MAINTENANCE STRATEGY AND BUDGETING FOR ROAD NETWORK IN KARNATAKA STATE USING HDM-4

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The Public Works, Ports and Inland Water Transport Department maintains a road network of about 76060 Kms of in the state of Karnataka. Out of the total road network, a length of about 25000 Kms of roads are declared as Core Road network which includes the National Highways, State Highways and some important Major District Roads. The functional condition data which includes roughness in IRI, rut depth surface distress like cracking, raveling, patching including geometric characteristics are collected using a laser based Road Condition Data Collection Vehicle (RCDCV). The structural condition of the pavement has been determined using a Falling Weight Deflectometer (FWD). The maintenance and rehabilitation history is obtained by the Road Information System of the Department.

The maintenance and works budgeting for the Core Road Network is prepared by the Department utilizing the data collected as described above. The data collected is analyzed in Karnataka Road Asset Management System and the Annual Works Program (AWP) for the Core Road Network is prepared by the Department. The entire Core Road network is divided into number of homogenous sections, as they contain varied traffic conditions.

The output of the analysis includes the change in deterioration of the pavement on application of different maintenance and rehabilitation strategy. Different budget constraints are defined and a budget optimization is carried out in HDM–4, to obtain an optimum alternative for the maintenance and rehabilitation of the sections in the network.

KEYWORDS: Asset Management; Highway Development and Management – 4, Pavement Maintenance, Network Analysis, Pavement Maintenance and Management; Annual Works Program

1. INTRODUCTION

A well designed and coordinated system of transportation system plays a vital role in the sustainable development of the country. The road transportation system plays a key role in the economic and social development of the country. More preference is given to road transport because it provides easy access, flexibility and reliability for both passengers as well as freight movement compared to other modes of transport. The share of the overall transportation system in the Gross Domestic Product (GDP) is about 4.80 % in 2013-2014; whereas the GDP Share of

the road transportation system is about 3.10%. The road transportation sector occupies the large part of GDP produced by the transportation sector. There is an unprecedented increase in the number of vehicles is the post-independence era. The registered motor vehicles increased about 700 times between 1951 and 2015. The corresponding growth in road network has not been commensurate with the growth of vehicular population. The road network has grown from about 0.4 million km as on the year 1951 to about 5.47 million Km as on March 2015 which has only increased by 13.4 times.[1]

The funds for maintenance of Highway Network are allocated based on thumb rules, judgment of the Engineer in charge and knowledge which is based on little data. This method of allocation of funds may be feasible when there is no limitation on the fund availability but will be an incorrect method when there is a restriction on the availability of funds. Thus, a scientific methodology should be devised for helping the highway planners in allotting the proper funds so that the most cost effective and optimum treatment strategy can be provided for the road network for maintaining the same at a good serviceability level. The selection of maintenance and rehabilitation strategy for a road section should be based on the present condition and the predicted future conditions of the road section.

2. OBJECTIVE OF THE STUDY

The broad objective of the study is to optimize the maintenance and rehabilitation for the Core Road Network of Karnataka state. Various Maintenance and Rehabilitation and Improvement alternatives are compared with respect to a base alternative of do minimum and are optimized for different budget conditions.

3. LITERATURE REVIEW

Sanjiv Aggarwal et al. have tried to develop a pavement management strategy for a selected road network of National Highways in India. The total network considered for this study was 310Km, which was divided into 22 homogeneous sections. The data required for development of Pavement Management System was collected from primary and secondary sources. HDM - 4 program was considered for carrying out the pavement management strategies.
The data collected was used to prepare the vehicle fleet database, Maintenance and Rehabilitation Work Database, Cost Data and Road Network Data. The maintenance and rehabilitation strategy for the road network was prepared at both project level as well as at network level. Finally, budget optimization was carried out to get the final Maintenance and Rehabilitation strategy under the constraint budget.[2]

