DEVELOPMENT OF PAVEMENT MANAGEMENT SYSTEM FOR URBAN ROADS IN NEW DELHI

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ABSTRACT

The urban roads particularly in metropolitan cities and state capitals carry large volume of traffic. The economic losses due to poor road condition amounts to a huge sum in spite of their small mileage. Funds are not sufficient to maintain all the roads to the desired level-of-service. In such a situation Pavement Management System (PMS) provides relevant logistics for prioritisation of roads for maintenance in consonance with the availability of funds. In the present study, twelve road sections located in different urban areas of Indian Capital city of New Delhi have been identified for the development of a PMS. The Highway Development and Management Model (HDM-4), duly calibrated to suit to the local conditions has been used for life–cycle costing analysis. The output of the study provide the prioritisation of twelve road segments, to be taken up for maintenance during the analysis period of ten years from 2007-2016, based on NPV/Cost method of economic analysis. Besides prioritisation, the PMS provides the availability of timely information with respect to pavement condition, maintenance, rehabilitation, reconstruction actions and cost for each road section.

1. INTRODUCTION

In India, the Urban Roads are those roads, which fall within the jurisdiction of Municipal Corporations, Municipal Boards, Cantonment Boards and Port Trusts, which are the statutory bodies in the urban areas. The urban roads form a very small percentage i.e. 6.7% of the total road length in the country. The urban roads particularly those in metropolitan cities carry large volume of traffic and the economic loss due to poor road condition amounts to a huge sum in spite of their small mileage. The use of intra-city or urban roads and the problems of maintenance and construction are much different than inter-city roads, such as National Highways or State Highways. In case of urban roads the trip length is small, number of stops and diversion is large, and the intensity of traffic is heavy and non-uniform. The distress in road pavement takes place because of extra forces of braking during acceleration and deceleration at intersections. The multiplicity of the traffic/vehicles results in higher density and congestion of vehicles at intersections. Inadequate drainage is largely responsible for failure of city roads. Carrying out of maintenance and rehabilitation activities on roads have inherent difficulties, as the work has to be done at the minimum inconvenience to road users.

1.1 Existing Practices for Maintenance of Urban Roads

The current engineering practice in India is to design pavements and select maintenance and rehabilitation alternatives based on subjective judgement and engineering experience. Even if the engineer responsible for making decisions has a significant experience base to draw up the maintenance strategies, there are no available analytical tools for use by the highway agencies to assist the practicing highway engineers in selecting the best strategy based upon economics of 'life cycle cost analysis'. 'The existing practice of maintenance of urban roads comprise of stipulating the type of maintenance and rehabilitation treatment and its periodicity in terms of years for the different traffic range in terms of commercial vehicles per day as given in Table 1.

Table 1 - Intervention criteria adopted in current maintenance norms

Category of Traffic	Commercial Vehicles* per day (cvpd)	Renewal Treatment	Duration
I	< 150	20 mm MSS	5 years
II	150-450	20 mm MSS	4 years
III	450-1500	25 mm AC	5 years
IV	1500-4500	40 mm AC	5 years
V	> 4500	40 mm AC	4 years

* Commercial vehicle = having gross weight more than 3 tonnes

The intervention criteria adopted in current maintenance norms is scheduled cycle period is also given in Table 2. This fixed and rigid cycle of renewal by a particular treatment may not be need based but it does entail over–maintenance of certain sections while starving others for funds. For optimum deployment of the available resources on urban roads, it is essential that a condition responsive system, for different types of maintenance of pavement, should be worked out on scientific basis. In the present study, efforts have been made to develop a condition responsive-cum-scheduled maintenance methodology.

1.2 An Approach to Pavement Management System

There are two distinct level of PMS decision making, i.e., at Network Level and Project Level. The network – level decisions are concerned with the overall network requirement and its preservation, identify priorities among projects, estimating funding needs and allocating budgets for maintenance, rehabilitation and reconstruction (MR & R), etc. The Project – level decision deals with link/section level decision. Once the results from the network – MR & R programme have been established, the Project – level analysis include to determine the best appropriate technical solution and then prepare plan and specifications for individual link or section. However, the objective functions of PMS at both the levels, i.e., Network – Level and Project – Level are same as to minimize total transportation cost and maximize the benefit/cost ratio.

