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Study on Different Alternative Maintenance Strategy for Flexible Pavement Using HDM

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Abstract: *Pavements which are left to weaken without promising support treatment are probably going to require major rehabilitation and reconstruction much sooner than those which are legally kept up. Highway Development and Management device, HDM-4 programming, created by the World Bank for worldwide applications is used for recognizing an ideal upkeep technique for roadway pavements. The HDM-4 tool provides the deterministic approach in data input and processing also utilizes data on existing road condition, traffic volume and crust composition to predict road deterioration as per the road conditions in terms of any one variable such as cracks, roughness, pothole, raveling, etc.,. HDM-4 simulates the best alternative that need to be applied based on Economic Internal Rate of Return (EIRR) which consist Total Transportation Cost (TTC), Vehicle Operating Cost (VOC), roughness pattern for various alternatives which are evaluated using HDM-4. HDM-4 is used for the present project analysis by using the existing data of upgraded six lane road in order to select the best economic alternative from four different maintenance alternative strategies. Optimum alternative is selected based on alternative which yields maximum Net Present Value /Cost Ration and high Economic Internal Rate of Return (EIIR).*

Key words: *Highway Development and Management (HDM), Economic Internal Rate of Return (EIRR), Net Present Value (NPV)*

I. Project Background

Presently NHAI has called for the concessionaires to take up the improvement proposals in two packages as listed below, to upgrade the existing divided dual two lane carriageway to dual three lane carriageway with service roads on either side to ease the traffic flow.

Package 1: From Bengaluru to Nidghatta (before Maddur) from km 18.000 (Ex.Ch 341+900) to km 74.200 (Ex.Ch 286+900) around 56.2 kms.

Package 2: From Nidghata (before Maddur to Mysuru from km 74.200 (Ex.Ch 286+900) to km 135.300 (Ex.Ch 224+000) around 61.1 kms.

For the academic purpose and partial fulfillment of MTech in Highway Engineering, the present study is limited to the **Road Section from Bengaluru to Bidadi from Km 18.000 to Km 28.950 (length 10.95 km).**

II. Objective of the study

The broad objective of the study includes the analysis of different maintenance strategy alternatives and selection of most economic maintenance strategy using HDM-4, for the proposed up gradation of existing dual two lane carriageway to dual six lane carriageway configuration.

III. Literature Review

Jain et al. (2013) considered the study which consisted of one Expressway and National Highway. Expressway had been divided into five subsections and NH had been divided into8 sub-sections. The sub-segments so partitioned were very homogeneous inside themselves to the extent climatic and geometric conditions are considered however differ extensively from each other in activity qualities and asphalt surface conditions. Information for the examination was characterized as the 'Multilane Highway Network' and 'Multilane Vehicle Fleet' database records which included different parameters. The aggregate activity regarding Annual Average Daily Traffic (AADT), introductory synthesis of different vehicles for the chose asphalt areas had been utilized for the investigation in HDM-4. The intervention criteria's for various alternatives were selected accordingly. One of main objectives for long-term pavement management was to find the optimal number of maintenance treatments and the best timings and intensities thereof to maintain a given road section during a predefined analysis period. Overall objective of this research work was to tackle the lack of innovative techniques and to support decision-making on optimal strategies of investment and preservation for road infrastructure. HDM-4 has emerged as a very powerful tool for developing various aspects of pavement maintenance management system such as predicting the pavement deterioration, programming of maintenance and rehabilitation works, carrying out lifecycle cost analysis and cost optimization.

Daeseok Han et.al (2013) tried to address this criticism by introducing Section based Multi-functional Calibration Method for Pavement Deterioration. Truth be told, numerous HDM-4 clients regularly surrender usage because of these reasons. To relieve these issues, the creator recommends an enhanced adjustment strategy for the HDM-4 decay models significant to the weakening pace and state of the bend. The advantage of these new methodologies is thought to be stretched out to adjusting the product with least information, tending to issues on inadequate asphalt stock information which is the most significant issues in the alignment procedure.

IV. Field Data Collection for the Study

To assess the structural and functional condition of existing pavement, and to suggest suitable recommendations on corrective measures for the improvement the following studies, in the field, were undertaken:

- ✓ Reconnaissance Survey
- ✓ Road Inventory Survey
- ✓ Assessment of existing pavement surface condition
- ✓ Traffic Study
- ✓ Test Pit Observations

Reconnaissance Survey

The Project road section under study is a part of NH 275 between Bengaluru and Mysuru which starts at NICE road interchange junction near Panchmukhi Ganesh temple in Bengaluru at km 18+000 (Ex.Ch 341+900) and ends at km 28+950 (Ex.Ch 330+800) near Bidadi. Total length of the road section is around 10.95 kms. It passes through Bengaluru, Ramanagara and Mandya Districts..

