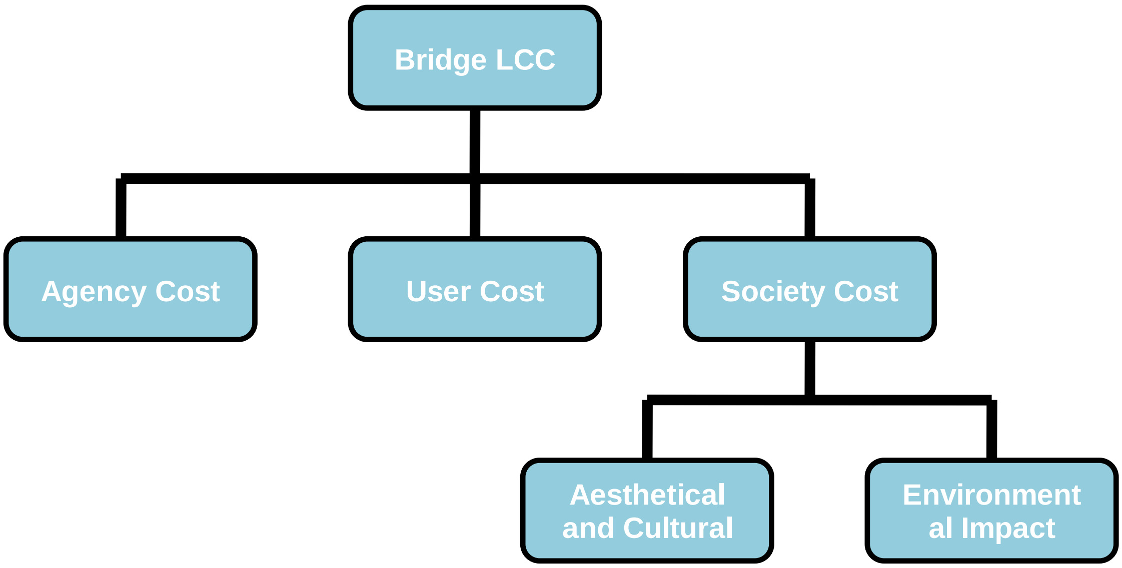

Figure No- 2: Cost by the entity that bears the cost (Level 1)

Where in each time-step considers costs associated for that year.
$C_{lifecycle}$ is the cost associated with the bridge during its whole life
$C_{lifecycle} = C_{initial} + C_{Repair, maintenance, Rehabilitation} + C_{user} + C_{failure}$

4.1.1 *Impact of discount rate on present value*

The choice of real discount rate has a huge influence on the outcome of the LCCA and therefore should be chosen carefully. Low real discount rates favour current expenditures whereas high rates reduce the present value of future costs and consequently tend to favour options with low capital cost, short life and high recurring cost.

The discount rate can have a significant impact on the analysis, as can be seen in Figure No- 3. A low discount rate favours projects with long-term benefits and near-term costs. When evaluating alternative projects, a sensitivity analysis using a range of discount rates can be used to determine the importance or impact of the discount rate in the relative project performance. Even with a low discount rate, values far in the future have a relatively low present value.

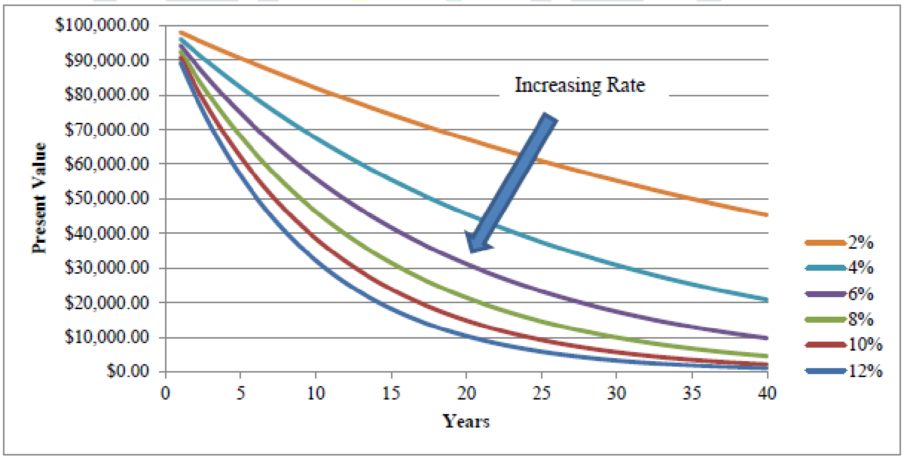

Figure No- 3: Effect of discount rates on present value.

