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LIFE CYCLE COST ANALYSIS FOR SELECTING PAVEMENT MAINTENANCE ALTERNATIVES, A CASE STUDY OF KOTA - BARAN ROAD (NH-27)

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***Abstract* — Most of our roads are bituminous pavements. Bituminous pavements are showing early sign of distresses worldwide due to increasing loads, intensity of traffic, high tyre pressure, etc. The rutting, cracking, ageing, etc. are quite common. Performance of bituminous pavements in hot climatic regions is thus becoming somewhat doubtful. Concrete on the other hand is known to be a relatively stiffer material and is relatively less sensitive to high temperature. Accordingly, concrete pavements can be adopted as an alternative to traditional bituminous pavements. Therefore, cost-effectiveness of PCC overlays (whitetopping) over bituminous overlay needs to be examined. Use of concrete overlay as a rehabilitation measure for strengthening of deteriorated bituminous pavements is increasing. This is one of the rehabilitation method which results in lower maintenance cost. This method of maintenance and rehabilitation of deteriorated bituminous pavements can be adopted after Life Cycle Cost Analysis. By adopting whitetopping, a large network of roads can be rehabilitated at reasonable costs and these rehabilitated roads will have an improved lifespan than conventional flexible pavements. Whitetopped roads on an average have proved to be quite cost-effective besides giving an additional life of 20 to 30 years on average. In the present study, an attempt is made to evaluate the structural and functional condition of the existing flexible pavement at Kota Baran Road (NH-27) s and provide a cost effective rehabilitation solution. The field work consists of road inventory, traffic studies, Bump Integrator, Visual pavement condition survey and BBD studies. The summary of overall condition assessment on functional and structural evaluation resulted overlay. In the present work, an attempt is made to design concrete overlay section as a rehabilitation alternative for the in-service flexible pavements and compared to conventional flexible overlays with Life Cycle Cost Analysis. Sensitivity analysis for risk and uncertainty analysis is done for different discount rate and inflation rate*.**

Key words: Life Cycle Cost Analysis; Pavement Maintenance and rehabilitation; Conventional Whitetopping; flexible overlay

I. INTRODUCTION

India has the second largest road network in the world at 4.7 million km. This road network transports more than 60 per cent of all goods in the country and 85 percent of India's total passenger traffic. Road transportation has gradually increased over the years with the improvement in connectivity between cities, towns and villages in the country which can provide fast movement of goods and people with safely and economical cost to user. The Ministry of Road Transports and Highways plans to construct 33 km of National Highway everyday. Today's focus is on the construction of long-term performing pavement. Most of our roads are bituminous pavements. Bituminous pavements are showing early sign of distresses worldwide due to increasing loads, intensity of traffic, high tyre pressure, etc. The rutting, cracking, ageing, etc. are quite common. Reflective cracking is another form of distress in bituminous overlay. These distresses get more pronounced in hot climatic regions like India, since bitumen is highly sensitive to temperature. Performance of bituminous pavements in hot climatic regions is thus becoming somewhat doubtful. Concrete on the other hand is known to be a relatively stiffer material and is relatively less sensitive to high temperature. Accordingly, concrete pavements can be adopted as an alternative to traditional bituminous pavements. Whitetopped roads on an average have proved to be quite cost-effective besides giving an additional life of 20 to 30 years on average. Therefore, cost-effectiveness of PCC overlays (whitetopping) over bituminous overlay needs to be examined.

In the present work, road selected is Kota Baran Road (NH-27) in Rajasthan, India for evaluation and to provide a rehabilitation solution. Both field and laboratory investigations were carried out to evaluate the pavement performance. Selected road stretch is evaluated both functionally and structurally. Pavement condition was computed based on the distress parameters such as rut, patch, pothole and cracks.

Here, an attempt is made to design concrete overlay section as rehabilitation alternative for the in-service flexible pavements and compared to conventional flexible overlays with Life Cycle Cost Analysis. Sensitivity analysis for risk and uncertainty analysis is done for different discount rate and inflation rate.

