Pavements Life Cycle Cost Analysis Guide

Pavement Analysis and Design – Maintenance Division

LIFE CYCLE COST ANALYSIS GUIDE

Introduction

There are several key factors that contribute to the selection of pavement type, such as soil properties, traffic load and spectrum, geographical location, construction constraints, and life cycle cost. Life Cycle Cost Analysis (LCCA) is a useful tool that can assist in pavement type selection by comparing the life cycle cost between pavement alternatives. LCCA includes initial cost, annual maintenance cost, and future rehabilitation cost over a selected analysis period. The FHWA policy on LCCA states that “it is a decision support tool, and the results of the life cycle cost analysis are not decisions in and of themselves”

This guide provides an overall description of LCCA components and recommended default input values for certain parameters. As of now, this guide is limited to a deterministic LCCA approach without user costs consideration.

Analysis Period

All alternatives being compared should be evaluated over the same analysis period. Typically, the analysis period should go beyond the design life for all alternatives to reflect long-term cost differences. The current TxDOT Pavement Manual states a 20-year design life for flexible pavements and 30-year for rigid pavements. A 40-year analysis period should be used for this analysis. This analysis period will cover routine maintenance and major rehabilitation (or reconstruction) for both types of pavements.

Performance (service) Life

Service life refers to the time between new construction and first rehabilitation treatment, or between two rehabilitation treatments. The estimated service life of a rehabilitation treatment should be based on an overall state performance history, or based on district performance data from multiple projects with a minimum of 10 comparable projects in terms of traffic.

A statewide survey and analysis of pavements constructed in Texas from 1960 to present was conducted. The analysis found that thick asphalt pavements (ACP>5.5”) were rehabilitated after 12 years and rigid pavements were rehabilitated after 35 years. On average, both flexible and rigid pavements received subsequent rehabilitations every 12 years or preventive maintenance treatments every 10 years. The analysis focused on identifying the construction or reconstruction of thick asphalt concrete pavements and continuously reinforced concrete pavements, and then tracking the work history on these sections of pavement.

A total of 1,021 asphalt and 49 concrete pavement construction and rehabilitation projects were analysed. The majority of these projects were on interstate highways and heavy trafficked routes in Texas. Examples of life cycle cost over a 40-year analysis period for flexible and rigid pavements are illustrated in figures 1 and 2, respectively.

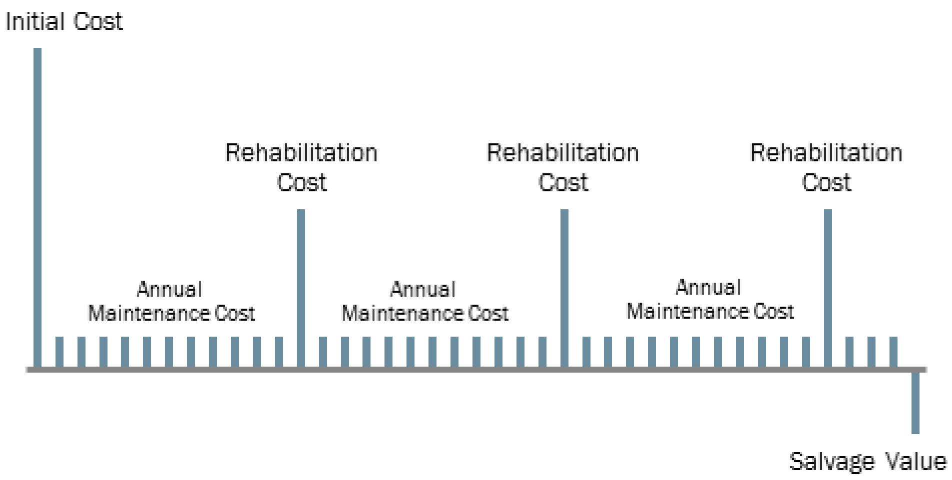

Figure 1. Example of flexible pavement construction, maintenance and rehabilitation life cycle cost