Road Inventory

Entire project road stretch is in plain terrain. Land use is of mixed nature with agricultural, built-ups, industrial and partial built up. Major settlements encountered along the road include Kumbalgodu and Bidadi (both industrial and built-up).

Main carriageway is of bituminous surface having divided dual two lane configurations with earthen shoulders on either side at most of the locations. At few locations divided three lane configurations were also observed. Earthen Shoulder on either side of the carriageway is varying from 2.5m to 3.5m.

Median width was varying from 1.5m to 2.5m with central fencing and electric poles at most of the urban locations. Summary of carriageway configurations are given in **Table 1.**

Table 1: Summary of Carriageway Configuration

Carriageway Configuration	LHS		RHS	
2 Lane with Earthen Shoulder	7.3 m	66%	10.1 m	91%
2 Lane with Paved Shoulder	0.8 m	7%	1.0 m	9%
3 Lane with Earthen Shoulder	1.0 m	9%	---	---
3 lane with Paved Shoulder	2.0 m	18%	---	---

Existing Pavement & Its Surface Condition

Existing pavement surface is flexible pavement layers comprising of Bituminous Concrete (BC) as wearing surface, Dense Bituminous Macadam (DBM) as binder course, Wet Mix Macadam (WMM) as granular base layer and Granular Sub Base (GSB) layer above sub grade. Generally, the existing pavement surface is found to be in fair to good condition with minor cracks

Traffic Study

Average Daily Traffic (ADT) & Annual Average Daily Traffic (AADT)

The seven-day average of the traffic is estimated as the Average Daily Traffic (ADT). The ADT has been multiplied with the seasonal correction factor derived from fuel sales data to estimate the AADT. The seasonal factor estimated for the month of April is taken into account as the volume count survey was carried out in the same month. For goods vehicles, diesel sale considering the fact that goods vehicles are diesel based. The factor for goods vehicles is 1.02. While for Car, combined sale of petrol and diesel (50:50) has been adopted as both petrol based and diesel based cars ply in the region. The estimated value for Car is 0.98. Considering that there is no seasonal variation present for bus, two- wheeler and three- wheeler traffic, a factor of 1.0 has been adopted. The summary of ADT & AADT for base year is given below in **Table 2.**

Table 2: Summary of ADT & AADT

Mode	**ADT**	**AADT**
Two Wheeler	11910	11910
Three Wheeler	1241	1241
Car / Jeep /Van/Taxi	25823	25307
Mini Bus	1085	1085
Standard Bus	2933	2933
Mini LCV	1725	1760
LCV 4 tyre	746.6	762
LCV 6 tyre	1514.4	1545
2 Axle Truck	1393	1421
3 Axle Truck	1282	1308
MAV	761	776
HME	3	3
Tractor	19	19
Tractor + Trailer	11	11
Cycle	5	5
Cycle Rickshaw	0	0
Animal drawn	0	0
Total vehicles	**50452**	**50084**

Width Requirements and Recommendations: The projected traffic is compared with Design Service Volume (DSV) at LOS B and the lane requirement on the project corridors are presented in **Table 3.**

Table 3: Lane Requirement for the project corridor

Year	Vehicles	PCU	Width Requirements and Recommendations
2018-19	53,414	63,737	6 Lane

Thus the project road section under study warrants 6 lane from 2018-2019. Hence the proposal of widening of existing dual two lane to dual three lane is justified.

Existing Pavement Composition

Type of the pavement layers was visually observed and thickness of each layer was measured. Summary of the existing crust thickness details are shown in **Table 4**

Table 4: Details of Average Pavement Crust Composition in mm

Sl No	Existing Chainage, km		Bituminous Layers, mm	Granular Base layer, mm	Granular Sub Base layer, mm
	From	To			
1	341.9	341.0	235	235	210
2	341.0	340.0	185	280	225
3	340.0	339.0	195	250	195
4	339.0	338.0	225	235	205
5	338.0	337.0	150	280	200
6	337.0	336.0	195	235	190
7	336.0	335.0	155	280	185
8	335.0	334.0	195	260	200
9	334.0	333.0	215	250	220
10	333.0	332.0	185	280	210
11	332.0	330.9	195	240	200

V. Streamlining and listing of Maintenance Approaches

Economic benefits from road investments are determined by comparing the total cost streams for various road works and construction alternatives against a base option (without project or do nothing) alternative. Base Option is analysis of a project section with up gradation of existing dual two-lane carriageway to dual three lane carriageway (construction years 2 years). No maintenance is recommended after up gradation of the stretch. Different alternatives of maintenance strategy are as summarized below for the present study and the details of proposed maintenance strategies and their intervention criteria is given in **Table 5.**

Table 5: Proposed Maintenance Strategies and Intervention Criteria for Project Analysis.