II. LITERATURE REVIEW

There is a few research available in India for Life Cycle Cost Analysis. LCCA is process for pavement selection which is used by government agencies and consultants. Wall and smith (1998) [8] gives a guidelines for US federal agencies and stepwise procedure for LCCA. IRC SP-30 (2009) [4] gives formula for NPV and Road User Cost equations for calculation of user cost. Agency Costs are calculated from Schedule of Rates of Kota region. Criteria for Intervention and permissible limits for Roughness are tabulated in IRC-SP-76 (2008) [5] described stepwise procedure for design of whitetopping overlay. Dr, Ramachandra (2011) [2] gives overview and technical viability of Whitetopping overlay as cost effective rehabilitation alternative and case study is also explained .B Prasad (2005) [1] has done Life Cycle Cost Analysis in his research for bituminous roads Vs concrete roads. Rengaraju et al. (2008) [7] studies current practice of LCCA in United States and framed a state of art-LCCA for South Carolina state. RealCost is a Software tool available for LCCA in United States.

III. AIM & OBJECTIVES OF THE STUDY

Aim of research is to use LCCA tools and techniques to assist agencies to evaluate the costs and life of pavement improve decision-making process in order to determine a cost effective pavement alternative.

Objectives of study are as enlisted below.

1. To study current practice of LCCA.
2. To carry out assessment of governing key parameters and framework of LCCA for Indian context.
3. To develop a Maintenance and Rehabilitation Strategy with Life Cycle Cost Analysis.
4. A case study on Kota – Baran Toll Road NH 27 (1084.000 to 1184.000)

IV. DATA COLLECTION

General data

The general data presents the geometric details of the roads which were collected visually by walking along the entire stretch. The details are shown in Table 1. Road is four lane divided National highway with carriage way width of 7.25 m on each direction and paved shoulder of 1.5 m.

Existing Flexible Layers

In evaluating the condition of existing pavements, it is necessary to know the design features such as the thickness of the pavement component layers. The existing flexible pavements crust thickness were measured by excavating trail pits at the pavement-shoulder interface extending through the pavement layers and up to the level of subgrade. The details are presented in Table 1

Table 1 Road inventory and general Data

Sr No	Features	Details
1	Name of Road	Kota Baran Toll Road
2	Category of road	NH (E-W Corridor) NHDP phase 2
3	Number of lanes	4
4	Main Carriageway Width (m) (single direction)	7.25 m
5	Width of median	5.00 m
6	Width of Paved Shoulder (m)	1.25 m
7	Width of Earthen Shoulder (m)	1.00 m
8	Surface type	Flexible pavement
9	Layer composition	Sand-500mm GSB-300mm WMM-225mm DBM-75mm BM-75mm BC-40mm

Traffic volume count

Traffic census is another important aspect of pavement evaluation. Traffic survey was carried out to analyze the traffic characteristics. In the present study, the classified traffic volume study was carried out. Trucks with more than one rear axle were considered as multi axle vehicles. Traffic surveys were conducted manually, for 24 hours round the clock, by engaging 9 number of enumerators. The traffic volume survey included classified traffic volume count. The vehicles were classified as per the representative vehicles; say jeep & car are considered as car. Vehicles having more than 2 Axle and less than 6 Axel are combined in to Multi Axle Vehicle. Vehicles with configuration of more than 7 Axel are termed as Over Sized Vehicles. Selection of location is on homogenous section. So that, accurate traffic can be counted. Vehicle count is performed on both Up and Down direction at same location.

Pavement distress survey

This is one of the key aspects required for assessing the pavement condition which would help in finding rehabilitation alternatives. In the present work four types of physical distresses namely cracks, potholes, patches and rutting were considered. The identification of distress type, severity and amount were done through on-site visual survey according to IRC - 82. The pavement distress measurements were carried out for every 200m intervals on the selected roads manually. The measurements collected regarding four distress parameters in the field were used to assess. The study showed that, rutting has been the major distress affecting the roads out of all the four distress parameters

Roughness measurements

The roughness data obtained from fifth wheel Bump Integrator were calibrated by recording its response and comparing the same with that of dipstick. Dipstick is class-1 equipment which produces absolute road profiles in terms of International Roughness Index (IRI) in mm/km. The compared results reveal that all the selected roads have I.R.I values above 4.0 mm/km which indicates that the road are having frequent minor depressions and frequent shallow depressions, which is true with the existing field condition. The unevenness index of all the roads is above 4000 mm/km which indicates very poor riding quality as per IRC 16, requiring resurfacing as maintenance. Untreated roughness may affect vehicle the operating cost, comfort and safety. The reasons for higher range of roughness on all the roads may be the weathering or raveling of wearing surface with time due to traffic loading, poor drainage condition and localized failures due to the combination of causes. The roughness in terms of IRI and calibrated BI.

