# Life Cycle Cost Analysis of Tunnel

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**Abstract -** *Tunnels in general represent a significant financial investment with challenging design, construction, and operational issues. Tunnels that are not adequately planned, designed, and constructed usually require more costly and extensive repairs. Tunnel Life Cycle Cost Analysis (LCCA) is a data-driven tool that provides a detailed account of the total costs of the project over its expected life. In order to realize an optimal trade-off between investment and maintenance of tunnel projects, LCCA should be applied. The main problematic issue is the water infiltration through the tunnel, which is described in detail in this paper. LCCA has several applications, including help in selecting the best alternative to meet a project objective. Lifecycle cost analysis is a dynamic process.*

***Key Words***: LCCA, Tunnel, life cycle costs

## 1. INTRODUCTION

This Paper provides details about the tunnel LCCA. In order to evaluate the cheapest possible solution the LCCA is an efficient way to analyse options that meet the requirements. In this report, it is tried to analyse the cost estimation of the tunnel in the life cycle and to propose an advantageous solution.

### OBJECTIVES:

1) To identify how different methodologies that account for life cycle cost can be used in tunnel planning, design and management in order to support minimized costs.

2) To make an inventory of tunnel planning and design process for an overview of implications for life cycle cost implementation.

3) To estimate future costs in tunnel planning, design and management.

4) To describe consequences of life cycle cost decisions based on results from case studies and implications for investment and management.

## 2. LIFE CYCLE COST ANALYSIS (LCCA)

Life Cycle Cost (LCC) is a technique that enables comparison of cost assessments which was made over a specified period of time having the account of all relevant economic factors including initial investment costs and future operational and maintenance cost flows over a specific period considered for analysis. Life Cycle Cost Analysis (LCCA) is a tool that provides the total costs of a project over its expected life span or a specific period of time under consideration in detail manner. During decision making process under constrained budget, it is usual that the decision makers make conclusions based on short term costs that is cost associated with design and construction without considering the costs incurred with the project in the future which may be of maintenance, operation, repair and retiring of the project. Analysis of life time cost has to be done thoroughly which includes cost incurred in the project from procurement of raw materials till destruction of the project when its life ends technically. This analysis is done to give the total life cycle cost of the project including every cost the project is associated with such as planning cost, construction cost, maintenance cost, management cost and disposal cost as on Figure 1.


**Figure 1. Life cycle of a construction project**

LCCA has been proven to create savings in many projects by helping the decision makers and policy makers to identify the most beneficial and cost effective project alternates comparing many alternates of a project than to get the true cost of the project.

Life cycle cost analysis initiation can be done in any of these stages of construction of project but most often initiated in design phase which helps in comparing different deign alternates finding the most effective solution. This phase is the key phase of savings since the cost required for any changes increases rapidly once the design has been chosen. During the project in service, LCC can be used to choose the repair alternate helping the decision maker to take decision such as whether to repair or replace. Finally, it can also be used to choose the optimal demolition strategy at the end of its life in cost perspective.

## 3. LCCA OF TUNNEL

Life cycle cost of tunnel include agency costs, user costs and society costs with further subdivisions as on Figure 2. Most of the costs occur at different times during the life cycle of the project. Comparing of past, present and future costs on a common basis is usually done with Net Present Value (NPV) method[1], which is based on the principal that having money at hand today more valuable than to have at future. NPV method transfer all future and present costs to today's value.

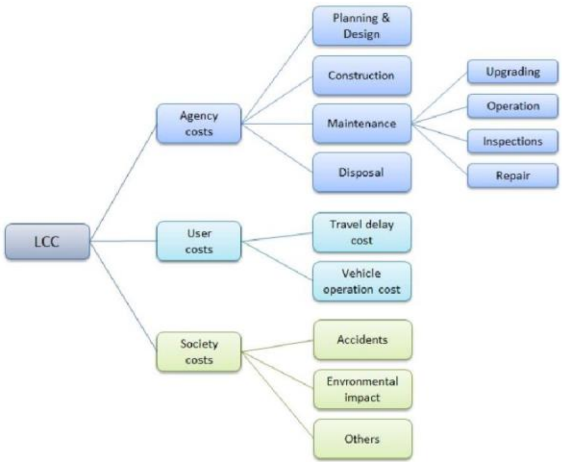


**Figure 2. Life Cycle Cost of Tunnel**

Since the inflation is hard to predict, it is excluded in LCC calculations for the projects of long term investments. The value of discount rate depends on the purpose of analysis. Lower the discount rate, larger the consideration of future costs and maximum usage by public authorities. Larger the discount rate, larger the risks on investment and future cost not considered as important. Discount rate have a greater impact on LCC. LCC can be subdivided as shown in Figure 2. [1]

3.1 AGENCY COST

Agency costs [1] are direct expenses by the owner of the project which includes design cost, investment cost, insurance, utilities, servicing, remedial action costs and end of life management costs. Calculating agency cost with NPV method requires time and cost of every maintenance activity. Since these parameters are difficult to predict which is the greatest constraints for LCCA, assumptions are made for operation and maintenance cost based on historical data from actual bridge inspections and repairs. Agency costs may be subdivided as shown in Figure 3. The percentage divisions are based on European Telecommunication Standards Institute (ETSI) Standards.