Alternative	Works Standard	Description of Work	Intervention Level
Base Option	Up gradation of existing 4 lane to 6 lane, do nothing case		
Alternative 1	Routine Maintenance	Crack Sealing + Pothole Patching	Pothole >=2 no/km Wide Structural Cracks >=5%
Alternative 2	Routine Maintenance +Overlay with 25mm BC	Crack Sealing + Pothole Patching +Surfacing by 25 mm BC	Pothole >=2 no/km Wide Structural Cracks >=5% Roughness > 4.2 IRI
Alternative 3	Routine Maintenance +Overlay with 50mm BC	Crack Sealing + Pothole Patching +Surfacing by 50 mm BC	Pothole >=2 no/km Wide Structural Cracks >=5% Roughness > 4.2 IRI
Alternative 4	Routine Maintenance +Overlay with 50mm BC+50mm DBM	Crack Sealing + Pothole Patching +Providing 50mm DBM + 40 mm BC	Pothole >=2 no/km Wide Structural Cracks >=5% Roughness > 4.2 IRI

A discount rate of 12 % is considered in this study and the analysis period is considered as 15 years. The optimum Alternative is selected on the basis of Economic Internal Rate of Return (EIRR).

VI. HDM Output

Traffic

Figure 1 represents the projected annual average daily traffic of motorized vehicles wrt vehicles/day for the design period of 15 years for the study area as obtained from HDM output.

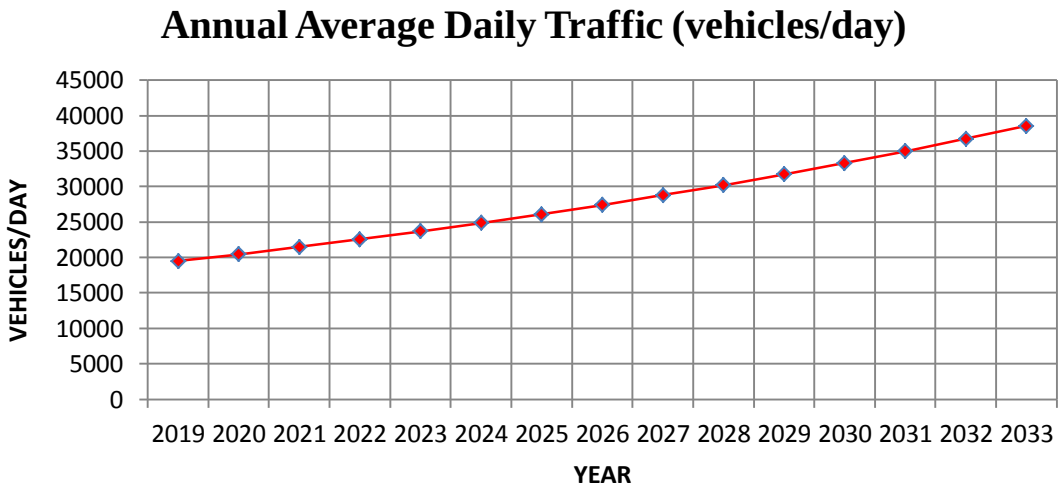

Figure 1: Projected AADT for the study area

Annual Pavement Deterioration

Annual Pavement Deterioration such as roughness, cracking, raveling, and potholing etc. which progress over the analysis period as per the respective deterioration models in HDM-4 for project section is obtained. Summary of the annual pavement deterioration of the study section, for analysis period of 15 years are given in **Table 6**

Table 6: Summary of Annual pavement deterioration for each alternative maintenance strategy

28-08-2017

HDM-4 HIGHWAY DEVELOPMENT & MANAGEMENT

Annual Pavement Deterioration Summary (Combined)

Study Name: BENGALURU BIDADI ROAD1
Run Date: 28-08-2017

Alternative:	ALTERNATIVE 1 (RM)		
Section:	BENGALURU-BIDADI ROAD	Road Class:	Primary or Trunk
Surface Class:	Bituminous		
Length:	11.00km	Width:	10.50m