2. OBJECTIVE AND SCOPE OF THE STUDY

The objective of present study is to analyse the collected field data to develop the PMS for urban roads. For the present study, twelve road sections have been identified, from the existing road network of New Delhi city managed by different agencies, and these road sections are representative of overall urban road length in New Delhi. The fieldwork comprised of collection of inventory data, traffic data, functional evaluation and structural evaluation of pavements. The Highway Development and Management Model (HDM-4) duly calibrated and adapted to Indian conditions have been used as the life-cycle costing model. All input data, has been converted into the format suitable to the requirements of HDM–4. Prioritization ranking has been proposed for the various M&R activities based on NPV/Cost method of economic analysis.

2.1 Identification of Test Sections

The city of New Delhi has a radial pattern of road network consisting of 2248 km length of urban roads. Depending on administrative boundaries and jurisdictions, different roads (and segment of roads) and intersections are maintained by Municipal Corporation of Delhi (MCD), the New Delhi Municipal Council (NDMC), the Public Works Department (PWD) and Cantonment Board (MES). For identification of road sections, it is proposed to divide New Delhi city into five zones as Central Zone (CZ), South West Zone (SWZ), North West Zone (NWZ), North East Zone (NEZ) and South East Zone (SEZ) as shown in Fig. 1. The following criteria has been adopted for selection of test sections:

(i) Minimum two road sections from each zone have been taken from the above, i.e., C, SW, NW, NE & SE Zones;
(ii) Minimum two road sections from area under the jurisdiction of each of the above mentioned controlling/maintaining authorities, i.e., MCD, NDMC, PWD & MES;
(iii) Importance of the road keeping in view the high traffic intensity corridor serving the large incoming and outgoing traffic through ring road.
(iv) Roads serving the traffic of villages around Delhi and satellite towns and commercial areas, like, Connaught Place and Nehru Place.

A representative length of 2km has been selected uniformly for each road section. The list of selected road sections is given in Table 2.

2.2 Data Collection

A Pavement Management System must have usable, accurate, timely information in order to produce desired results. During this study, the strategy of the data collection was planned, keeping in view the input requirement of HDM Model. Firstly, formats were developed, to collect the data from field survey (primary surveys) and secondary sources. The data collection has been divided in following heads:

2.2.1 Inventory data

It includes details of road network such as category of road, surface type and thickness, carriageway width, crust details and construction & maintenance history etc. This data was obtained from local authorities in charge of the selected road sections.

2.2.2 Structural evaluation

The structural capacity of the test sections was evaluated by measurement of surface deflection by Benkelman Beam Deflection (BBD) method. This deflection value is used to determine the Adjusted Structural Number (SNP) of the pavement sections.