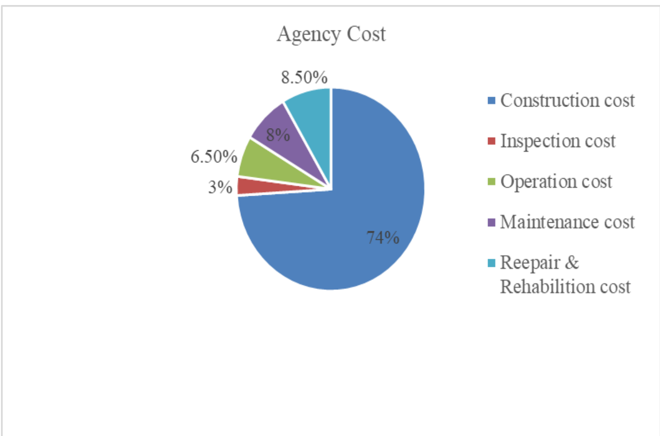


**Figure 3. Agency Cost**

**3.1.1 INVESTMENT COST**

Investment cost of a project which is expected to be productive for many years, is the costs that are incurred with procurement of materials that are required for the project, construction and installation of the project.

Cost of Construction of Tunnel = Rs. 128 Cr. (Data Collected)

Future Value = Present Value x $(1+r)^n$

R = 4 %(For Tunnel)*

n = (2016-1988) = 27

Cost of Construction = Rs. 128 Crores (80% of Tunnel in 2019 Agency Cost)

**3.1.2 OPERATION COST**

Maintenance is the preservation of a structure in its original condition and preventing deterioration which includes cleaning, painting, applying protective systems and minor repairs. It has to be done every year throughout its life span.

**3.1.4 INSPECTION COST**

Inspection is to ensure safety and traffic ability revealing the physical and functional condition of the Tunnel for efficient and economical management. The general inspection is to detect and access new damages. Every structural part of the tunnel are to be visually inspected. Major inspection is done when the damages affect the traffic safety. It is done to detect any minor defect if not attended to can cause increased repair costs in a short period. Special inspection has to be done when the tunnel requires sudden inspection due to unexpected happenings by nature or manmade leading to damages and repair. Inspection is done once for every 5 years.

**3.1.5 REPAIR, REPLACEMENT AND**

**REHABILITATION COST**

Repair includes any activity intended to correct the affected material due to deterioration to its original condition so far in practice. The improvement of the structure to meet or to exceed the current design standards.

**Table 2. LCCA of Tunnel**

| **Costs Involved** | **% of CC** | **Cost (Rs.) (Crore** |
|---|---|---|
| Construction Cost (CC) | | 128 |
| Inspection Cost | 3% | 3.84 |

| | | |
|---|---|---|
| Operation Cost | 6.5% | 8.32 |
| Maintenance Cost | 8% | 10.24 |
| Repair and Rehabilitation Cost | 8.5% | 10.88 |
| Decomposition & Demolition cost | 20% | 25.6 |
| Total Life Cycle Cost | | 186.88 |

Life Cycle Cost of Tunnel = Rs. 186.88 Crores for 1Km Tunnel over a Life Span of 100 years

## 4. RESULTS

| | Tunnel (Rs) |
|---|---|
| Initial Cost | 128 Cr. |
| Life Cycle Cost | 186.88 Cr. |

## 5. CONCLUSIONS

In this research, the life cycle cost studies for the tunnel are completed for 1 km In order to realize an optimal trade-off between investment and maintenance of tunnel projects, LCCA should be applied. LCCA has several applications, including help in selecting the best alternative to meet a project objective.

The feasibility study on selecting a tunnel goes beyond costs and LCCA e.g. the geological conditions; duration of construction, environmental impact, technology availability, constructability and ecological and even political consideration dominates the decision.

To properly plan for future repairs or scheduled maintenance in a tunnel, it is beneficial to perform a LCCA of the different options involved for each anticipated major repair to ensure the greatest cost efficiency over the life of the tunnel.

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