4.2 Agency Costs

Agency costs are all costs incurred by the project's owner or agent over the study period. These include but are not limited to design costs, capital costs, insurance, utilities, and servicing and repair of the facility (Figure No-4) . Agency costs are relatively easy to estimate for conventional material/designs since historical data on similar projects reveal these costs.

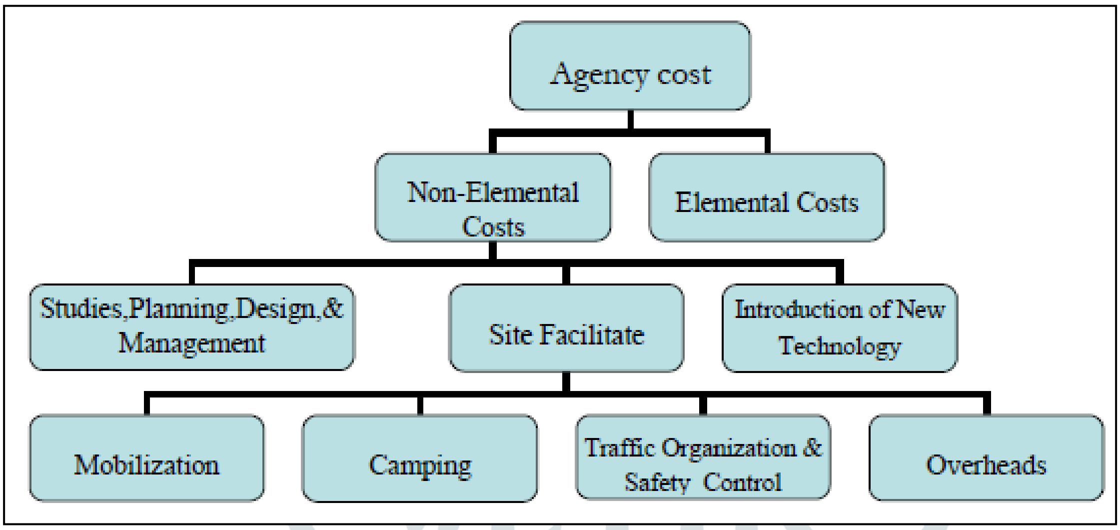

Figure No- 4: Agency Costs by Elemental Breakdown (Level 2)

4.1.2 Bridge User Cost Components

Before addressing bridge user cost calculation procedures, it is helpful to understand the bridge user cost components. Figure No- 5 illustrates the user cost components and their appearance events.

