CHAPTER 4
LIFE CYCLE COST ANALYSIS

4.1 Introduction

There is a common notion that the cost of construction of roads with concrete pavement is more when compared to flexible pavement and requires large quantity of cement and other aggregate materials. The cost of construction of pavement is a major criterion for choice of pavement type, flexible or rigid, particularly when the funds are scarce and the government funding is limited. It is therefore required to examine the economics of various pavement types not only for the initial construction cost but also for the life cycle costs which includes the discounted maintenance and overlay costs that are incurred during the design life of the pavement. The cost of pavement thus include a) initial construction Cost b) Maintenance and Rehabilitation/Strengthening Costs

4.1.1 Initial Construction Costs

The initial cost of construction of pavement depends on various factors like:

Type of the Pavement, Flexible or Rigid

Pavement design thickness and Composition of various layers of pavement governed by the strength of the subgrade soil and traffic loading.

Cost of various ingredients, which include cement, bitumen, stone aggregates, sand etc. Cost of mixing and laying, i.e. construction.

The above ingredients have a wide range of variability in rates across the country and is difficult to generalise.

4.1.2 Maintenance Costs

The Maintenance includes the upkeep of pavement during the design life of pavement. The maintenance details are discussed in the succeeding paragraphs.

4.2 Life Cycle Cost Analysis (LCC)

The choice of appropriate economically advantageous pavement type, flexible or rigid, is made by carrying out Life Cycle Cost (LCC) analysis which takes in to account the initial investment cost plus the maintenance/ rehabilitation cost over the design life of

the pavement structure. Life cycle cost analysis can be defined as a procedure by which a pavement design alternative will be selected which will provide a satisfactory level of service at the lowest cost over design life. The economic analysis methods used most commonly for this purpose include present worth, annualised cost, and rate of return. The analysis is most sensitive to the factors of inflation, discount rate, and analysis period.

In the subsequent paragraphs an attempt has been made to study the long-term economic viability of pavement types using Present-Worth method of analysis. Thus, as a case study, comparative cost of one kilometre each of flexible pavement and rigid pavement representing a uniform section has been worked out at current market rate/DSR rate, with respective maintenance strategy. For ease of presentation, it is assumed the road is to be constructed with entirely new carriageway and the year of opening for traffic is 2008.

4.2.1 Design Parameters

(i) Flexible Pavement

Flexible Pavement is designed for life of 20 years. The pavement crust for flexible pavement is given in **Table 4.1**

Table 4.1 Composition of Flexible Pavement

Period	Thickness of layer, mm
Drainage layer (GSB II)	200
Granular sub-base (GSB I)	200
Wet-mix macadam (WMM)	250
Dense bituminous macadam(DBM)	140
Bituminous concrete (BC)	40

The overlays to be constructed at 10 years are essentially for strengthening purposes. The overlay crust is given in **Table 4.2** .

Table 4.2 Composition of Flexible Overlay

Period	Thickness of layer, mm
Profile Correction course (BM) Bituminous macadam(BM)	50 50
Bituminous concrete (BC)	40

It is estimated that due to high intensity of traffic, it will take about 5 years of passage of traffic for 40 mm thick bituminous concrete laid initially at roughness

value of 1500 mm/km to attain fair to poor category of roughness value of 3500 mm/km. Hence the flexible pavement needs to be resurfaced every 5 years for improvement of its riding quality with a layer of 40 mm thick bituminous concrete, to be laid at intervals of 5, 10 , 15 years, while strengthening has to be undertaken at 10 years.

(ii) Rigid Pavement

Rigid pavement is also designed for 20 year life. The crust of the same is given in **Table 4.3**.

Table 4.3 Composition of Rigid Pavement

Sl. No.	Item	Details	Remarks
1	M-35 Pavement Quality Concrete (PQC)	300 mm thick	
2	Dry Lean Concrete (DLC)	150 mm thick	
3	Granular Sub-Base (GSBI)	200 mm thick	
4	Granular Sub-Base (GSBII)	200 mm thick	
5	Dowel Bars (MS)	32 mm dia x 600 mm long	Spacing @ 300 mm c/c
6	Tie Bar	12 mm dia x 640 mm long	Spacing @ 600 mm c/c

4.2.2 Other Comparison Parameters

The various parameters as Input to LCC model are described as follows:

Capital Cost : Capital Cost consisting the initial cost of construction.

Maintenance Cost : *Flexible alternatives*

Routine maintenance in the form of patching, pothole repair, sealing of cracks etc. as per IRC-82.

Periodic Rehabilitation by way of strengthening overlays.

		Functional overlays
	:	*Rigid Alternatives* *Joint sealing, Repairs of joint spalling and Pavement Retexturing.*
Period of Analysis	:	20 years
Discount Rate	:	12-10 % *
Inflation Rate	***:***	***5.5 %***

Alternatives to be considered:

(i) Flexible pavement designed for 20 years and strengthened at every 10 year and functional overlays at every 5 year and routine maintenance as and when required over the analysis period.