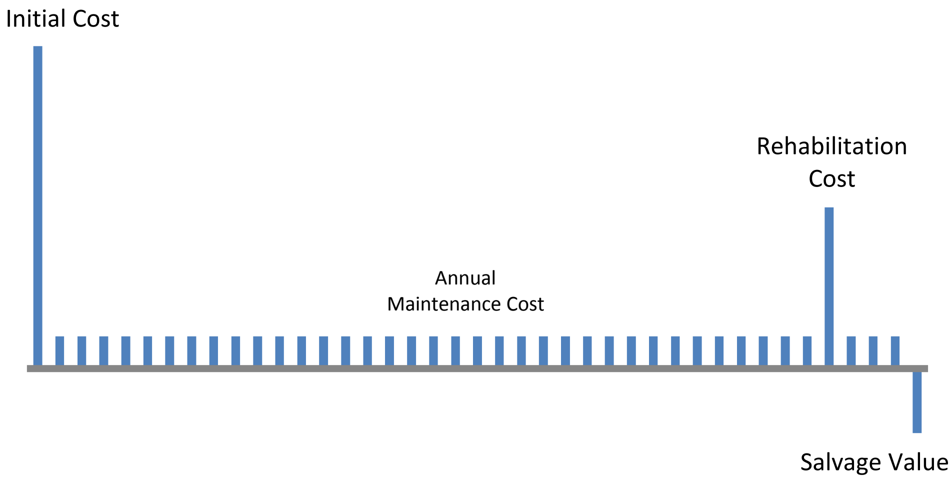

Figure 2. Example of rigid pavement construction, maintenance and rehabilitation life cycle cost

Initial Construction/Reconstruction Cost

Initial cost includes all expenses required to build the pavement section in question according to the plans and specifications. Previous experience and utilizing average bids submitted for similar recent projects can be used to estimate the initial cost. This is one of the most important factors in LCCA and should be estimated as accurately as possible, using the best available data. In addition to the material quantities calculated, other bid items associated with the different alternatives should be included. For example, traffic control cost could potentially vary from one alternative to another. If that is the case, traffic control cost should be included in the initial construction cost.

Maintenance and Rehabilitation Cost

Annual maintenance cost should be based on available district data. The TxDOT maintenance management system statewide compiled data is summarized in Figures 3 and 4 for flexible and rigid pavements, respectively, while Table 1 summarizes the overall and 10-year moving average. This data spans from 1996 to 2016 and averages costs for the entire TxDOT on-system network.

