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Schedule and Condition Responsive Maintenance Strategies for Optimum Utilization of Maintenance Budget

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Abstract**—***The maintenance of pavements and particularly for flexible pavement is an essential requirement for the efficiency of highway network. For better serviceability, flexible pavements require more maintenance as compared to maintenance required for rigid pavements. But developing counties like India does not have sufficient budget or funds to satisfy the requirements. The maintenance & rehabilitation (M&R) Strategy should be selected on the basis of optimum utilization of maintenance funds. The magnitude of the work involved in maintenance is very large as the multilane network is increasing at manifolds. The funds available are not enough to meet the requirements. As per MORT&H (Ministry of Road Transport & Highways) 2004, approximately 50% budget is generally approved in place of required budget. So, in developing countries like India, where the budget is limited, an optimum strategy should be selected on the basis of scheduled or condition responsive maintenance strategies. The objective of this paper is to analyze the data of identified flexible pavement sections to compare the schedule and condition responsive maintenance strategies. The scheduled M&R strategy has been selected as per the current maintenance norms provided by the Ministry of Road Transport & Highways in year 2001. whereas the condition responsive M&R strategy has been selected as per the serviceability levels up to which the respective pavement section is to be maintained. The study is to show the optimum utilization of maintenance funds on the basis of comparison. The effect of International Roughness Index (IRI) was taken for this comparative study. For this study a National Highway section from Ghaziabad – Hapur (NH-24) was taken.*

Keywords: *Schedule and condition responsive maintenance strategies, HDM-4, Maintenance Funds*

I. INTRODUCTION

Pavement management, in its broadest sense, encompasses all the activities involved in the long term planning, design, construction, maintenance, and rehabilitation of the pavement portion of a public works program [6]. Since the deterioration of pavement is more gradual while in its "preventative" maintenance stage, it would be possible to keep the roads at "Fair to Better" conditions by the timely budgeting of sufficient "preventative" treatment funds. If more (beyond the "preventative" costs) was budgeted, then jurisdictions could bring roads up from "Poor or Worse" conditions by catching up on the deferred rehabilitation and reconstruction projects [9].

By examining the effects on these indicators, the advantages and disadvantages of different funding levels and maintenance strategies become clear. It is difficult to address roads in good condition when they have a large backlog. In developing countries like India funding is not dedicated to the programme. The funds are not sufficient to the maintenance requirements. With the maintenance of pavement at right time leads to reduce the life cycle cost of preserving a pavement as well as road user cost. If the funds available for maintenance programmes are insufficient, the Maintenance & Rehabilitation (M&R) strategy selected for a particular highway section can be scheduled annually or it can be pavement condition responsive. Thus, this study is intended to compare the effect of an M&R strategy adopted as scheduled or condition responsive for a highway section. Due to traffic loading and the environment, pavements gradually deteriorate in serviceability with time to a terminal level, which may be defined as failure. The rate of deterioration often accelerates as failure approaches. To reduce the rate of deterioration, maintenance and rehabilitation (M&R) activities should be applied through a maintenance plan to preserve pavement condition, safety and ride quality, leading to achieving pavement design life in a cost effective manner [1],[2],[5]. The ability to relate between the network condition and its maintenance needs is one of the important benefits of the maintenance plan.

Due to the poor condition of roads, it is estimated that an annual loss of approximately over Rs. 6000 crores ($1.33 billion) is resulted in vehicle operating costs (VOC) alone. Timely maintenance is missing due to many reasons, which otherwise could have minimized the losses to the exchequer. A rough estimate suggests that more than 50% of the primary road network is in bad shape and needing immediate attention. It should be borne in mind that for achieving the desired economic growth, the foremost requirement is to ensure a good and effective road network [4]. Maintenance and rehabilitation (M&R) requirements of roads depends upon the extent of damage and strengthening on the existing roads. The limited fund available should be used scientifically to have maximum benefit. For this, an investment strategy is developed to meet the requirements for the maintenance and rehabilitation of roads. There would be no need for optimum M&R strategy if unlimited financial resources are available.