V. Life Cycle Cost Analysis

Initial Construction cost

This is the cost of construction of the pavement which mainly depends upon the pavement thickness governed by the strength of subgrade soil and traffic loading, cost of materials and cost of execution of the work. The above have a wide range of variability across the country and is difficult to generalize.

The existing road has flexible pavement design as described above. The construction cost of highway is as per presented in table 2.

Table 2 Construction Cost of flexible pavement

Item No.	Descriptions	Unit	Rate	Quantity	Cost
1	Subgrade	cum	154	16610.0	2557940
2	Granular Sub-base	cum	989	6750.0	6675750
3	Wet Mix Macadam	cum	1330	6307.5	8388875
4	Median and Island	cum	177	7500	1327500
5	Dense Graded Bituminous Macadam	cum	7415	1087.5	8063812.5
7	Bituminous Macadam	cum	5945	1087.5	6465187.5
6	Bituminous Concrete	cum	8493	580.0	4925940
8	Prime coat	sqm	35	45000.0	1575000
9	Tack coat	sqm	19	29000.0	551000
10	Seal Coat	sqm	60	14500.0	870000
Total Construction Cost					4,14,01,005

Maintenance cost

The maintenance cost includes the maintenance of pavement during the design life of pavement to keep the pavement at the specified service level. The choice of appropriate economically advantageous pavement type, flexible or rigid is made by Life Cycle Cost Analysis (LCCA) which takes in to account the initial investment cost and also he maintenance & rehabilitation cost over the design life of pavement. LCCA 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 least cost over life cycle. The economic analysis methods used most commonly for this includes present worth, annualized 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 Net Present Value method of analysis. Thus, as a case study, comparative cost of 1 km each of flexible and whitetopping overlay representing the uniform section has been worked out at current market rate, with respective maintenance strategy.

Accordingly, for this purpose, a typical pavement composition and its cost for a four lane Kota Baran road (NH-27) has been adopted for the assessment.

Routine maintenance schedule for flexible pavement is as per following.

- It is assumed bituminous overlay will laid on 10th, 20th and 30th year after construction having 75 mm Dense Bituminous Macadam (DBM) with 40 mm Bituminous Concrete(BC).
- Surface Renewal for flexible pavement are to be provided as per MoRTH guidelines once in 5 years of 25 mm Bituminous Concrete (BC).

Cost of flexible maintenance are as tabulated in table 3 and table 4 for rehabilitation and resurfacing respectively.

Table 3 Rehabilitation Cost of Flexible Overlay (BC 40 mm with DBM 75mm)

Item No.	Description of Work	Unit	Rate	Quantity	Cost (Rs.)
1	Bituminous Concrete	cum	8493	580	4925940
2	Dense Graded Bituminous Macadam	cum	7415	1087.5	8063812
3	Scarifying existing bituminous surface	sqm	4	8500	34000
4	Tack Coat	sqm	19	14500	275500
5	Prime coat	sqm	35	14500	507500
6	Seal Coat	sqm	60	14500	870000
	Total Rehabilitation Cost	1,44,01,252 Rs/km			

Table 4 Resurfacing Cost for Flexible overlay (BC 25 mm)

Item No.	Description of Work	Unit	Rate	Quantity	Cost (Rs.)
1	Bituminous Concrete	cum	8493	362.5	3078712
2	Prime coat	sqm	35	14500	507500
3	Seal Coat	sqm	60	14500	870000
	Total Surface Renewal		44,56,212,Rs./km		

- For White topping Overlay, design period is 20 years, so no overlay or strengthening is required, only routine crack repairs and joint sealing is done.
- Design of whitetopping overlay is as described following
- Design of whitetopping is done as per IRC SP 76 - 2008 "Tentative guidelines for conventional, thin and ultrathin whitetopping"