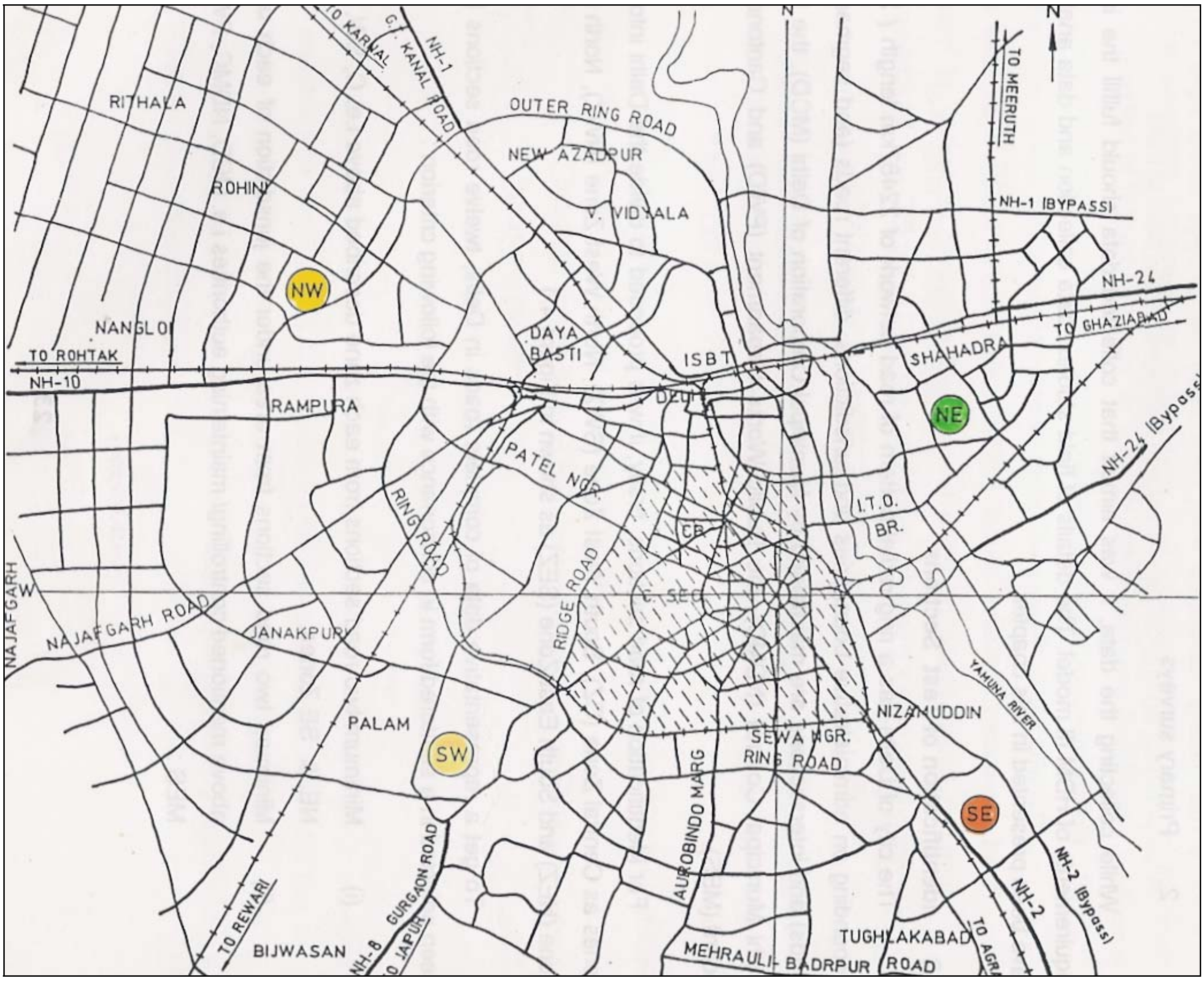

Figure 1 - Map of New Delhi showing the zoning system adopted for the study

2.2.3 Functional evaluation

It includes the collection of pavement condition data pertinent to surface distresses in the form of crack area, ravelled area, pot-holed area, rut depth etc. using conventional measurement methods. Surface roughness measurements are made using the Fifth- Wheel Bump Integrator (BI). The BI roughness values are converted to International Roughness Index values using the following equation:

$$BI = 630\ IRI^{1.12}$$

2.2.4 Traffic data

Classified traffic volume was obtained at all test sections by conducting the 24-hour traffic survey. Only the motorized (MT) vehicles have been taken into consideration and non-motorized (NMT) traffic is not included in the study because it does not contribute much towards the pavement deterioration. Axle load survey has been carried out using the portable weigh pads. The annual growth rates of different categories of vehicles have been assumed on the basis of past data.

2.2.5 Cost data

The unit rates of road construction/maintenance activities have been collected from various engineering departments of New Delhi. Only economic costs have been taken into consideration, which are exclusive of any kind of taxes and subsidies. While carrying out economic analysis all the economic costs have been taken as 80% of the market cost (financial cost).