A. Veeraragavan et. al. has worked on the application of Highway Development Management (HDM – 4) for the low – volume roads. In their study, they have considered a network of low volume roads. The total network they have considered is about 1085 km, consisting of nine different sections. The data for each section are collected based on visual observations. The vehicle fleet and maintenance data are prepared to suite the local conditions. An initial composition and growth rate of the vehicles fleet are also assured. Various levels of maintenance strategies are defined. A strategic level analysis is performed. Three different Investment alternatives are defined. The strategic analysis is carried out for 20 years, by considering a discount rate of 12%. The analysis was carried out to maximize the NPV. At the end of the study, the final budget investment of each section is predicted.[3]

M.U. Khan et. al. has studied on obtaining consistent results in HDM – 4. This study was done in the local council of Muswellbrook Shrine Council in Australia. The road network was about 625km, out of which 85% are paved. It has been noted that HDM – 4 results are always not consistent with the treatments undertaken. The authors have studied the process of obtaining sound asset management program using HDM – 4. The analysis indicated that there was about 76% reliability of the results which was obtained by HDM – 4 compared with the manual planned maintenance and rehabilitation strategies. The maintenance and rehabilitation strategies were verified in field for the selected maintenance and rehabilitation strategy suitability. The authors conclude that the HDM – 4 results should be verified in the field to obtain a realistic pavement management strategy. It is recommended that each local agency should carry out a study for finalizing the maintenance and rehabilitation strategy adopted for the study network.[4]

3.1 Highway Development and Management (HDM – 4)

The Highway Development and Management system HDM-4 is most widely used software for Highway Development and Maintenance Management System. The HDM-4 assists the pavement managers in making effective investment choice at all management levels. The possibilities range from policy or strategic planning studies. Programmed allocation of funds for maintenance and or improvement works on a network, to the detailed economic assessment of investment options at the project level.

The four main areas of application of HDM - 4 are

- Strategic Planning
- Roadwork Programming
- Project Analysis
- Research and Policy Studies

The network level analysis can be done using HDM-4, depending upon the size of the highway network involved in the analysis and the length of analysis period. Since the size of the highway network is not very large and the analysis period is of medium duration, ‘Programme Analysis’ is used for the network level analysis.

3.1.1 Models

The models present in HDM – 4 tool are:

- Road Deterioration Model predicts the road deterioration based on the present condition for future years.
- Work Effects Model implements road works program and determine the effects and the cost
- Road User Effects Model determines the cost of vehicle operation and travel time
- Social and Environmental Effects Model determines effect of emissions and noise and predicts the number of accidents and energy consumptions.

3.1.2 Outputs

- Pavement Deterioration and road works, which includes the summary of annual pavement condition before and after doing maintenance alternatives
- Road user effects including the vehicle operation costs, traffic volume capacity ratios
- Environmental effects, which include the vehicular emissions, energy consumptions

- Economic Analysis results which include annual cost streams, Net Present Value (NPV), economic indicators like Internal Rate of Return (IRR)

4. DATA COLLECTION

4.1 Road Network

The road network data collected includes both functional condition and the structural condition. The functional condition survey for the selected road network was conducted by Planning and Road Asset Management Center (PRAMC) of Karnataka Public Works, Ports & Inland Water Transport Department (KPWP&IWTD) using a laser based Road Condition Data Collection Vehicle (RCDCV). The functional data used in this analysis includes IRI, rut depth, type and extent of distress, etc. with a sample interval of 100m. The structural condition survey was conducted by PRAMC using a vehicle mounted Falling Weight Deflectometer. The sampling interval was 500m for the selected stretches of the road network. The secondary data like the details of earlier M&R works were obtained from the road Information System.