					Average Annual Values											
Year	MT AADT	ESAL millions /ELANE	IRI bef. m/km	IRI Avg. m/km	All Str. Cracks %	Rave-lling %	Edge Break sq.m	Rut Depth mm	No. of Pot-holes	Struct. No.	Gravel Thick. mm	Avg. Faulting mm	Spalled Joints %	No. of Failures per km	Cracked Slabs %	Det. Cracks No/km
2019	19,469	0.81	4.25	4.13	10.88	17.02	1.00	7.44	1	5.97						
2020	20,443	0.85	4.59	4.42	18.13	49.86	1.00	11.11	2	5.91						
2021	21,465	0.89	4.97	4.78	28.32	71.66	1.00	14.97	2	5.84						
2022	22,538	0.94	5.38	5.18	42.11	57.88	1.00	19.02	2	5.73						
2023	23,665	0.99	5.84	5.61	58.88	41.11	1.00	23.27	2	5.59						
2024	24,848	1.04	6.28	6.06	72.42	27.57	1.00	27.75	1	5.41						
2025	26,090	1.09	6.72	6.50	82.41	17.58	1.00	32.46	2	5.32						
2026	27,395	1.14	7.16	6.94	83.65	10.50	1.00	37.43	1	5.28						
2027	28,765	1.20	7.55	7.32	86.27	13.72	1.00	42.68	0	5.30						
2028	30,203	1.26	8.01	7.78	86.60	7.87	1.00	48.23	0	5.27						
2029	31,713	1.32	8.43	8.19	88.56	11.43	1.00	54.13	0	5.29						
2030	33,299	1.39	8.93	8.68	88.12	6.35	1.00	60.41	0	5.26						
2031	34,964	1.46	9.39	9.13	89.61	10.38	1.00	67.15	0	5.28						
2032	36,712	1.53	9.93	9.66	88.80	5.67	1.00	74.37	0	5.25						
2033	38,547	1.61	10.43	10.14	90.08	9.91	1.00	82.16	0	5.28						

HDM-4 **Annual Pavement Deterioration Summary (Combined)** 28-08-2017

Alternative: ALTERNATIVE 2 (25MM THIN OVERLAY)
Section: BENGALURU-BIDADI ROAD **Road Class:** Primary or Trunk
Surface Class: Bituminous
Length: 11.00km **Width:** 10.50m

					Average Annual Values										
Year	MT AADT	ESAL millions /ELANE	IRI bef. m/km	IRI Avg. m/km	All Str. Cracks %	Rave-lling %	Edge Break sq.m	Rut Depth mm	No. of Pot-holes	Struct. No.	Gravel Thick. mm	Avg. Faulting mm	Spalled Joints %	No. of Failures per km	Cracked Slabs %	Det. Cracks No/km
2019	19,469	0.81	4.25	4.13	5.44	8.51	0.50	4.28	1	5.97						
2020	20,443	0.85	3.53	3.39	0.00	0.00	0.00	5.09	0	6.36						
2021	21,465	0.89	3.84	3.69	0.00	0.00	0.00	9.25	0	6.36						
2022	22,538	0.94	4.17	4.01	0.00	0.00	0.00	13.61	0	6.36						
2023	23,665	0.99	4.50	4.34	0.00	0.00	0.00	10.46	0	6.36						
2024	24,848	1.04	3.73	3.55	0.00	0.00	0.00	7.88	0	6.75						
2025	26,090	1.09	4.10	3.91	0.00	0.00	0.00	13.28	0	6.75						
2026	27,395	1.14	4.48	4.29	0.00	0.00	0.00	10.89	0	6.75						
2027	28,765	1.20	3.76	3.56	0.00	0.00	0.00	9.18	0	7.14						
2028	30,203	1.26	4.18	3.97	0.00	0.00	0.00	15.84	0	7.14						
2029	31,713	1.32	4.60	4.39	0.00	0.00	0.00	13.12	0	7.14						
2030	33,299	1.39	3.87	3.65	0.00	0.00	0.00	11.21	0	7.54						
2031	34,964	1.46	4.33	4.10	0.00	0.00	0.00	11.15	0	7.54						
2032	36,712	1.53	3.75	3.51	0.00	0.00	0.00	11.99	0	7.93						
2033	38,547	1.61	4.22	3.99	0.00	0.00	0.00	12.38	0	7.93						

Alternative: ALTERNATIVE 3 (50MM MODERATE OVERLAY)
Section: BENGALURU-BIDADI ROAD **Road Class:** Primary or Trunk
Surface Class: Bituminous
Length: 11.00km **Width:** 10.50m