Design of conventional whitetopping overlay

The Design Principle adopted for conventional whittopping is similar to those of normal concrete pavements are provided in IRC: 58 "Guidelines for the design of plain jointed rigid pavements for highways" and IRC: 15 "Standard Specifications and code of practice for construction of concrete roads". These standards may be followed for design of conventional whitetopping, except determination of modified/ effective/ support modulus of subgrade reaction ("k-value"). The correlation between CBR and "k-value" for the subgrade as given in IRC 58 can be used for the design. IRC 58 does not furnish any correlating table for determining effective "k-value" for bituminous sub-base, which will be the actual sub-base for conventional whitetopping. No laboratory test results for such correlation are available in country because conventional whitetopping has not be used in the country on a significant scale. American Concrete Pavement Association (ACPA) in its engineering bulletin has given two charts for determination of modified "k-value "on the top of bituminous pavement.

One chart is for the case when the existing bituminous pavement is atop granular base and the other chart is when the existing atop cement treated base.

Design of conventional whitetopping is as described as following

- Design life = 20 years
- Growth rate (r) = 0.075
- Commercial Traffic =1250 CVPD
- Grade of Concrete = M40
- Flexural Strength of concrete = 45 kg/cm^2
- Effective modulus of Subgrade = 10 kg/cm^3
- Poisson's ratio = 0.15
- Thermal co-efficient of concrete = 10 x 10^4 / ^{0}C
- Cumulative Repetition in 20 years = 1250 * 365 * [(1.075)^{20}- 1]/0.075= 19757761 CVPD
- Design traffic on Edge = 25% of 19757761 = 4939449 CVPD
- Spacing of contraction joints = 3.5 m
- CBR (%)= 3%

Profile correction course minimum 50 mm thickness of bituminous macadam (using 60/70 bitumen) as per MoRTH Specification 2013 is suggested to correct the profile and for repair of existing bituminous pavements.
A minimum value of modified modulus of subgrade reaction 10.0 kg/cm^2/cm has been considered in the design.
Percentage of different Axle Loads assumed are given in the Table 5

Table 5 Percentages of Axle Load for the design of Conventional whitetopping

Single Axle Loads		Tandem Axle Loads	
Axle Load Class, tonnes	% of axle loads	Axle Load Class, tonnes	% of axle loads
19-21	0.6	34-38	0.3
17-19	1.5	30-34	0.3
15-17	4.8	26-30	0.6
13-15	10.8	22-26	1.8
13-11	22.0	18-22	1.5
09-11	23.3	14-18	0.5
Less than 9	30.0	Less than 14	2.0
Total	93.0	Total	7.0

Traffic for design consideration is taken as =1250 CVPD .Design from fatigue Consideration using IRC 58-2011 is given under Table 6 as per the parameters presumed.
Trail Thickness = 26cm
Subgrade modulus = 10.0 kg/cm^2/cm
Design Period = 20 years

Table 6 Design from fatigue consideration

Single Axle Loads		Tandem Axle Loads	
Load in tonnes	Expected Repetition	Load in tonnes	Expected Repetition
20	29637	36	14818
18	74092	32	14818
16	237093	28	29637
14	533460	24	88910
12	1086676.84	20	74092
10	4801135	16	24697
Less than 10	1481832	Less than 14	98789
Total	4593679	Total	345761

Modulus of Rupture= 45kg/cm^2/cm (Third point loading)
Load Safety Factor = 1.0

Table 7 Stress Ratio at different Axle Load under the category of single axles

Single Axle Load, tonnes	Stress Kg/cm^2	Stress Ratio	Expected Repetitions	Allowable Repetitions	Fatigue Life Consumed
20	27.5	0.61	29637	2.34 x 10^4	1.26
18	25.0	0.55	74092	1.24 x 10^5	
16	22.3	0.48	237093	2.4 x 10^6	
14	20.1	0.44	533460	571500	
12	17.4	0.37	1086676.84	Infinite	
10	15.6	0.33	4801135	Infinite	
Less than 10	12.5	0.27	1481832	Infinite	
		Total	4593679	4593679	>1

Hence fatigue life shows that design is not safe.
So can make an attempt by increasing trail design thickness of slab
Trial Thickness = 26cm
Subgrade modulus = 10.0 kg/cm^2/cm
Design Period = 20 years
Modulus of Rupture = 45kg/cm^2/cm (Third point loading)
Load Safety Factor = 1.