The Road Network considered (excluding the National Highways) consist of State Highway for a length of 14,963km was divided into 1210 homogenous sections. The Homogenous sections were based on carriageway width, road roughness and level of traffic on each road section. The summary of the Study network is indicated in TABLE 1.[5]

TABLE 1 Summary of Study Road Network

Road Class	**Good**	**Fair**	**Poor**	**Bad**	**Total**
IRI Range(m/km)	**<4**	**4 – 6**	**6 - 8**	**>9**	
State Highway	2144	5917	4284	2618	14963
	14%	40%	29%	17%	*100%*

4.2 Vehicle Data Base

This includes the parameters of the representative vehicles, which are considered to be plying in the road network considered for the study. The representative vehicles for the road network was considered based on the 7-day classified traffic volume survey which conducted by KPWP&IWTD. The representative vehicles were considered based upon the classified traffic volume study, which is carried out by KPWP&IWTD every year

The cost of each vehicle is combination of both economical coast and the taxes levied on them. The economic cost of the new vehicle, new tyres and the fuel cost were considered. The economic cost of the vehicle and the new tyres were worked out by considering the average market price of the product based on the vehicular type was considered and the various taxes which are applied were deducted to obtain the economic cost. The economic fuel costs and lubricant costs were obtained from the websites of the refineries such as IOC, HP etc. The wages for the drivers of the vehicle is considered based on the standard wages fixed for each type driver for different category of the vehicles. The annual overheads are calculated based on the annual cost which is spent on maintenance of the vehicles. The cargo cost calculated based on the prevailing rates for transportation of cargo.

4.3 Project Costing

4.3.1 Capital Cost

The capital costs in financial terms are based on cost estimates based on the Schedule of Rates for the year 2016-17 which is continues for the current year. Widening of the roads has been based on the traffic projection and if there is requirement of widening in the next 10 years, then widening has been proposed. Cost of the widening has been considered for the base year 2017. Cost for widening for different proposals are presented below in financial and economic values. For widening, 40mm BC + 50mm DBM + 250mm WMM + 250 mm GSB + 500mm subgrade has been considered. The details are enumerated in TABLE 2.

TABLE 2 Cost of widening including overlay on existing road (Rs. Lakhs Per km)

Widening proposals	Financial Cost (Lakh Rs)	Economic cost (Lakh Rs)
Single lane to Intermediate lane	54.00	48.6
Single lane to 2-lane	82.00	73.8
Single lane to 2-lane with paved shoulder	138.00	124.2
Single lane to 4-lane	258.00	232.2
Intermediate lane to 2-lane	54.00	48.6
Intermediate lane to 2-lane with paved shoulder	108.00	97.2
Intermediate lane to 4-lane	280.00	252.0
2-lane to 2-lane with paved shoulder	86.00	77.4
2-lane to 4-lane	220.00	198
2-lane with paved shoulder to 4-lane	200.00	180

4.3.2 Routine and Periodic Maintenance Costs (Improvement & Renewals cost)

Preventive maintenance in addition to the routine maintenance will be done for road condition has been demanding based on the maintenance strategy. For budget scenario BC of 40 mm thickness was proposed as thin overlay when roughness of the road will reach more than 4.0 and less than6.0. Structural overlay of 40 mm BC and 50 mm DBM has been proposed as a structural overlay if the roughness of the road is between 6 and 8. Roads are proposed for the reconstruction, if the roughness of the road exceeds 8.0. Cost of the preventive overlay has been presented in TABLE 3.

TABLE 3 Cost of preventive maintenance (Rs. per sq. m)

Type of maintenance	Financial Cost	Economic cost
Thin overlay	444	400
Structural overlay	830	747
Reconstruction	1,928	1,735

In addition to preventive maintenance, there is also routine annual maintenance, which is done throughout the year to maintain the road in good condition. Cost of routine maintenance for different sub works are indicated in TABLE 4.

TABLE 4 Cost of Routine Maintenance

Type of maintenance	Unit	Economic Cost (Rs.)	Financial cost (Rs.)
Patching	Per sq. m	335	372
Shoulder repair	Per km	12,294	13,360
Jungle clearance	Per km	7,034	7,816
Darin maintenance	Per km	28,217	31,352

5. BUDGET ANALYSIS

The direct benefits accruing from the proposed improvement in the study include VOC savings and time savings for passengers and goods in transit. The benefit streams have been computed annually over the 10-year period for the changing traffic volume and changes in road condition.