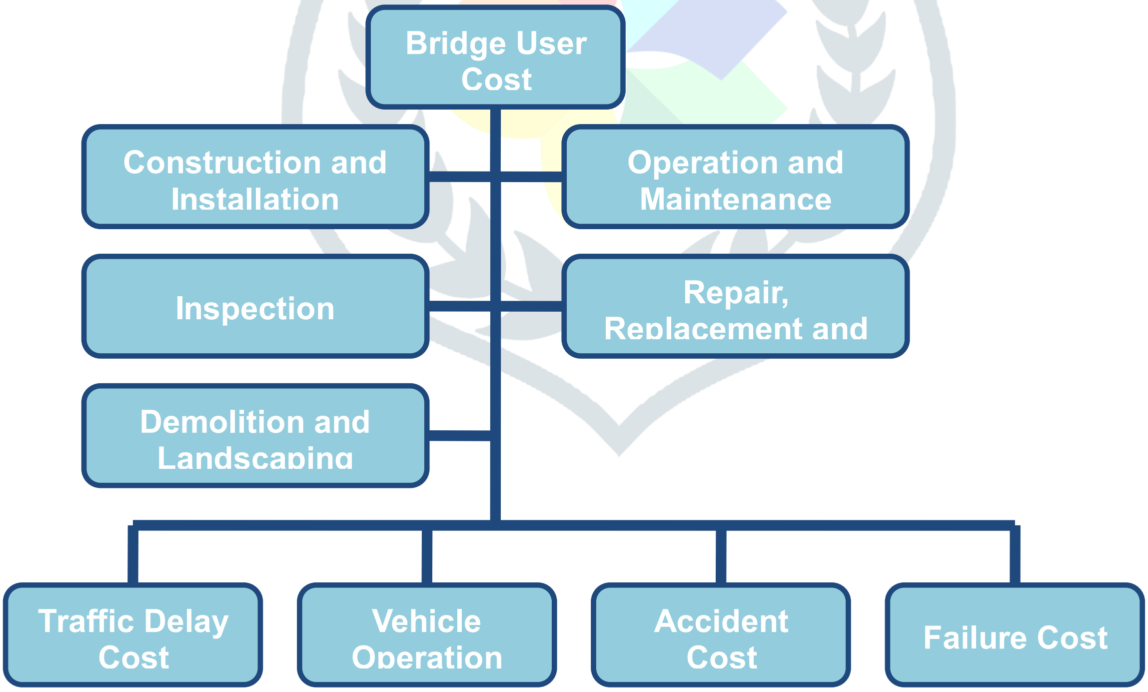

Figure No- 5: Bridge user cost components and appearance events (Level 3)

LCCA can consider all agency expenditures and user costs throughout the life of bridge, not only initial investments. As it is generally the transportation official's policy decision to include user costs in decision-making, comparisons may be made both with and without consideration of user costs.

4.1.2.1 Estimate user costs. User costs accrue to the direct users of the project. For example, bridge construction often causes congestion and long delays for private and commercial traffic. New bridge construction impacts traffic on existing alignment road, the adjoining; nearby roads over which it passes. Maintenance and repair of an existing bridge, along with the rerouting of traffic, can impact drivers' personal time as well as the operating cost of vehicles sitting in traffic. Accidents, involving harm to both vehicles and human life, tend to increase the user cost too.

User costs are costs to the public resulting from work zone activities, including lost time and vehicle expenses. In LCCA, user costs of primary interest include vehicle operating costs, travel time costs, and crash costs. Because work zones typically restrict the normal capacity of the facility and reduce traffic flow, work zone user costs are caused by speed changes, stops, travel delay costs, detours, crash costs, and accident cost etc. Resulting from construction, maintenance, or rehabilitation activity. Maintenance may require partial closures of traffic and incurrence agency costs due to mobilization and maintenance of traffic, and user costs due to delay. Finally, the total PV cost for the entire bridge structure is determined by summation of all total PV costs for each component. In the present example, the total PV cost to be expected for maintenance tasks during the 100-year service life of the bridge.

Bridge user cost during a work zone are usually evaluated with respect to the traffic delay costs (TDC), the additional vehicle operating costs (VOC) to cross the work zone, the related-accident costs (AC), and the risk of failure cost (FC). The following equation is used to determine bridge user cost during a work zone. Bridge User Cost = TDC +VOC + AC + FC.
The costs should be calculated to present value and added up for all foreseen maintenance and Repair works for the studied time interval TE.

4.1.2.2 Society Costs or Third-Party Costs

Third-party or spill over costs is all costs incurred by entities who are neither the agency/owners themselves nor direct users of the project. One example is the lost sales for a business establishment whose customer access has been impeded by construction of the project, or whose business property has been lost through the exercise of eminent domain. A second example is cost to humans and the environment from a construction process that pollutes the water, land, or atmosphere. These costs can be subdivided into two main categories:

- ***Bridge Aesthetical & Cultural Value (ACV)***

  Some projects have exceeded all cost estimates but still it has been possible to fulfil them with success. One of the main aims of bridge projects is to preserve the harmony of the scenery. Location of a bridge, cultural values of the surroundings, landscape and the viewpoints of local people have influence on the goals that are set to a bridge in the beginning of a project. Bridges are often seen more or less as sculptures and icons which the citizens may relate with the soul of the city. This atmosphere and the will to identify the town and its values with an icon may motivate for bold and spectacular solutions. So, absolutely there is a hidden value for the external appearance and the beauty of the bridge, it should be considered during the design and in the LCCA process. This value is called the ACV. Adopt all considerations and principles, which will be helpful to eliminate the worst aspects of bridge design and encourage the best.