II. SELECTED STUDY AREA

The study area consists of One National Highway (NH 24 Ghaziabad – Hapur). NH has been divided into 8 sub-sections. The sub-sections so divided are quite homogeneous within themselves as far as climatic and geometric conditions are considered but vary considerably from each other in traffic characteristics and pavement surface conditions. All the selected pavement sections have been assigned unique 'Section ID' and a 'Section Name' for ease in identification and for input, as shown in **Table 1**.

The information and data collected for the above highway sections for selecting the M & R strategy are as mentioned in the **Table 2.**

Table 1: Selected Pavement Sections

S. No.	Road Section	Section ID	Section Name	Length (KM)	Width (M)
1	National Highway 24 : Ghaziabad to Hapur (Total Length = 40.0 KM)	NH-24-01	Km Stone Delhi 11.0 km to 16.0 km	5.0	7.0
2		NH-24-02	Km Stone Delhi 16.0 km to 21.0 km	5.0	7.0
3		NH-24-03	Km Stone Delhi 21.0 km to 26.0 km	5.0	7.0
4		NH-24-04	Km Stone Delhi 26.0 km to 31.0 km	5.0	7.0
5		NH-24-05	Km Stone Delhi 31.0 km to 36.0 km	5.0	7.0
6		NH-24-06	Km Stone Delhi 36.0 km to 41.0 km	5.0	7.0
7		NH-24-07	Km Stone Delhi 41.0 km to 46.0 km	5.0	7.0
8		NH-24-08	Km Stone Delhi 46.0 km to 51.0 km	5.0	7.0

Table 2 : Input Data

Input	Description
Pavement condition data	Basic road details, Geometrics, Pavement history, Pavement condition etc.
Traffic data	Traffic volume count
Pavement age	Pavement history, Pavement construction year
Deflection data	Light weight falling weight deflectometer deflection data

III. FIELD DATA COLLECTION

A. Traffic volume count

Traffic surveys were conducted manually, for 24 hours round the clock, by engaging adequate 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.

B. Road Inventory

The inventory data includes the following details about selected pavement sections: Name of Road, category of road, carriageway width road geometrics, surface type, details regarding the history of maintenance and construction of these roads, etc. The same was collected from visual inspection of pavement sections, as well as from the construction and maintenance records of the highway division's in-charge of the maintenance

C. Functional Evaluation

Functional Evaluation is the collection of road data pertinent to surface distress like crack area, pothole area with depth, ravelled area, rut depth, surface roughness. The type and extent of distress developed at the surface were observed, based on visual condition survey. It was also measured in quantitative term. The information on the drainage conditions for the existing side drains was also observed. The riding quality of pavement was measured in terms of roughness for all the 8 sections by duly calibrated towed Fifth Wheel Bump Integrator (FWBI) which is a response type road roughness measurement device. The functional evaluation is carried out in such a manner that data will be suitable for analysis of HDM-4 models in the present study. Figure 1 shows the working of Fifth wheel bump integrator on road while collecting the roughness data.

Figure 1. A View of Fifth Wheel Bump Integrator Measuring Surface Roughness

D. Structural Evaluation by Benkelman Beam Deflection Method

The magnitude of pavement rebound deflection is an indicator of the ability of the pavement to withstand traffic loading. Higher the rebound deflection, poor is the structural capacity and performance. To assess the structural condition of 8 sections selected for detailed investigations, Benkelman Beam rebound deflection method has been used which is a non destructive method. The deflection measurements were taken as per the procedure laid down in IRC: 81(1997).

IV. INTERVENTION CRITERIA FOR MAINTENANCE OF PRIMARY ROADS

There are two types of maintenance inputs in practice, viz.; time bound (scheduled) maintenance, and pavement condition responsive maintenance.

A. Time Bound (Scheduled) Maintenance

The present policy of maintenance of pavements is based on providing routine maintenance whenever required and renewal/strengthening after every five years without analyzing its economic implications. The main drawback of this policy is that some pavements, though good, are resurfaced as per time specific renewal cycle, while some other pavements deteriorate quickly, even though needing renewal but not covered by the maintenance cycle.

B. Pavement Condition Responsive Maintenance

It is very useful for judicious disbursement of maintenance funds. Most recently developed tools/software packages such as HDM-4, though have provision for time bound maintenance intervention criteria, but prefer for condition responsive maintenance intervention.