Programme analysis has been conducted using the HDM-4 to prioritize the roads and optimize maintenance works. The Annual Budget has been prepared for 6 scenarios, one for the unconstrained budget and 5 different scenarios for a constrained budget. All the 5 constrained budget scenarios have been considered in the budget optimization procedure in HDM-4 together with the above mentioned unconstrained budget.

In the analysis, the constrained budget scenarios considered are 10%, 15%, 20%, 25% of current year (2016/17) budget allocation for State Highways and a 10% increment on overall Budget Scenario (Rs. 3000 Crore for the first three years each and rest of unconstrained budget for the next seven years) for the unconstrained budget. The 10% increment on overall PWD Budget Scenario is proposed based on the practical consideration that in the unconstrained budget scenario the first year (2017) investment required is Rs. 8941 Crore, which is an ideal objective. Instead of this huge investment in the first year, it could be distributed in the first three years with a static budget of Rs. 3000 Crore for year 2017 to 2019 in order to clear all backlog maintenance on the road network and bring the roughness at the desired level of less than 4 IRI. Thereafter, the network can be maintained at this level with a nominal annual budget of around Rs.1000 Crore. The Year wise Capital Cost and Budget Scenarios for Optimization is indicated in TABLE 5.[6]

TABLE 5 Year wise Capital Cost and Budget Scenarios for Optimization

Year	Unconstrained Budget Scenario	Budget Scenarios (Rs. In Crore)				
		10% Incremental Budget Scenario	15% Incremental Budget Scenario	20% Incremental Budget Scenario	25% Incremental Budget Scenario	10% Increment on Overall PWD Budget Scenario
2017	8940.9	495	517	540	562	3000
2018	969.3	544	595	648	703	3000
2019	918.4	599	684	778	879	3000
2020	1087.1	659	787	933	1099	1636
2021	770.2	725	905	1119	1373	1005
2022	911.1	797	1041	1344	1717	1212
2023	1208.7	877	1197	1612	2145	1591
2024	1206.9	964	1376	1935	2682	1316
2025	858.3	1061	1583	2322	3353	831
2026	1256.7	378	461	695	1056	1258
Total	**18128**	**7099**	**9147**	**11925**	**15569**	**17848**

In the unconstrained budget (Rs. 18,128 Crore in 10 years), improvements can be carried out as and when required, with the majority being in the first year to clear all backlog maintenance. Priority will be given to roads with higher NPV/CAP and thereby the network will be maintained at the “Average” IRC Standard. On the contrary, if SH Network is required to maintain at “Good” IRC Standard at IRI 2.5, the whole of the SH network will require major improvement works in the first year and then to maintain at good level for the next 9 years, which will require around Rs. 20,000 Crore, which sounds convincing but practically difficult to maintain with the

present level of technology available with the PWD and therefore not recommendable.

The annual works program for the year 2017 – 2026 as generated by the HDM-4 model for considered road network of Karnataka for Unconstrained and Constrained Budget Scenarios are presented in TABLE 6, TABLE 7, FIGURE 1 and FIGURE 2.

TABLE 6 Summary of Annual Works Programme Proposed by Road Length in Km

Year	10% Incremental Budget Scenario	15% Incremental Budget Scenario	20% Incremental Budget Scenario	25% Incremental Budget Scenario	10% Increment on Overall PWD Budget Scenario	Unconstrained Budget Scenario
2017	471	465	477	505	2308	12569.2
2018	350	404	426	454	4188	1534.7
2019	413	494	558	661	4810	1011.2
2020	491	514	694	883	2627	1679.3
2021	533	800	849	1109	1299	1086.9
2022	734	797	1407	1942	1636	1141.3
2023	683	1089	1405	2246	1686	1119.2
2024	791	1270	2038	2934	1185	1187.8
2025	830	1326	2493	3981	938	1119.4
2026	267	333	466	696	1172	1459.7