Table 2 - Details of the identified road sections

Sr. no.	Name of Road	Section ID	Section Length (KM)	Controlling Authority	Zone
1	Kasturba Gandhi Marg	DUR-01	2.00	NDMC	CZ
2	Sardar Patel Marg	DUR-02	2.00	NDMC	CZ
3	Thimmaiya Marg	DUR-03	2.00	MES	SWZ
4	Carriappa Marg	DUR-04	2.00	MES	SWZ
5	Barrar Square – Naraina	DUR-05	2.00	PWD	NWZ
6	Peera Garhi – Vikas Puri	DUR-06	2.00	MCD	NEZ
7	Kingsway Camp – Dhaka	DUR-07	2.00	MCD	NEZ
8	GTB Hospital – Tahirpur	DUR-08	2.00	PWD	NEZ
9	Maharajpur Check Post	DUR-09	2.00	PWD	SEZ
10	Bhairon Road	DUR-10	2.00	MCD	SEZ
11	Nehru Place – Chirag Delhi	DUR-11	2.00	PWD	SEZ
12	S.A. Road	DUR-12	2.00	PWD	SEZ

3. HIGHWAY DEVELOPMENT AND MANAGEMENT MODEL (HDM-4)

The Highway Development and Management Model (HDM-4) is a support system for decision making for highway administrators and technicians to predict the economic, social, and environmental impacts that they might occur when making investment decisions. The HDM-4 system can be implemented to assist the highway agencies establish realistic levels of funding for road maintenance and to set levels and priorities for road maintenance activities to maximize the effectiveness of maintenance expenditure. The HDM-4 analytical framework is based on the concept of pavement life cycle analysis as shown in Figure 2. This is applied to life-cycle of the road pavements through the following sub-models of HDM-4:

- Road Deterioration (RD)
- Works Effects (WE)
- Road User Effects (RUE)
- Socio-Economic and Environmental Effects (SEE)

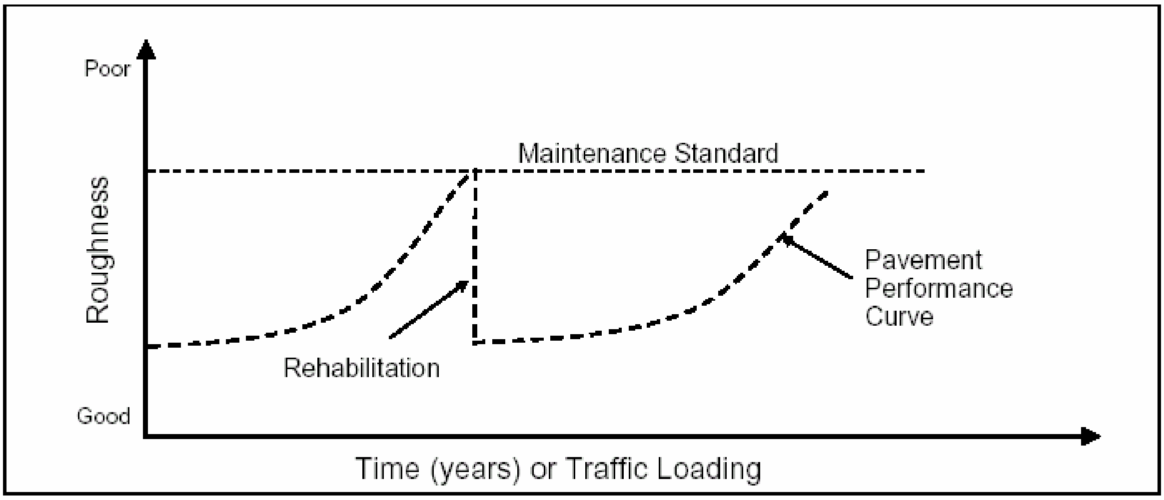

Figure 2 - Concept of life cycle analysis in HDM-4

3.1 Role of HDM-4 in Pavement Management

The HDM-4 system is designed with a modular structure, thereby permitting its total or selected integration with Pavement Management Systems. Any of the three application modules i.e. Project, Programme or Strategy Analysis can be incorporated within a PMS. In addition, the technical relationships built into HDM-4 can be linked into existing PMS so that a common set of pavement deterioration and road user cost models can be incorporated in other PMS.

4. DEVELOPMENT OF PMS METHODOLOGY

The primary objective of PMS is to derive the maximum benefits from the scarce funds available for the preservation of road infrastructure. Its aim is to determine the pragmatic cost-effective strategies for maintenance and rehabilitation of pavements. In this study an effort has been made to develop a PMS for urban roads and to use the same for prioritization of maintenance and rehabilitation alternatives in the event of constrained funds.