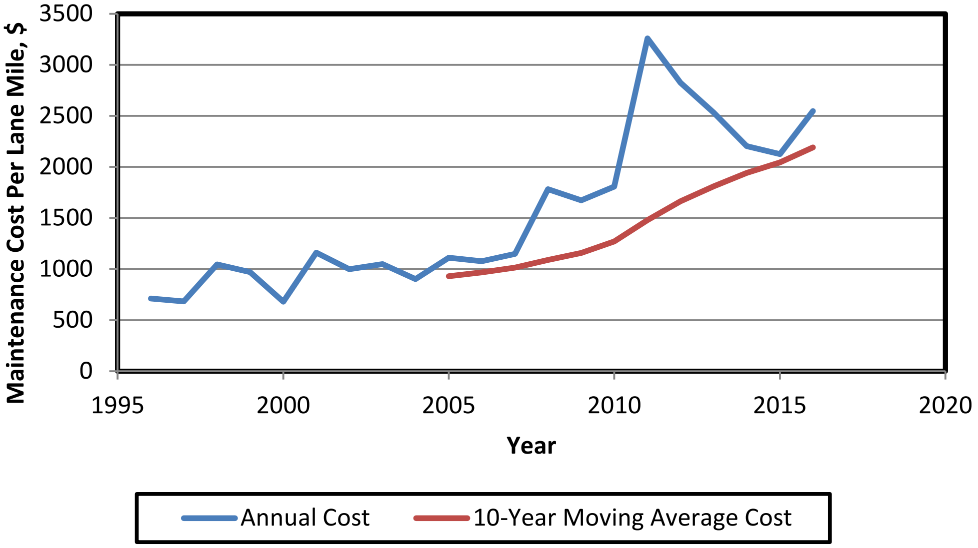

Figure 3. Annual Maintenance Cost Per Lane Miles of flexible pavements

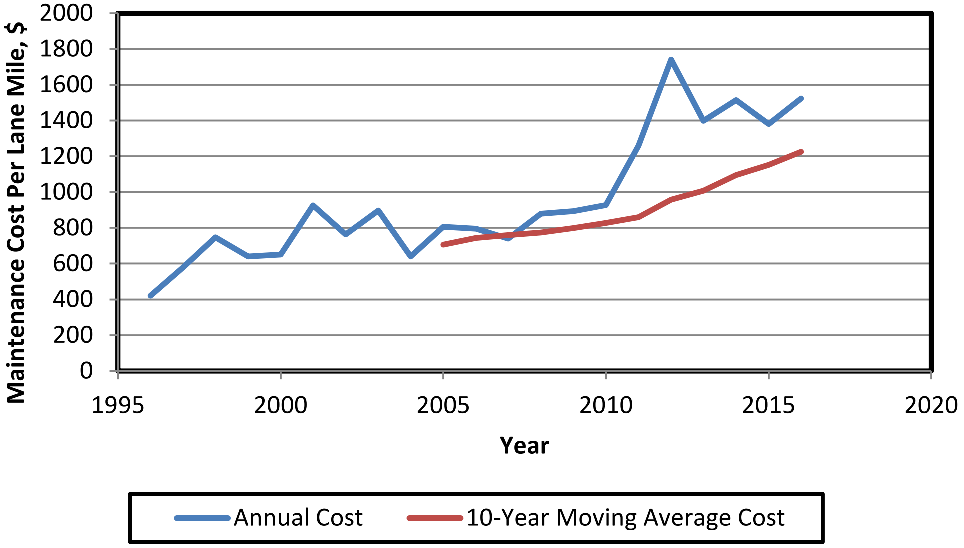

Figure 4. Annual Maintenance Cost Per Lane Miles of rigid pavements

Table 1. Annual Maintenance Cost Per Lane Mile

Pavement Type	**Annual Maintenance Cost Per Lane Mile**		**Average Lane Miles**
	Overall Average	10-years moving average	
Flexible	$1,537	$2,189	~60,000
Rigid	$958	$1,225	~17,000

Salvage Value

The salvage value represents the value of the pavement asset at the end of the analysis period, and is based on the remaining service life of the last rehabilitation treatment. For example, if a rehabilitation treatment with expected performance life of 10 years was applied at year 35, for a 40-year LCCA, the pavement will have an expected 5 years of service life left. The salvage value would be considered 5/10 of the cost of the rehabilitation treatment (Equation 1).

$$SV = (RL/TL)*RTC \qquad \text{Eq.1}$$

Where:
SV: salvage value,
RL: remaining life of rehabilitation treatment,
TL: total life of rehabilitation treatment,
RTC: rehabilitation treatment cost.

Discount Rate

Discount rate, by definition, is the difference between the market interest rate and the inflation rate, and is used to adjust all future costs in the analysis to a present value. These adjusted costs can then be combined with the initial construction cost to give a total present cost for all the activities over the life cycle analysis period. Total present costs for all alternatives can then be compared to decide on the most economical pavement alternative. Equations 2 & 3 can be used to calculate the present value for a future single payment and an annuity, respectively. While equations 4 & 5 are used to calculate the discount factors used in Equations 2 & 3.

$$P = F\ (P/F,\ i\%,\ n) \qquad \text{Eq.2}$$

$$P = A\ (P/A,\ i\%,\ n) \qquad \text{Eq.3}$$

Where:
P: single payment present worth
F: future single payment at year n
(P/F, i%, n): discount factor “Find P given F”
i%: discount rate
n: number of years
A: annual payments over n years
(P/A, i%, n): discount factor “find P given A”

$$(P/F, i\%, n) = (1+i)^{-n} \qquad \text{Eq.4}$$

$$(P/A, i\%, n) = ((1+i)^{n} - 1)/(i(1+i)^{n}) \qquad \text{Eq.5}$$

The Office of Management and Budget (OMB) publishes on an annual basis, the real treasury interest rates for various analysis periods (Table 2). The 2018 30-year analysis period rate is 0.6%. A 10-year moving average for the 30-year analysis period is 1.69%, while the historical average is 3.72% for the same analysis period. Figure 5 illustrates the trend in the 30-year analysis period real interest rate and the 10-year moving average. The use of the historical average is required by these guidelines until further FHWA guidelines are provided.