- ***Bridge Environmental Impact (LCA)***

  Environmental impact categories evaluated include energy and material resource consumption, air and water pollutant emissions, solid waste generation, energy use, fuel consumption, and emissions for the traffic. Life cycle assessment is an analytical technique for evaluating the full environmental burdens and impacts associated with a product system, will deeply discuss it later in this chapter

4.3 Costs by LCC Category (Level 2) during bridge service condition

Level 2 groups the costs according to the life-cycle categories which may be classified in ascending chronology by their occurrence during the bridge life cycle, with these proposed titles as follow and shown in Figure No- 6.

- Investment Cost (Purchasing, Construction, & Installation)
- Operation & Maintenance Cost
- Inspection Cost
- Repair/Rehabilitation & Replacement Cost
- End of life Management Cost (Demolition and Landscaping)

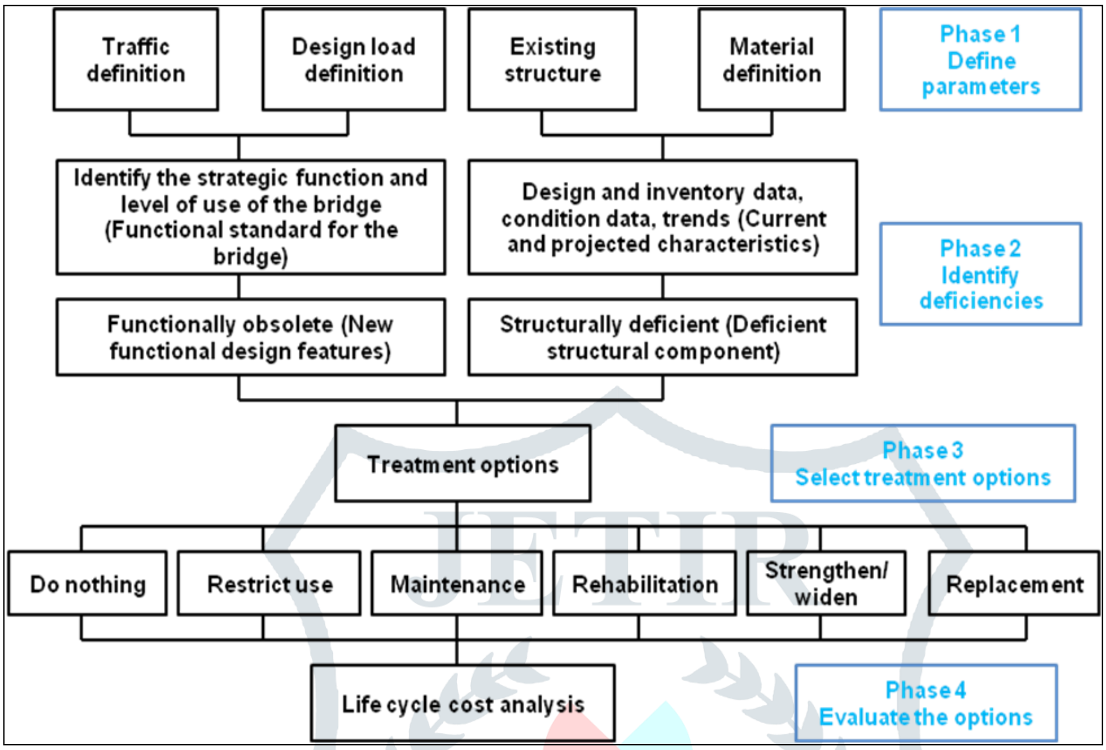

Figure No- 6: Flow-chart for the Maintenance, Repair and rehabilitation of bridge structures

4.3.1 Operation & Maintenance

Operation: - The preservation and upkeep of a structure, including all its appurtenances, in its original condition (or as subsequently improved). Maintenance includes any activity intended to "maintain" an existing condition or to prevent deterioration. Examples include: cleaning, lubricating, painting, and application of protective systems.