For Indian conditions, it is suggested that condition responsive maintenance intervention criteria may be adopted. To formulate condition responsive maintenance criteria, some basic minimum desired serviceability level need to be fixed. The suggested criteria are based on the widely accepted performance indicators such as roughness, cracks, rutting, skid, potholes, etc. Based on these performance indicators, the suggested intervention criteria for primary, secondary and urban roads are given in [2]. The intervention criteria for urban roads are given in **Table 3.**

Table 3: Intervention Levels for Primary Roads.

S.No.	Serviceability Indicator	Level 1 (Good)	Level 2 (Average)	Level 3 (Acceptable)
1	Roughness by B.I (max. permissible)	2000 mm/km	3000 mm/km	4000 mm/km
2	Potholes per km (max. number)	Nil	2-3	4-8
3	Cracking and patching area (max. permissible)	5 percent	10 percent	10-15 percent
4	Rutting – 20 mm (maximum permissible)	5mm	5-10 mm	10-20 mm
5	Skid Number (minimum desirable)	50 SN	40 SN	35 SN

[Source: 6]

V. M & R ALTERNATIVE ADOPTED FOR ANALYSIS

The following five M & R alternatives defined in Table 4 are considered in this study**.** The first alternative includes the basic routine maintenance for crack, pothole and ravel patching. It is considered as the Base Alternative for the analysis. Other alternatives include resealing with 25 mm SDBC, Overlay of 40 mm BC, Resealing with overlay of 40 mm BC and strengthening with Overlay of BC 40 mm upon DBM 50 mm. The serviceability level considered for this study is Level 1

(Good) as the selected highways sections belong to highest serviceability level of the pavement groups. The intervention criteria's for various alternatives are selected accordingly.

Table 4: Proposed M & R Alternative

S.N.	Alternatives	Work Standard	Description of Work	Intervention Criteria
1	Routine Maintenance	Routine Maintenance	Crack Repairs	>5%
			Ravel Patching	>10%
			Pothole Patching	>=5%
			Shoulder Repair	Structural crack>=5%
2	Alternative 1	Resealing SDBC	Resealing with 25mm SDBC	Damage Area >= 5%
3	Alternative 2	Thick Overlay	Overlay of 40mm BC	IRI >= 2.8 m/km
4	Alternative 3	Resealing & Overlay	25mm SDBC Reseal + Overlay of 40mm BC	IRI >= 2.8m/km
5	Alternative 4	Strengthening	Overlay of 40mm BC + DBM 50 mm	IRI >= 2.8m/km

VI. ANALYSIS & RESULTS

The project application of HDM 4 was run with above M&R alternatives for 8 selected National highways pavement sections of NH-24. The pavement condition of the pavement sections was simulated under the four defined M&R alternatives over the analysis period of 10 years. An economic analysis is also conducted with a discount rate of 12 per cent.

A. Effect on Roughness Progression

The progression of roughness over the analysis period of 10 years, under the three alternatives for one representative section i.e. section NH-24-01 is shown in Figure 2, Figure 3, Figure 4 and Figure 5. On comparing the roughness progression for different M & R alternatives following observations can be made:

- For M & R alternative of thin overlay, in case of 'Condition Responsive' alternative, overlay is triggered as soon as the roughness progresses to IRI = 3 m/km, but in case of 'Scheduled' alternative the overlay is triggered every two years, but at roughness value of IRI < 3m/km, which is well below the limiting values of IRI = 4 m/km (Figure 2).
- For M & R alternative of thick overlay, in case of 'Condition Responsive' alternative, overlay is triggered as soon as the roughness progresses to IRI = 3.3 m/km, but in case of 'Scheduled' alternative the overlay is triggered every five years, but at roughness value of IRI < 3 m/km, which is well below the limiting values of IRI = 3 m/km (Figure 3).
- For M & R alternative of Resealing + 40mm Overlay, in case of 'Condition Responsive' alternative, overlay is triggered as soon as the roughness progresses to IRI = 3.3 m/km, but in case of 'Scheduled' alternative the overlay is triggered every six years, but at roughness value of IRI < 2.5 m/km, which is well below the limiting values of IRI = 3 m/km (Figure 4).
- For M & R alternative of strengthening, in case of 'Condition Responsive' alternative, overlay is triggered as soon as the roughness progresses to IRI = 3.5 m/km, but in case of 'Scheduled' alternative the overlay is triggered every seven years, but as the ten years completed before next application of maintenance (Figure 5).