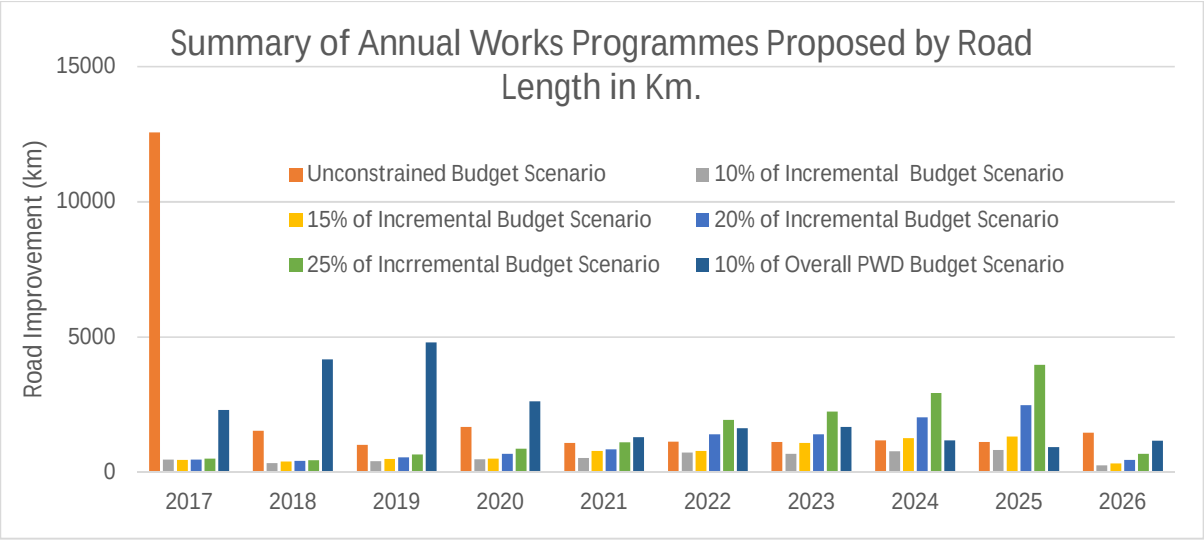

FIGURE 1 Length of selected Total Road Sections in Annual Works programme for Constrained and Unconstrained Budget for State Highway Network in each year

TABLE 7 Summary of Annual Works Program by Annual Budgets Required in Rs. Cr.

Year	10% Incremental Budget Scenario	15% Incremental Budget Scenario	20% Incremental Budget Scenario	25% Incremental Budget Scenario	10% Increment on Overall PWD	Unconstrained Budget

					Budget Scenario	
2017	495	517	540	562	3000	8940
2018	544	595	648	703	3000	969
2019	599	684	778	879	2999	918
2020	659	787	933	1099	1636	1087
2021	725	905	1119	1373	1005	770
2022	797	1041	1344	1717	1212	911
2023	877	1197	1612	2145	1591	1208
2024	964	1376	1935	2682	1316	1206
2025	1061	1583	2322	3353	831	858
2026	378	461	695	1056	1258	1256