Maintenance: - The minor repair and preventative maintenance activities necessary to maintain a satisfactory and efficient structure, usually prescheduled maintenance and repair activities. An example of historical agency data for bridge operation and maintenance costs can be as shown in following table:

4.3.2 Inspection

The main purpose of the inspections is to ensure that the safety and traffic ability of the bridges meet the requirements; the inspections reveal the physical and functional condition thus providing the basis for an efficient and economical bridge management. The bridge inspections in Sweden are since 1987 divided into three types, according to the nature of their aim, scope and frequency.

- General inspection
- Major inspection
- Special inspection

4.3.3 Maintenance of Bridge Components(Repair/Rehabilitation & Replacement)

Repair: - The restoration of a structure, including all its appurtenances, to its original condition (or as subsequently improved) insofar as practicable. Repair includes any activity intended to correct the affects of material deterioration by restoring or replacing in-kind any damaged member.

Rehabilitation: - The improvement or betterment of a structure, including all its appurtenances, to a condition which meets or exceeds current design standards. Examples of rehabilitation include, widening a bridge to meet lane/shoulder width requirements, raising a bridge to meet clearance requirements, replacement of substandard bridge rails, strengthening a bridge to increase load carrying capacity to accepted limits, replacement of deck, rehabilitation of deck, and rehabilitation of superstructure**.**

Replacement: - The erection of a new structure at or near an existing structure, with the new Structure intended to receive the service loads from the existing structure which is eventually abandoned, relocated, or demolished.

5 Life-Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is decision making process for selecting optimum cost effective bridge systems, subsystems and elements that can achieve long term service life. It concentrates on general features and elements of incorporating LCCA in the design process, emphasizing consideration of project costs throughout its service life. LCCA aids in evaluating alternatives for bridge components such as deck slab, superstructures, substructures or more specialized bridge element applications, such as comparing alternatives for deck joints or bearings. Identify suitable approaches for mitigating the failure modes or assessing risk of damage, through life cycle cost analysis.

The basic steps involved in the LCCA estimation are shown in Figure No- 7.