4.1 HDM-4 Programme Analysis

In this study, the 'Programme Analysis' application of the HDM-4 model has been used for simulating the life-cycle costs of road construction and maintenance, and road user costs and their trade-off with in the designated life cycle. This deals primarily with the prioritisation of a defined long list of candidate road projects into a one-year or multi-year work programme under defined budget constraints. An opening screen shot of the HDM-4 Programme Analysis used for this study is shown in Figure 3.

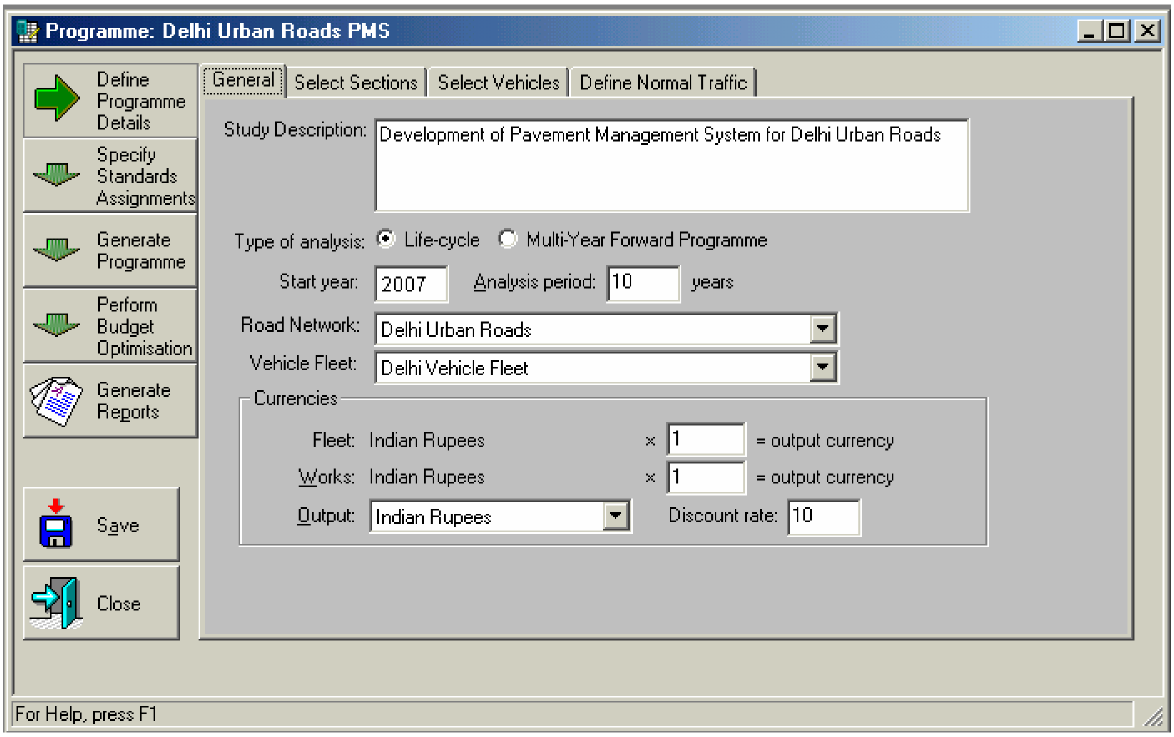

Figure 3 - Opening screen shot of HDM-4 Programme Analysis

4.2 Calibration of HDM-4 Sub-models

The two main sub models of HDM-4 of particular relevance to the present study are the Road Deterioration (RD) and the Road User Effect (RUE) model. A fundamental assumption made prior to using HDM is that the road deterioration models would be calibrated to reflect the observed rates of pavement deterioration on the roads where the models are applied. Since HDM-4 is designed to be used in a wide range of environments, configuration and calibration of HDM-4 provides the facility to customize system operation to reflect the norms that are customary in the environment under study. Calibration of HDM-4 is intended to improve the accuracy of predicted pavement performance and vehicle resource consumption.