(ii) Rigid pavement designed for 20-year period with routine maintenance.

4.3 Cost Estimate

4.3.1 Flexible Pavement

Based on the above design, the cost estimate for flexible pavement is summarised in **Table 4.4**, **Table 4.5** and **Table 4.6**.

Table 4.4 - Initial Cost Estimate for Flexible Pavement (New)

Pavement Layer	Cost/km	Length (m)	Thickness (mm)	Width(m)	Rate (Rs)
BC	1,181,880	1000	40	7.00	4221/Cu m
DBM	3,452,540	1000	140	7.00	3523/Cu m
WMM	820,750	1000	250	7.00	469/Cu m
GSB I	593,600	1000	200	7.00	424/Cu m
GSB II	506,800	1000	200	7.00	362/Cu m
Prime Coat	112,000	1000	1 Coat	7.00	16/Sq m
Tack Coat	126,000	1000	2 Coats	7.00	9/Sq m
Initial Cost	**6,793,570**				

Table 4.5 - Cost Estimate for Flexible Pavement-Strengthening Overlays (10^{th} and 20^{th} year)

Pavement Layer	Cost(Rs.)	Length (m)	Thickness(mm)	Width(m)	Rate (Rs)
BC	1,181,880	1000	40	7.00	4221/Cu m
BM	975,100	1000	50	7.00	2786/Cu m
PCC	975,110	1000	50 Av	7.00	2786/Cu m
Total	**3,132,080**	PCC – Profile Corrective Course			

Table 4.6 - Cost Estimate for Flexible Pavement-Renewal (Functional) Overlays (5^{th}, 10^{th} and 15^{th} year)

Pavement Layer	Cost	Length(m)	Thick (mm)	Width(m)	Rate (Rs)
BC	1,181,880	1000	BC - 40 mm	7.00	4221/cu m

4.3.2 Rigid Pavement

Based on the above design, the cost estimate for flexible pavement is summarised in **Table 4.7**.

Table 4.7 - Cost Estimate for Rigid Pavement

Pavement Layer	Cost (Rs.)	Length (m)	Thickness(mm)	Width(m)	Rate (Rs)
PQC	6,350,400	1000	300	7.00	3024/Cu m
DLC	1,074,150	1000	150	7.00	1023/Cu m
GSB-I	593,600	1000	200	7.00	424/Cu m
GSB-II	506,800	1000	200	7.00	362/Cu m
Total	**8,524,950**				

Maintenance Cost of Rigid Pavement

a) Joint Seals (Preformed Seals)

50 % of the joint sealants are to be replaced in every 5 year

Joint Length

Contraction Joint length	1556 m
Longitudinal Joint length	1000 m

Length to be replaced every 5 years

Contraction Joint	778 m
Longitudinal Joint	500 m

Table 4.8 - Cost Estimate for Joint Seals (Preformed Seals)

Joint Sealant	Unit	Quantity	Rate	Cost
Contraction Joint	m	778	20	15560
Longitudinal Joint	m	500	20	20000
			Total	35560

b) Concrete Spalling

0.5% of Joint length for a width of .50m in every year

10th year spalling concrete =94.65 Sqm

c) Surface Texture

2 Times in 30 years i.e., 10^{th} and 20^{th} year

Table 4.9 Cost Estimate for Concrete Spalling and Surface Texturing

Maintenance Item	Unit	Quantity	Rate	Cost
Repairs for Concrete Spalling	Sq m	94.7	3000	28410
Re-texturing	Sq m	8000	80	640000

4.4 Construction and Maintenance - Investment Options

4.4.1 Flexible pavements

The total capital cost of construction is proposed to be invested over a period of two years as follows:

Total Cost	:	Rs 6,793,570
First Year Investment	:	Rs 3,396,785 – 50%
Second Year Investment	:	Rs 3,396,785 – 50%

4.4.2 Rigid Pavements

The total capital cost of construction is proposed to be invested over a period of two years as follows:

Total Cost	:	Rs 8,524,950
First Year Investment	:	Rs 4,262,475 – 50%
Second Year Investment	:	Rs 4,262,475 – 50%

4.5 Economic Analysis

The details of economic analysis based on present-worth method, i.e. present value of total of construction and maintenance costs over the analysis period of 20 years are provided in **Annexure-4.1.**

4.6 Conclusions

In the Life Cycle Cost Analysis, the present values of all the costs for each of the alternative have been computed. The alternative giving the lowest present value of the costs is to be considered as the most advantageous option from economic perspective.

Taking into consideration the above parameters, the net present value at 12 % discount rate for flexible option is Rs.9,740,233/- and for rigid option, it is Rs.8,265,409/- at current market rates. Similarly the net present values are calculated at 11 & 10 percent discount values and presented in **Annexure-4.1**.

As per the life-cycle cost analysis rigid pavement proves to be economical as compared to flexible pavement while developing all together new crust. Therefore, it is suggested to develop major road 1,2,3,7, 8 ,16,17,18,19,28 and 32 with rigid pavement and others with flexible pavement.