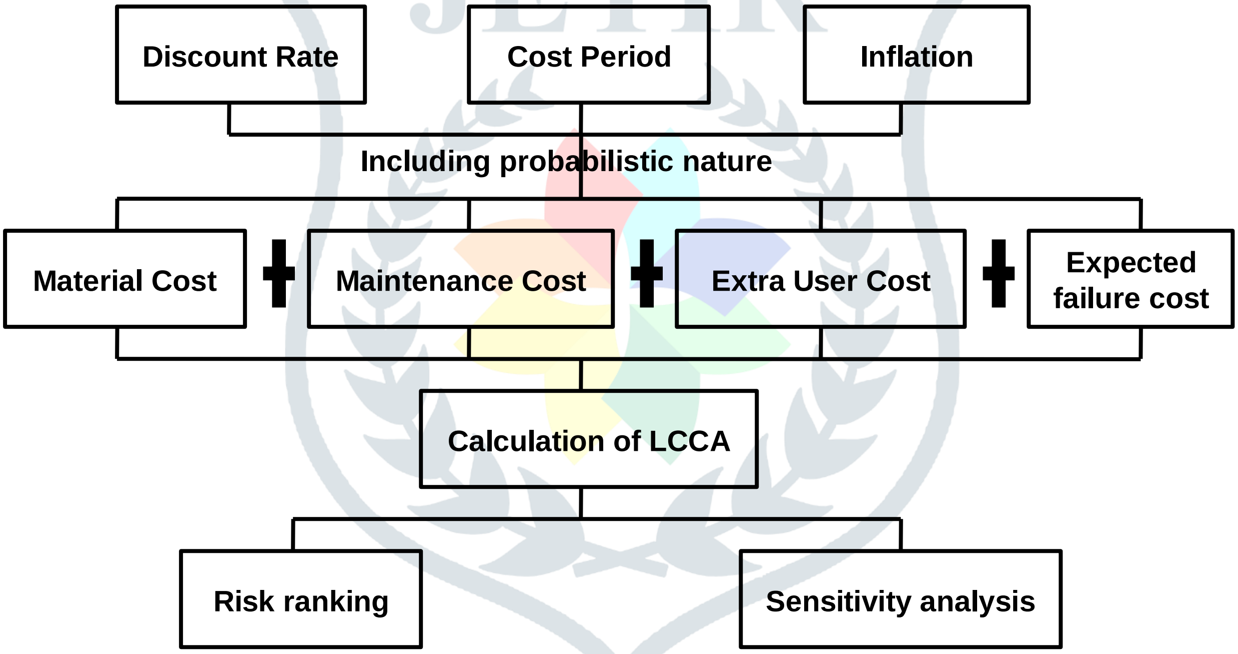

Figure No- 7: Flow-chart for the LCCA estimation

6 Risk analysis

Most of the analytical models use input variables as discrete fixed values. They are considered to be certain in such situations. However, normally the majority of the input variables are uncertain. Uncertainty may be the result of the assumptions, estimates and projections made in the analysis. For example time to first rehabilitation may occur in a range of years, the bid cost of the materials is not fixed and discount rate can be varying (Darter and Smith). Therefore the resulting mean LCCA value is always probability based. As a result there is a risk involved in calculating LCCA value for any of the Rehabilitation method. As shown by Darter and Smith it is necessary to include a risk analysis or risk ranking in any LCCA calculation. Table 8 shows the LCCA input variables and the general method of initializing them (FHWA, 1998).

LCCA Component	Input Variable	Source
Initial and Future Costs	Preliminary Engineering	Estimate
	Construction	Estimate
	Maintenance	Assumption
Timing of Costs	Bridge performance	Projection
User costs	Current traffic	Estimate
	Future traffic	Projection
	Hourly demand	Estimate
	Vehicle distribution	Estimate
	Dollar value and delay time	Assumption
	Work zone configuration	Assumption
	Work zone of hours operation	Assumption
	Work for duration	Assumption
	Wok zone activity years	Projection
	Crash rates	Estimate
	Crash cost rates	Assumption
NPV	Discount rate	Assumption

Table 8 : LCCA input variables

7 Sensitivity Analysis

There is uncertainty in analysis period, discount rate, traffic growth rates, traffic speeds, capital costs and accident predictions. Sensitivity analysis is done to get most effective present value of the project, using minimum, average, and maximum expected unit cost values so that this uncertainty is considered

Austroads (1996) has suggested the variables and ranges for a road project as shown in Table 9

Variable	Suggested minimum value	Suggested maximum value
Capital cost (final costing)	-10% of estimate	+10% to 20% of estimate
Operating and maintenance cost	-10% of estimate	+10% of estimate
Total traffic volume	-10% to 20% of estimate	+10% to 20% of estimate
Normal traffic growth rate	-2% pa (absolute) of the forecast rate	+2% pa (absolute) of the forecast rate
Traffic generated or diverted by project	-50% of estimate	50% of estimate
Traffic speed changes	-25% of estimated change in speed	+25% of estimated change in speed
Accident changes	-50% of estimated change	+50% of estimated change

Table 9: Sensitivity tests – Variables and ranges (Austroads, 1996)

8 Summary

Bridge investment decisions should consider all of the costs and considerations incurred during the service life period over which the alternatives are being compared. The ability of a bridge to provide service without any interruption is predicated on its being maintained appropriately by the agency. It is important to note that the lowest agency cost option may not necessarily be implemented when other considerations such as aesthetical and cultural value, user cost, and environmental concerns must be taken into account to get optimised value for service life tenure. The purpose of LCCA is to specify an economically efficient set of actions and their timing during the bridge's life cycle to achieve the desired service life and thereby ensuring longevity of the bridge structure. Moreover, cost comparison based on LCCA can be used to select the most cost-effective solution by finding the right balance between initial cost, maintenance cost, user cost and the desired condition of the bridge. Timely Maintenance of bridge components greatly reduces the rate of deterioration. Maintenance costs (assuming proper regular maintenance) are typically less by earlier action taken against deterioration because the lack of maintenance accelerates the deterioration and decay rate.

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