HDM-4 **Annual Pavement Deterioration Summary (Combined)** 28-08-2017

					Average Annual Values										
Year	MT AADT	ESAL millions /ELANE	IRI bef. m/km	IRI Avg. m/km	All Str. Cracks %	Rave-lling %	Edge Break sq.m	Rut Depth mm	No. of Pot-holes	Struct. No.	Gravel Thick. mm	Avg. Faulting mm	Spalled Joints %	No. of Failures per km	Cracked Slabs %	Det. Cracks No/km
2019	19,469	0.81	4.25	4.13	5.44	8.51	0.50	4.28	1	5.97						
2020	20,443	0.85	2.98	2.83	0.00	0.00	0.00	5.37	0	6.75						
2021	21,465	0.89	3.30	3.14	0.00	0.00	0.00	9.83	0	6.75						
2022	22,538	0.94	3.63	3.46	0.00	0.00	0.00	14.51	0	6.75						
2023	23,665	0.99	3.97	3.80	0.00	0.00	0.00	19.42	0	6.75						
2024	24,848	1.04	4.33	4.15	0.00	0.00	0.00	14.13	0	6.75						
2025	26,090	1.09	3.08	2.89	0.00	0.00	0.00	9.80	0	7.54						
2026	27,395	1.14	3.48	3.28	0.00	0.00	0.00	16.21	0	7.54						
2027	28,765	1.20	3.89	3.69	0.00	0.00	0.00	22.93	0	7.54						
2028	30,203	1.26	4.32	4.10	0.00	0.00	0.00	17.25	0	7.54						
2029	31,713	1.32	3.14	2.92	0.00	0.00	0.00	12.74	0	8.32						
2030	33,299	1.39	3.59	3.37	0.00	0.00	0.00	21.40	0	8.32						
2031	34,964	1.46	4.06	3.83	0.00	0.00	0.00	30.49	0	8.32						
2032	36,712	1.53	4.54	4.30	0.00	0.00	0.00	23.03	0	8.32						
2033	38,547	1.61	3.24	3.00	0.00	0.00	0.00	17.03	0	9.10						

Alternative: ALTERNATIVE 4 (100MM THICK OVERLAY)
Section: BENGALURU-BIDADI ROAD **Road Class:** Primary or Trunk
Surface Class: Bituminous
Length: 11.00km **Width:** 10.50m

					Average Annual Values										
Year	MT AADT	ESAL millions /ELANE	IRI bef. m/km	IRI Avg. m/km	All Str. Cracks %	Rave-lling %	Edge Break sq.m	Rut Depth mm	No. of Pot-holes	Struct. No.	Gravel Thick. mm	Avg. Faulting mm	Spalled Joints %	No. of Failures per km	Cracked Slabs %	Det. Cracks No/km
2019	19,469	0.81	4.25	4.13	10.88	17.02	1.00	7.44	1	5.97						

HDM-4 Annual Pavement Deterioration Summary (Combined) 28-08-2017

2020	20,443	0.85	4.59	4.42	18.13	49.86	1.00	11.11	2	5.91
2021	21,465	0.89	4.97	4.78	14.16	35.83	0.50	8.61	2	5.84
2022	22,538	0.94	2.49	2.24	0.00	0.00	0.00	19.85	0	7.42
2023	23,665	0.99	3.00	2.75	0.00	0.00	0.00	38.29	0	7.42
2024	24,848	1.04	3.55	3.27	0.00	0.00	0.00	57.65	0	7.42
2025	26,090	1.09	4.12	3.83	0.00	0.00	0.00	77.98	0	7.42
2026	27,395	1.14	4.73	4.43	0.00	0.00	0.00	57.11	0	7.42
2027	28,765	1.20	2.75	2.37	0.00	0.00	0.00	42.36	0	8.99
2028	30,203	1.26	3.54	3.14	0.00	0.00	0.00	71.16	0	8.99
2029	31,713	1.32	4.33	3.94	0.00	0.00	0.00	100.00	0	8.99
2030	33,299	1.39	4.38	4.36	0.00	0.00	0.00	100.00	0	8.99
2031	34,964	1.46	4.43	4.40	0.00	0.00	0.00	57.50	0	8.99
2032	36,712	1.53	3.11	2.55	0.00	0.00	0.00	56.17	0	10.55
2033	38,547	1.61	4.28	3.69	0.00	0.00	0.00	99.38	0	10.55