Table 8 below shows stress ratio for different single axel loads for trail thickness of 26 cm. Stress ratio and expected repetitions as obtained from charts of and Table 5 of IRC 58 respectively.

Table 9 shows stress ratio for tandem axel loads.

Table 8 Stress Ratio at different Axle Load under the category of single axles

Single Axle Load, tonnes	Stress Kg/cm^2	Stress Ratio	Expected Repetitions	Allowable Repetitions	Fatigue Life Consumed
20	25.2	0.56	29637	9.41×10^4	0.310
18	22.5	0.50	74092	7.62×10^5	0.099
16	20.5	0.45	237093	6.279×10^6	0.003
14	18.2	0.40	533460	Infinite	Infinite
12	16.4	0.35	1086676.84	Infinite	Infinite
10	13.5	0.30	4801135	Infinite	Infinite
Less than 10	12.0	0.26	1481832	Infinite	Infinite
		Total	4593679	4593679	0.412

Table 9 Stress Ratio at different Axle Load under the category of Tandem axles

Tandem Axle Load, tonnes	Stress Kg/cm^2	Stress Ratio	Expected Repetition	Allowable Repetitions	Fatigue Life Consumed
36	20.3	0.45	14818	6.279×10^6	0.0023
32	18.4	0.41	14818	Infinite	Infinite
28	17.8	0.39	29637	Infinite	Infinite
24	15.8	0.35	88910	Infinite	Infinite
20	-	-	74092	infinite	Infinite
16	-	-	24697	infinite	Infinite
Less than 16	-	-	98789	infinite	Infinite
		Total	138304		0.0023

The cumulative life consumed both by single and tandem is being less than 1; the design is safe for the traffic proposed from fatigue consideration.

➢ *Check for Temperature Stress*

Edge wrapping Stress = (E ᾱ t C) /2
L= 450 cm
B= 350 cm
l = 93.35 cm
L/l = 4.82
C = 0.67 from figure 2 of IRC 58 2002

- The temperature differential was taken for Rajasthan region.
- Total of temperature wrapping stress and highest axel load stress = 25.2+15.27 = 40.47 kg/cm^2 which is less than flexural strength 45 kg/cm^2. So the pavement thickness of 28 cm is safe under the combined action of wheel load and temperature.

➢ *Check for Corner Stress*

Corner stress is not critical in a dowel pavement, the corner stress can be calculated value from the following formula given in IRC 58-2002

- 98^{th} percentile axel load is 16 tonne. Therefore, wheel load is 8 tonne.
- Radius of relative stiffness is found from equation $l = (Eh^3/12(1-\mu^2)\ k)^{0.25}$

Where, E= Modulus of Elasticity =$3 \times 10^5 Kg/cm^2$
l= Radius of Relative Stiffness, cm
h= thickness of Concrete slab, cm
μ = Poisson's Ration = 0.15
k= modulus of subgrade reaction = 10 Kg/cm^3

- Considering a single axel dual wheel corner stress =15.53 Kg/cm^3
- This is less than minimum characteristic flexural Strength 45 kg/cm^2 flexural strength of concrete corresponding to M40 grade at 28 day of curing.

Hence, Design is safe.
Thickness adopted is 280 mm for heavy traffic road as per our condition.

As per IRC-SP: 76-2008, construction of conventional whitetopping is to be done in following manner. Table 10 shows cost of whitetopping. Pre overlay surface preparation is done in one of three ways which are direct placement, milling of existing pavement or placement of levelling course. Here in our case, existing site has deteriorated pavement conditions. So we can go for option of levelling course.

Levelling course of bituminous mix is used to produce a uniform surface for paving. A levelling course typically consist of minimum 50 mm of Bituminous Macadam (BM) or Dense Bituminous Macadam (DBM). Exact quantity will depend upon the undulations .Total construction cost are as calculated in Table 10.