Table 2. OMB real interest rate for 3, 5, 7, 10, and 30-year analysis periods

	3-Year	5-Year	7-Year	10-Year	30-Year	10-year moving average of 30-Year analysis period rates
1979	2.8	3.4	4.1	4.6	5.4	
1980	2.1	2.4	2.9	3.3	3.7	
1981	3.6	3.9	4.3	4.4	4.8	
1982	6.1	7.1	7.5	7.8	7.9	
1983	4.2	4.7	5.0	5.3	5.6	
1984	5.0	5.4	5.7	6.1	6.4	
1985	5.9	6.5	6.8	7.1	7.4	
1986	4.6	5.1	5.6	5.9	6.7	
1987	2.8	3.1	3.5	3.8	4.4	
1988	3.5	4.2	4.7	5.1	5.6	5.79
1989	4.1	4.8	5.3	5.8	6.1	5.86
1990	3.2	3.6	3.9	4.2	4.6	5.95
1991	3.2	3.5	3.7	3.9	4.2	5.89
1992	2.7	3.1	3.3	3.6	3.8	5.48
1993	3.1	3.6	3.9	4.3	4.5	5.37
1994	2.1	2.3	2.5	2.7	2.8	5.01
1995	4.2	4.5	4.6	4.8	4.9	4.76
1996	2.6	2.7	2.8	2.8	3.0	4.39
1997	3.2	3.3	3.4	3.5	3.6	4.31
1998	3.4	3.5	3.5	3.6	3.8	4.13
1999	2.6	2.7	2.7	2.7	2.9	3.81
2000	3.8	3.9	4.0	4.0	4.2	3.77
2001	3.2	3.2	3.2	3.2	3.2	3.67
2002	2.1	2.8	3.0	3.1	3.9	3.68
2003	1.6	1.9	2.2	2.5	3.2	3.55
2004	1.6	2.1	2.4	2.8	3.5	3.62
2005	1.7	2.0	2.3	2.5	3.1	3.44
2006	2.5	2.6	2.7	2.8	3.0	3.44
2007	2.5	2.6	2.7	2.8	3.0	3.38
2008	2.1	2.3	2.4	2.6	2.8	3.28
2009	0.9	1.6	1.9	2.4	2.7	3.26

2010	0.9	1.6	1.9	2.2	2.7	3.11
2011	0.0	0.4	0.8	1.3	2.3	3.02
2012	0.0	0.4	0.7	1.1	2.0	2.83
2013	-1.4	-0.8	-0.4	0.1	1.1	2.62
2014	-0.7	0.0	0.5	1.0	1.9	2.46
2015	0.1	0.4	0.7	0.9	1.4	2.29
2016	0.3	0.6	0.8	1.0	1.5	2.14
2017	-0.5	-0.3	0.0	0.1	0.7	1.91
2018	-0.8	0.6	0.3	0.1	0.6	1.69
Historical Average					3.72	