Alternative: BASE OPTION (DO NOTHING)
Section: BENGALURU-BIDADI ROAD **Road Class:** Primary or Trunk
Surface Class: Bituminous
Length: 11.00km **Width:** 10.50m

					Average Annual Values											
Year	MT AADT	ESAL millions /ELANE	IRI bef. m/km	IRI Avg. m/km	All Str. Cracks %	Rave-lling %	Edge Break sq.m	Rut Depth mm	No. of Pot-holes	Struct. No.	Gravel Thick. mm	Avg. Faulting mm	Spalled Joints %	No. of Failures per km	Cracked Slabs %	Det. Cracks No/km
2019	19,469	0.81	4.25	4.13	10.88	17.02	1.00	7.44	1	5.97						
2020	20,443	0.85	4.59	4.42	18.13	49.86	1.00	11.11	2	5.91						
2021	21,465	0.89	4.97	4.78	28.32	71.66	1.00	14.97	4	5.84						
2022	22,538	0.94	5.40	5.19	42.11	57.87	1.00	19.02	8	5.73						
2023	23,665	0.99	5.92	5.66	58.88	41.10	1.00	23.27	13	5.59						
2024	24,848	1.04	6.56	6.24	72.42	27.55	1.00	27.75	20	5.41						

HDM-4 Annual Pavement Deterioration Summary (Combined) 28-08-2017

2025	26,090	1.09	7.53	7.05	82.41	17.55	1.00	32.47	31	5.32
2026	27,395	1.14	9.58	8.55	89.49	10.46	1.00	37.49	48	5.28
2027	28,765	1.20	15.13	12.36	94.24	5.68	1.00	43.01	76	5.24
2028	30,203	1.26	16.00	15.57	97.20	2.67	1.00	50.10	125	5.22
2029	31,713	1.32	16.00	16.00	98.87	0.92	1.00	58.34	212	5.22
2030	33,299	1.39	16.00	16.00	99.64	0.00	1.00	66.99	364	5.22
2031	34,964	1.46	16.00	16.00	99.39	0.00	1.00	76.08	632	5.22
2032	36,712	1.53	16.00	16.00	98.93	0.00	1.00	85.60	1,113	5.22
2033	38,547	1.61	16.00	16.00	98.10	0.00	1.00	95.60	1,987	5.22

Roughness Progression

Roughness is the most important indicator of the pavement deterioration or average condition of the pavement section at any given point of time. The progression of roughness can be tracked to check that the works are correctly triggered according to the specified intervention criteria. **Figure 5.2** represents the average roughness carried out under each alternative

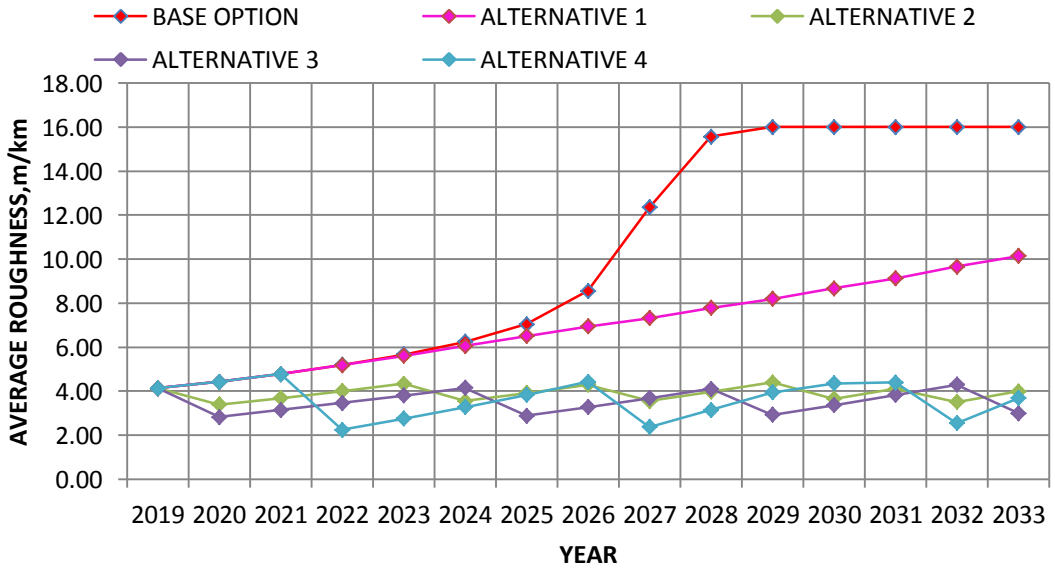

Figure 2: Average Roughness of Carriageway for the study area

Works Effects

The timings of works report is used to compare the works that would be implemented by the specified works standards in each analysis year under each project alternative. Two variants of timings of work by section and by year tear are available. **Table 7** gives the summary of works carried out for different alternative maintenance strategy.