Table 10 Construction Cost of White topping

Item No.	Descriptions	Unit	Rate (Rs)	Quantity	Cost
1	Scarifying existing bituminous surface	Sqm	4	14500	58000
2	Bituminous Concrete	Cum	8493	725	6157425
3	Cement Concrete Pavement Construction of un-reinforced, dowel jointed, plain cement concrete pavement M-40	Cum	5847	4060	23738820
Total Construction Cost (Rs)					2,99,54,245

Road User Cost

User cost are those that borne by the vehicles that travel on the road. These cost comprise of Vehicle Operating Cost (VOC), time costs of passenger and commodities in transit and accident cost. In the Present analysis, only VOC is considered, assuming the other two costs are equal in both types of pavements. VOC consists of wear and tear of vehicle, fuel, lubricants, depreciation and fixed cost. It has been observed that a well-constructed bituminous concrete surface has a smooth riding quality with a roughness index around 2000 mm/km but the riding quality deteriorate with traffic and may reach value of roughness of 4000 mm/km in a few years and renewal wearing course is given at the stage to improve the riding quality. On the other hand, initial roughness of cement concrete surface is maintained almost throughout its life with very little deterioration, for comparison of life cycle cost, roughness of bituminous surface is taken as analysis has been done and for concrete surface 2000 mm/km. Year wise VOC is calculated and given in table. VOC is calculated as
VOC per year = (No. of vehicle per day) * (365) * (VOC Rs /km)
VOC (Rs/km) is found from IRC SP: 30 Manual of economic evaluation for transportation projects. Table 11 shows Road User Cost for two alternatives.

Table 11 Road User Cost for flexible and rigid overlay

No	Year	VOC For Flexible alternative (in lakhs)	VOC For Rigid alternative (in lakhs)
1	2016	18788	16258
2	2017	20302	20197
3	2018	21939	21712
4	2019	23712	23340
5	2020	25635	25091
6	2021	26973	26972
7	2022	29146	28995
8	2023	31495	31170
9	2024	34041	33508
10	2025	36801	36021
11	2026	38723	38723
12	2027	41842	41627
13	2028	45215	44749
14	2029	48870	48105
15	2030	52833	51713
16	2031	55592	55592
17	2032	60072	59761
18	2033	64915	64243
19	2034	70166	69061
20	2035	75858	74241
21	2036	79810	79809
Total RUC		937101 (Rs in lakhs)	927163 (Rs in lakhs)

Life Cycle cost is total of Agency cost and Road User Cost. Extra fuel cost of 14% is taken as per research of FHWA in flexible for two alternatives life cycle cost is calculated as mentioned in following Table 12 and Table 13. Period of analysis has been considered as 20 years starting from 2016. The discount rate is adopted as 12% and inflation rate in 5 % as per government policy for future rise in price of materials.

Table 12 Life Cycle Cost for Flexible overlay

No	Year	construction and maintenance cost (Rs in lakhs)	VOC (Rs in lakhs)	Fuel Saving cost (Rs in lakhs)	Total Cost (Rs in lakhs)	$(1/1.12)^n$	NPV (Rs in lakhs)
1	2016	5.00	18788	9.58	18803	1.00	18802.82
2	2017	5.25	20302	10.78	20318	0.89	18141.31
3	2018	5.51	21939	12.13	21956	0.80	17503.31
4	2019	5.79	23712	13.64	23732	0.71	16891.68
5	2020	6.08	25635	15.35	25656	0.64	16305.16
6	2021	63.26	26973	17.27	27053	0.57	15350.86
7	2022	6.70	29146	19.42	29172	0.51	14779.28
8	2023	7.04	31495	21.85	31523	0.45	14259.61
9	2024	7.39	34041	24.58	34073	0.40	13761.42
10	2025	7.76	36801	27.66	36836	0.36	13283.57
11	2026	242.73	38723	31.11	38997	0.32	12555.99
12	2027	8.55	41842	35.00	41886	0.29	12041.15
13	2028	8.98	45215	39.38	45263	0.26	11617.86
14	2029	9.43	48870	44.30	48924	0.23	11212.05
15	2030	9.90	52833	49.84	52892	0.20	10822.81
16	2031	103.04	55592	56.07	55751	0.18	10185.53
17	2032	10.91	60072	63.08	60146	0.16	9811.09
18	2033	11.46	64915	70.96	64998	0.15	9466.58
19	2034	12.03	70166	79.83	70258	0.13	9136.29
20	2035	12.63	75858	89.81	75960	0.12	8819.48
21	2036	395.37	79810	101.04	80306	0.10	8325.07
				Total cost (Lakhs/km)			273072.9061