It clearly shows that under scheduled maintenance strategy, overlay is being applied at an earlier stage in comparison to as wanted by the serviceability requirements, thus causing more expenditure for the road agency.

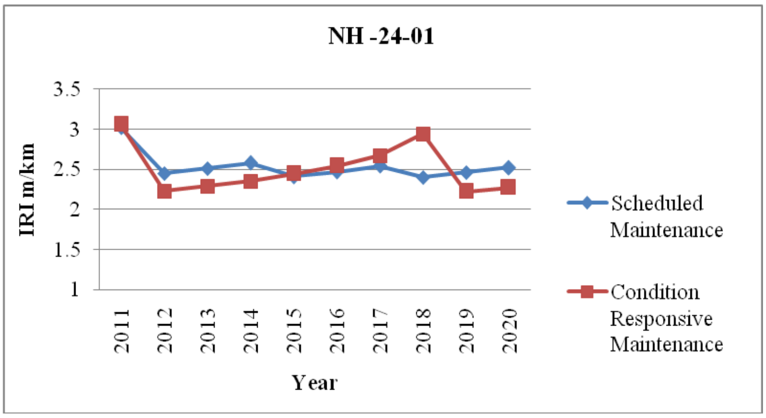

Figure 2. Comparison of Roughness Progression for Resealing SDBC

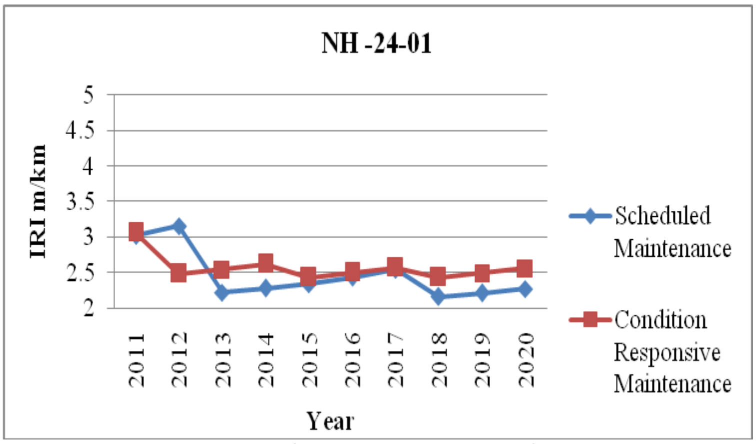

Figure 3. Comparison of Roughness Progression for Thick Overlay

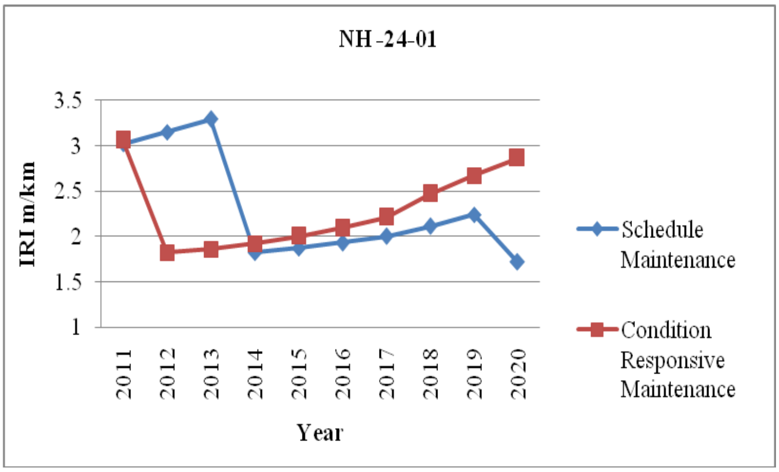

Figure 4. Comparison of Roughness Progression for Resealing + 40mm Overlay

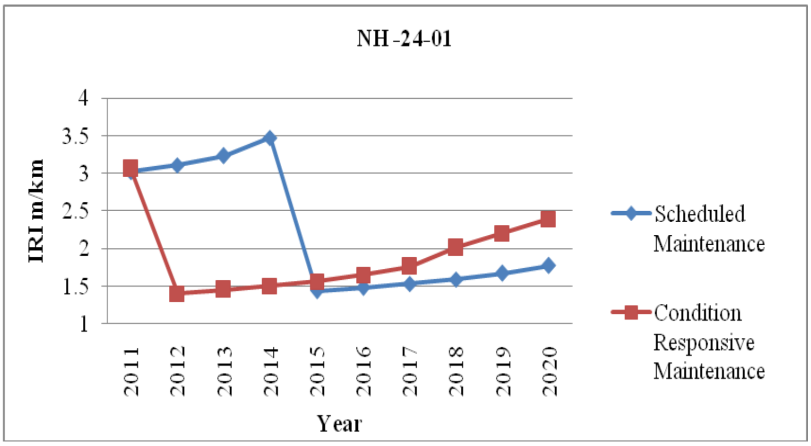

Figure 5. Comparison of Roughness Progression for Strengthening

B. Economic Analysis Summary

The economic analysis summary as shown in Table 5 gives a comparison of the NPV/cost ratio and Internal Rate of Return (IRR) for the two M&R strategies when compared against the base strategy of routine maintenance. A comparison of the NPV/Cost values indicates that the condition responsive maintenance strategy gives a higher NPV/Cost ratio than obtained in case of the scheduled maintenance strategy. Hence, maintenance decisions with condition responsive strategies were selected as an optimum M & R alternative. The optimum M & R alternative for the selected sections are given in Table 6 on the basis of maximum NPV/Cost.

Table 5: Economic Analysis Summary

NH Pavement Sections	M&R Strategy	NPV/Cost			
		Resealing SDBC	**Thick Overlay**	**Resealing & Overlay**	**Strengthening**
NH-24-01	Scheduled	7.793	12.133	11.907	9.297
	Condition Responsive	8.041	12.233	11.675	8.129
NH-24-02	Scheduled	9.018	14.008	13.763	10.73
	Condition Responsive	11.554	14.965	13.25	9.212
NH-24-03	Scheduled	10.361	15.618	14.968	11.507