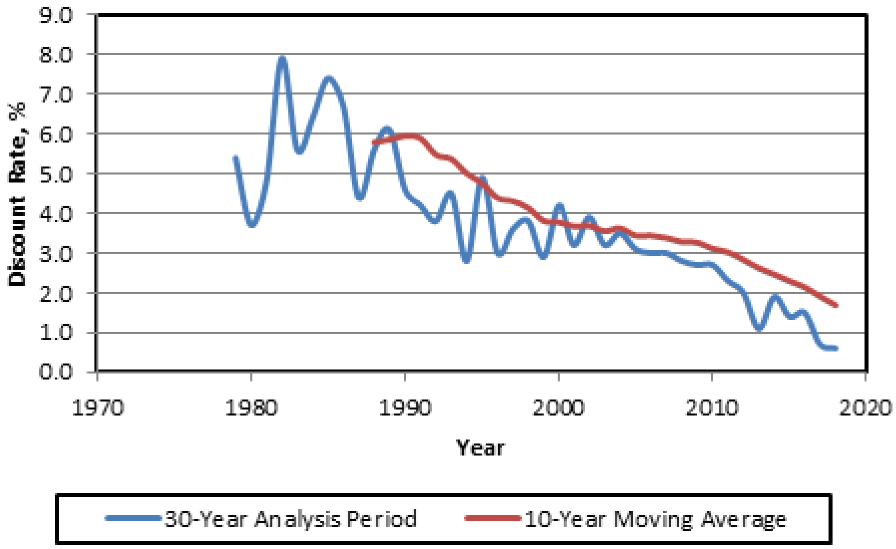

Figure 5. OMB 30-year analysis period real interest rate trend and 10-year moving average.

LCCA Implementation Guide

LCCA comparing flexible to rigid pavements will be prepared for all new alignments and reconstruction projects with:

- 10,000 or more ADT and 30% trucks or more, or
- ADT above 100,000 regardless of % trucks.

LCCA is not required for projects with ADT less than 10,000, and the criteria to determine if LCCA is optional or required is illustrated in Figure 6. The pavement design option that produces a 20% lower life cycle cost should be selected.

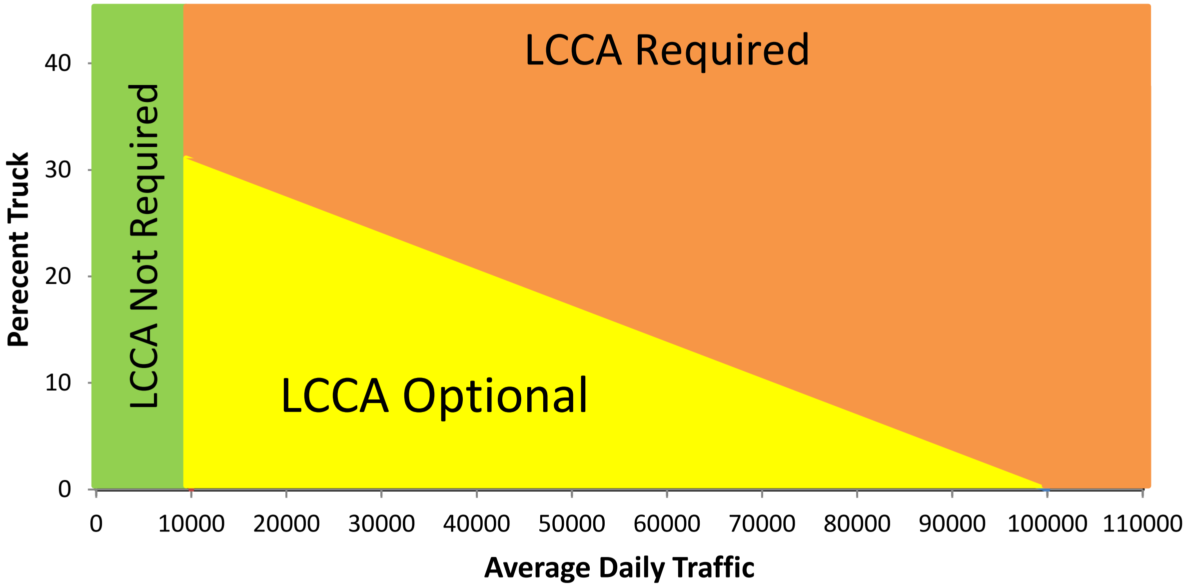

Figure 6. LCCA truck and daily traffic implementation requirements

Exceptions to this LCCA implementation guide include:

- Widening projects
- Short projects tying into pavements of the same type on both ends
- Projects where one pavement type is not feasible due to constructability issues, lane closure limitations, pavement profile elevation restrictions, geometric constraints, etc.