Table 7: Summary of works carried out for different alternative maintenance strategy as obtained from HDM output

YEAR	Description of Work			
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**
2019	---	25mm Overlay	50mm Overlay	---
2020	---	---		---
2021	Pothole Patching	---	---	50mm BC+50mm DBM Overlay
2022	---	---	---	---
2023	Pothole Patching	25mm Overlay	---	---
2024	---	---	50mm Overlay	---
2025	---	---	---	---
2026	Pothole Patching Crack Sealing	25mm Overlay		50mm BC+50mm DBM Overlay
2027	---	---	---	---
2028	Crack Sealing	---	50mm Overlay	---
2029		25mm Overlay	---	---
2030	Crack Sealing	---	---	---
2031	---	25mm Overlay		50mm BC+50mm DBM Overlay
2032	Crack Sealing	---	50mm Overlay	---
2033	---	25mm Overlay	---	---

Cost Streams

Summary of road agency cost (maintenance cost) and road user cost (vehicle operation cost and travel time cost) for discounted rate at 12% and undiscounted rates are given in **Table 8** and **Table 9** respectively.

Table 8: Summary of Road Agency & Road User Cost for Discounted Rate at 12%

Alternatives	**RAC**	**VOC**	**Travel Time**	**Total RUC**	**Total Transport Cost**
Alternative 1	0.038	186	67	252	252
Alternative 2	3.283	166	64	233	233
Alternative 3	2.741	164	64	228	231
Alternative 4	4.401	165	64	229	234

Table 9: Summary of Road Agency & Road User Cost for Undiscounted Rate

Alternatives	**RAC**	**VOC**	**Travel Time**	**Total RUC**	**Total Transport Cost**
Alternative 1	0.114	420	148	568	568
Alternative 2	6.861	361	140	500	507
Alternative 3	5.082	356	140	496	501
Alternative 4	8.766	358	140	498	507

Benefit Cost Ratio

Ideally, benefit-cost ratio analysis is carried out to decide the feasible budgetary of every alternate study. Summary of benefit cost ratio for each alternative as obtained from HDM output is shown in **Table 10.**

Table 10: Summary of benefit cost ratio as obtained from HDM output

HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Benefit Cost Ratios

Study Name: BENGALURU BIDADI ROAD1
Run Date: 28-08-2017
Currency: RUPEES (millions)
Discount Rate: 12.00%.

Alternative	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV = B + E- C)	NPV/Cost Ratio (NPV/C)	Internal Rate of Return (IRR)
BASE OPTION (DO NOTHING)	0.000	0.000	0.000	0.000	0.000	0.000
ALTERNATIVE 1 (RM)	0.038	34.170	0.000	34.132	896.236	No Solution
ALTERNATIVE 2 (25MM THIN OVERLAY)	3.283	56.103	0.000	52.820	16.089	92.4 (1)
ALTERNATIVE 3 (50MM MODERATE OVERLAY)	2.741	58.249	0.000	55.509	20.253	103.5 (1)
ALTERNATIVE 4 (100MM THICK OVERLAY)	4.401	56.735	0.000	52.333	11.890	95.5 (1)

Figure in brackets is number of IRR solutions in range -90 to +900

From the above benefit cost ratio summary table it is observed that alternative 3 (thick overlay of 50mm BC) has the highest NPV/Cost ratio and IRRI which indicates that maintenance proposal of thick overlay of 50mm is the most economical.

Economic Analysis Summary

The economic analysis synopsis gives a correlation of the present assessment of total agency costs and decrease in the road user costs for each alternative when correlated against the Base Option. The economic indicator gives the reduced NPV for every alternative when associated against the base option. The optimum Alternative is selected for both up and down carriageway which are selected on the basis of Economic Internal Rate of Return (EIRR). Economic analysis summary of each alternatives are summarized in **Table 11**

Table 11: Economic analysis summary of each different Alternative

HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Economic Analysis Summary

Study Name: BENGALURU BIDADI ROAD1
Run Date: 28-08-2017

This report shows total economic benefits using the following:
Currency: RUPEES (millions).
Discount rate: 12.00%.
Analysis Mode: Analysis-by-Project