	Condition Responsive	10.353	16.49	14.719	10.23
NH-24-04	Scheduled	8.845	13.815	13.675	10.775
	Condition Responsive	11.031	14.354	12.681	8.816
NH-24-05	Scheduled	7.188	11.306	11.242	8.853
	Condition Responsive	7.236	12.543	10.595	7.4
NH-24-06	Scheduled	9.811	15.151	14.833	11.551
	Condition Responsive	9.822	16.113	13.969	9.654
NH-24-07	Scheduled	12.836	18.702	17.427	13.12
	Condition Responsive	12.819	19.035	17.929	12.372
NH-24-08	Scheduled	6.294	10.051	10.123	7.96
	Condition Responsive	6.844	10.522	10.125	7.102

Table 6: Optimum M & R Alternative

NH Pavement Sections	M&R Strategy	M & R Alternative	NPV/Cost
NH-24-01	Condition Responsive	Thick Overlay	12.233
NH-24-02			14.965
NH-24-03			16.49
NH-24-04			14.354
NH-24-05			12.543
NH-24-06			16.113
NH-24-07			19.035
NH-24-08			10.522

VII. CONCLUSION

The following conclusions have been drawn on the basis of this study:

- Project analysis application of internationally recognised HDM-4 has been used for comparing the scheduled and condition responsive maintenance alternatives for the urban pavement sections.
- The effect of two M & R strategies on roughness progression showed that under scheduled maintenance strategy, overlay is being applied at an earlier stage in comparison to as warranted by the serviceability requirements.
- Economic analysis conducted for these urban pavement sections revealed that condition responsive maintenance is more beneficial over the scheduled maintenance over the design life of 10 years.
- Sections selected for this case study based on maximum NPV/Cost ratio.
- 40mm (AC) thick overlay was suggested as the optimum M & R alternative for all the pavement sections.

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