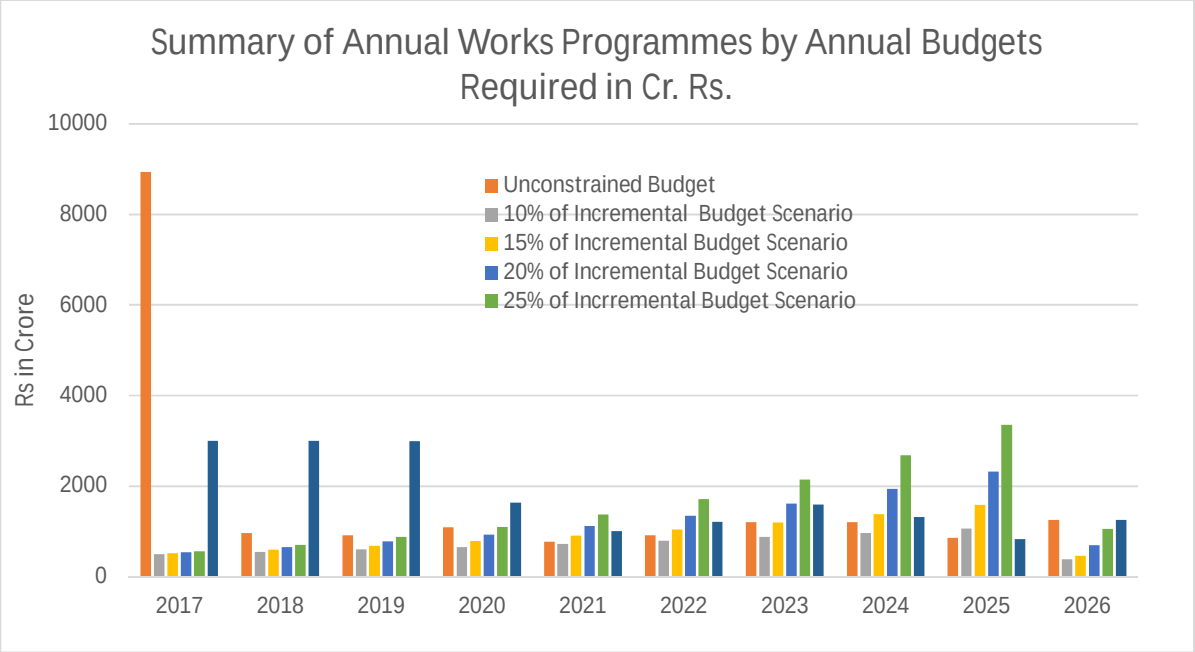

FIGURE 2 Constrained and Unconstrained Budget of Annual Works programme for State Highway Network

From TABLE 8 below, it can be seen that for the Unconstrained Budget scenario, the roughness values reduce to less than 4.0 in next year (2018) and for the 10% Increment on Overall PWD Budget Scenario the roughness value will reduce to less than 4.0 IRI in the third year. The predicted IRI values on the SH road sections as a result of various scenarios of unconstrained and constrained budget investments are presented in TABLE 8.

TABLE 8 Predicted IRI values on Road Network for proposed Unconstrained and Constrained Budget Scenario

Year	10% Incremental	15% Incremental	20% Incremental	25% Incremental	10% Increment	Unconstrained Budget

	Budget Scenario	Budget Scenario	Budget Scenario	Budget Scenario	on Overall PWD Budget Scenario	
2017	6.2	6.2	6.2	6.2	6.2	6.2
2018	6.2	6.2	6.2	6.2	5.6	3.5
2019	6.35	6.35	6.35	6.35	4.6	3.4
2020	6.5	6.45	6.4	6..4	3.75	3.4
2021	6.6	6.5	6.4	6.3	3.4	3.4
2022	6.6	6.5	6.4	6.15	3.4	3.35
2023	6.6	6.35	5.98	5.6	3.35	3.25
2024	6.55	6.1	5.75	5.15	3.35	3.2
2025	6.3	5.9	5.35	4.5	3.35	3.25
2026	6.3	5.7	4.7	3.5	3.45	3.35