Alternative: ALTERNATIVE 1 (RM) vs Alternative: BASE OPTION (DO NOTHING)

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	0.00	0.11	0.00	78.59	37.82	0.00	0.00	0.00	116.29
Discounted	0.00	0.04	0.00	23.23	10.94	0.00	0.00	0.00	34.13

No IRR solutions

Alternative: ALTERNATIVE 2 (25MM THIN OVERLAY) vs Alternative: BASE OPTION (DO NOTHING)

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	6.86	0.00	0.00	137.64	45.91	0.00	0.00	0.00	176.69
Discounted	3.28	0.00	0.00	42.92	13.19	0.00	0.00	0.00	52.82

Economic Internal Rate of Return (EIRR) = 92.4% (No. of solutions = 1)

HDM-4 Economic Analysis Summary

Alternative: ALTERNATIVE 3 (50MM MODERATE OVERLAY) vs Alternative: BASE OPTION (DO NOTHING)

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	5.08	0.00	0.00	142.19	45.98	0.00	0.00	0.00	183.08
Discounted	2.74	0.00	0.00	45.03	13.22	0.00	0.00	0.00	55.51

Economic Internal Rate of Return (EIRR) = 103.5% (No. of solutions = 1)

Alternative: ALTERNATIVE 4 (100MM THICK OVERLAY) vs Alternative: BASE OPTION (DO NOTHING)

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	8.77	0.00	0.00	139.80	45.92	0.00	0.00	0.00	176.95
Discounted	4.40	0.00	0.00	43.55	13.18	0.00	0.00	0.00	52.33

Economic Internal Rate of Return (EIRR) = 95.5% (No. of solutions = 1)

VII. Conclusion

Improvement Proposal

- ✓ The pavement performance for the present study area and riding quality is analysed by both Structural and Functional evaluation. From the analysis, it is concluded that the ***existing dual four lane pavement is structurally good***.
- ✓ From the traffic study and forecast, it is observed that the present road stretch will have traffic flow of 63737 PCUs in 2018-19. Comparing the traffic flow of 63737 PCUs with Design Service Volume (DSV) at LOS B, the project stretch warrants six laning. ***Thus, the proposal of upgrading of existing 4 lane to 6 lane in justified***.

Alternate Maintenance Strategy for HDM Analysis

- ✓ HDM-4 software was used for analysis using data of the above six laning project, to select the best economic alternative from the four-maintenance alternative strategy (standards) after the up gradation of the project.

Work Effects- Timing of work

Timing of work by year for the four alternatives for a design analysis period of 15 years are summarized as below-

- ✓ In alternative 2, thin overlay of 25mm BC is required for around 6 times in 15 years design analysis period
- ✓ In alternative 3, moderate overlay of 50mm BC is required for around 4 times in 15 years design analysis period
- ✓ In alternative 4, thick overlay of 50mm BC + 50mm DBM is required for around 3 times in 15 years design analysis period

Agency & Road User Costs

- ✓ Undiscounted Agency and Road user costs for alternative 1 is 568 million rupees
- ✓ Undiscounted Agency and road user costs for alternative 2 is 507 million rupees
- ✓ Undiscounted Agency and road user cost for alternative 3 is 501 million rupees
- ✓ Undiscounted Agency and road user cost for alternative 4 is 507 million rupees
- ✓ Discounted Agency and Road user costs for alternative 1 is 252 million rupees
- ✓ Discounted Agency and road user costs for alternative 2 is 233 million rupees
- ✓ Discounted Agency and road user cost for alternative 3 is 231 million rupees
- ✓ Discounted Agency and road user cost for alternative 4 is 234 million rupees
- ✓ Alternative 3 is having found to be least total transport cost (agency and road user cost)

Summary of the discounted and undiscounted total transport cost (agency +road user cost) in million rupees is summarized in **Table 12**

Table 12: Summary of discounted and un discounted TTC

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**
Undiscounted	568	507	501	507
Discounted	252	233	231	234
Priority	IV	II	I	III

- ✓ Thus, alternative 3 is found to be least and economical.

Benefit Cost Ratio

- ✓ Based on economic indicators (in comparison to base option), maintenance Alternative 3 (thick overlay by 50 mm BC) has been identified as the optimized maintenance standard for the analysis in 15 years of design life.

A summary of the works applied on the project road network during analysis, showing the increase in road agency costs and decrease in road user costs, as a result of selecting the maintenance alternative in comparison to the base option. All these costs have been discounted to the base year 2017, with a discount rate of 12%.

VIII. References

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