Table 13 Life Cycle Cost for rigid overlay

No	Year	Maintenance (Rs in lakhs)	VOC (Rs in lakhs)	Total Cost (Rs in lakhs)	$(1/1.12)^n$	NPV (Rs in lakhs)
1	2016	5.00	16258.07	16263.07	1.00	16263.07
2	2017	5.25	20197.35	20202.60	0.89	18038.04
3	2018	5.51	21712.16	21717.67	0.80	17313.19
4	2019	5.79	23340.57	23346.36	0.71	16617.48
5	2020	6.08	25091.11	25097.19	0.64	15949.72
6	2021	6.38	26972.94	26979.33	0.57	15308.79
7	2022	6.70	28995.92	29002.62	0.51	14693.63
8	2023	7.04	31170.61	31177.64	0.45	14103.18
9	2024	7.39	33508.40	33515.79	0.40	13536.47
10	2025	7.76	36021.53	36029.29	0.36	12992.52
11	2026	8.14	38723.15	38731.29	0.32	12470.44
12	2027	8.55	41627.39	41635.94	0.29	11969.34
13	2028	8.98	44749.44	44758.42	0.26	11488.37
14	2029	9.43	48105.65	48115.08	0.23	11026.73
15	2030	9.90	51713.57	51723.47	0.20	10583.65
16	2031	10.39	55592.09	55602.48	0.18	10158.37
17	2032	10.91	59761.50	59772.41	0.16	9750.17
18	2033	11.46	64243.61	64255.07	0.15	9358.39
19	2034	12.03	69061.88	69073.91	0.13	8982.34
20	2035	12.63	74241.52	74254.15	0.12	8621.41
21	2036	13.27	79809.63	79822.90	0.10	8274.98
			Total cost (Lakhs/km)			267500.29

VI. SENSITIVITY ANALYSIS

Life Cycle Cost Analysis is computation of cost over its life cycle. Thus it is about predicting future conditions, there are some uncertainty in predictions. Sensitivity analysis is done to check effect of governing parameters such as discount rate and inflation on Life Cycle Cost. LCCA at different discount rates and inflation rates are presented in table 14

Table 14 Sensitivity Analysis

No	Discount rate	Inflation Rate	LCCA (Flexible alternative) Rs in Lakhs	LCCA (Whitetopping alternative) Rs in Lakhs
1	12	5.00	267500.29	273072.90
2	14	5.5	231000.32	236125.57
3	10	4.5	310510.77	320243.85
4	8	4	374354.97	381234.34

VII. CONCLUSION AND RECOMMENDATIONS

Conclusion

- It has been concluded that there is heavy traffic, less number of light commercial vehicles and more number of commercial vehicles because of it is cement manufacturers factories in near Kota area.
- Pavement condition of Kota –Baran National highway is very poor because of black cotton soil subgrade and lower CBR value. Pavement maintenance cost is too much higher as per historical maintenance cost data.
- Site is located where cement and construction material is easily available so that construction cost of rigid overlay is lower than any other areas.
- Life cycle cost analysis shows that Rigid overlay has less NPV value than flexible overlay. So it is concluded that rigid overlay is beneficiary over flexible overlay as it requires less number of rehabilitation and resurfacing treatments and good pavement condition saves fuel cost and lowers road used cost.
- LCCA conclude that, not only construction and maintenance cost should be considered but also road user cost and fuel saving cost should be taken in to analysis in search of cost effective decision.

Recommendations

- In India, LCCA process should be adopted as code of practice for decision making of pavement alternative.
- A excel spread sheet should be available for standardized framed Life Cycle Cost Analysis in India.
- Several locations can be analyzed in India where soil subgrade is poor having low CBR value and easy availability of material. LCCA should be applied to find viable alternative.
- Planning commission should use LCCA tool for budgeting nation’s infrastructure development.

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