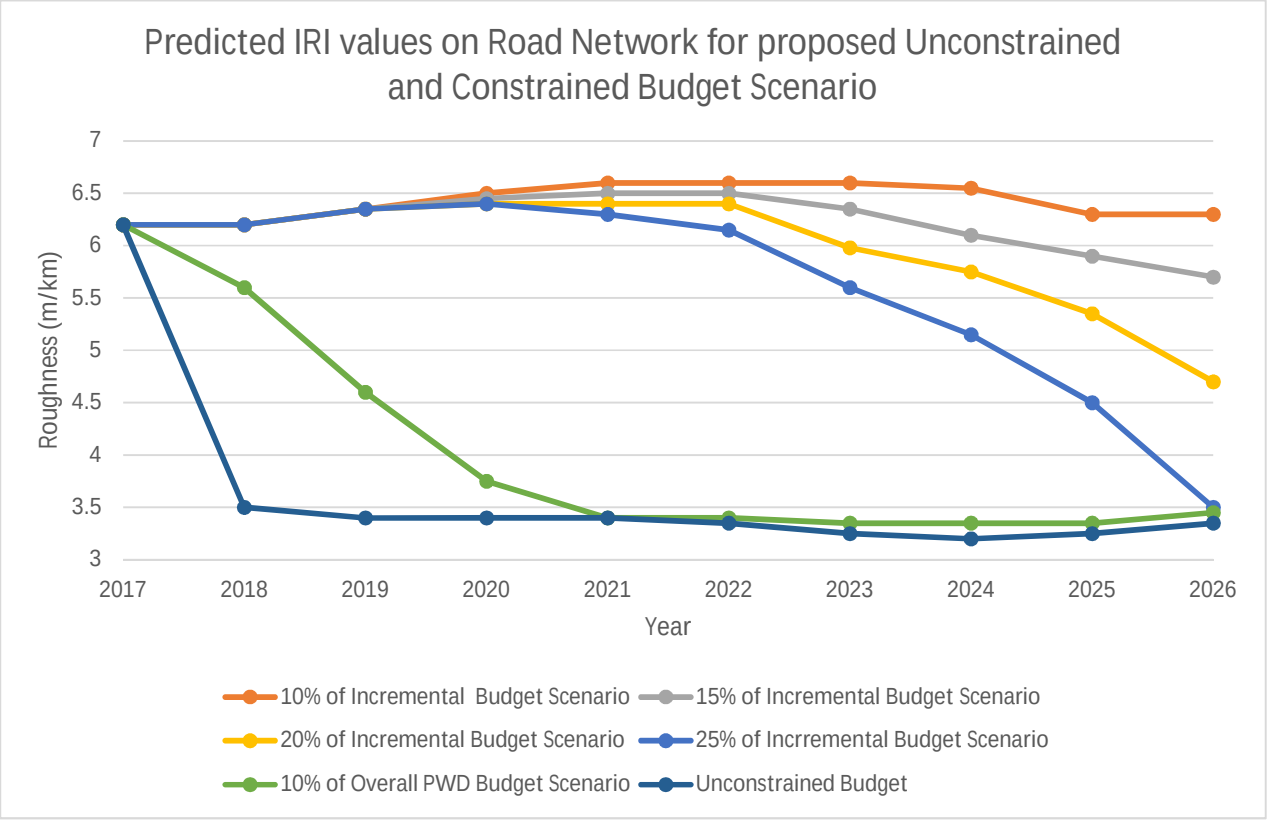

FIGURE 3 Annual Average Roughness of the Optimized Work Programme (weighted by length)

In summary, it is clear that the budget requirement is around Rs. 1000 Crore after reaching the desired average roughness index IRI to less than 4.0 after the first year of investment for the Unconstrained Budgets Scenario case and in the third year in case of the 10% Increment on Overall PWD Budget Scenario. In the other Budget Scenarios, such as 10%, 15%, and 20% incremental of the current year budget the IRI value does not come below 4.0, meaning that road condition will not come to the desired level of IRI with those levels of funding and is not recommended; only in case of 25% budget scenario the IRI level will come to desired level at the 10th year, which is also not desirable as the department should not wait upto ten years to get

back the road condition to desired level. Refer FIGURE 3.

It is also to be noted that for the unconstrained budget scenarios HDM-4 has recommended a substantial amount of investment in the first year, which indicates that there is a huge quantity of backlog maintenance that must be taken care of in the first instance. Otherwise, relatively low investments do not have any effect in reducing current roughness, which has already reached a very high average value of 6.2, which should not be ignored.

6. CONCLUSION

It is strongly recommended that there is an immediate need for capacity augmentation for most of the network roads. In almost all cases the traffic level has crossed the maximum allowable capacity of road sections with respect to IRC recommendations. To keep the desired roughness level (less than 4.0) with respect to current Roughness Condition, a minimum of **Rs. 8,941** Crore is required for the improvement as indicated in the Unconstrained Budget Scenario.

In case of non-availability of funds in one go, the 10% Increment on Overall Budget could be considered, whereby Rs. 3000 Crore could be allocated for the considered road network for 2017, 2018 and 2019 to bring down the current average roughness level from 6.2 to desired less than 4.0 in three years.

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