The RD model is provided with the facility for local calibration and adoption, to take into account the variations in the material characteristics, environmental characteristics (temperature and rainfall), and construction quality through the use of “Calibration factors”. The same has been calibrated by making use of the comprehensive data collected under the Pavement Performance Study for existing pavement sections [CRRI 1994].

The RUE model has been calibrated by making use of the unit cost values for Indian conditions, as specified in the Updated Road User Cost Study [Kadyali 1992]. These values have been updated to reflect the current values by making use of the concept of Consumer Price Index (CPI) and Wholesale Price Index (WPI), wherever applicable.

4.3 Maintenance Alternatives

HDM-4 economic analysis is conducted by comparing the total cost streams for various maintenance and rehabilitation (M&R) alternatives with a base option usually representing the minimal routine maintenance. Table 3 shows the three M&R alternatives and the corresponding intervention levels selected for this study.

Table 3 - Details of M&R Alternatives selected for comparison

M&R Alternative	Works Standard	Effective from Year	Intervention Level
Base Option	Routine Maintenance	2007	Crack Sealing (annually) Pothole Patching (annually)
Alternative1	Routine Maintenance +	2007	Crack Sealing (annually) Pothole Patching (annually) Single/Double Surface Dressing at Total
Alternative2	Routine Maintenance +	2007	Crack Sealing (annually) Pothole Patching (annually) Overlay 25 mm/40 mm at IRI > 6
Alternative3	Routine Maintenance + Reseal + Overlay	2007	Crack Sealing (annually) Pothole Patching (annually) Single/Double Surface Dressing at Total Crack Area > 15% Overlay 25 mm/40 mm at IRI > 6

4.4 Economic Evaluation and Optimization

The programme analysis application of HDM-4 has been used for economic analysis of the selected pavement sections. The purpose of programme analysis is to evaluate maintenance and rehabilitation options, and to try and select the set of investments to be made on a number of road sections, which will optimize an objective function. If the needed budget for each budget period is below the given budget constraints, no further economic analysis is necessary. However if the budget needs are higher than the available budgets, optimisation is necessary. The incremental NPV/cost ranking model is used for optimisation and prioritization.

The NPV (Net Present Value) is defined as the difference between the discounted benefits and costs of a project. In the economic appraisal of road projects, benefits are derived mainly from savings in road user costs. The NPV depends upon the discount rate used in the calculation of present values. As per the prevailing market conditions, a discount rate of 10% has been used in this analysis. For prioritization amongst a number of road projects, the projects with the highest NPV/cost ratio are selected in the decreasing order of priority.

4.5 Incremental NPV/cost Ranking

This method involves searching through investment options on the basis of incremental NPV/cost ratio of one alternative compared against another. The aim is to select options successively with the largest incremental NPV/cost ratio, since this attempts to maximize the NPV for any given budget constraint. The incremental NPV/cost ratio is defined as:

$$E_{ji} = \frac{(NPV_j - NPV_i)}{(cost_j - cost_i)}$$

where

NPV_k = the net present value of investment alternative k

$Cost_k$ = the investment cost of alternative k

i = index of the cheaper alternative

j = the index of more expensive alternative

The objective of this method is to select road sections successively starting with the largest NPV/cost ratio, since this maximizes the NPV for any given budget constraint. Where there is more than one investment option on any individual road section that with the lowest discounted investment costs is designated the base case alternative. This method considers all possible options and compares these incrementally starting against the base case, by using the incremental algorithm to select the combination that maximizes the selected objective function.

5. RESULTS

As a consequence of the above programme analysis, the following results have been obtained which are most important with regard to development of a pavement management system for the selected urban road sections.

5.1 Pavement Condition Prediction

The future condition of all the pavement sections in terms of various performance parameters such as cracking, ravelling, roughness has been determined as end of the year condition for each year of the analysis period. The effect of applicable M&R options and hence the corresponding intervening maintenance activities has also been taken into account in the pavement condition prediction. Table 4 shows the predicted end of the year pavement condition for the road section DUR-11 under M&R option 'Alternative2'for the analysis period of 10 years.

5.2 Timing and Type of M&R Activities

It is very important for the pavement managers to know about the appropriate type of the maintenance and rehabilitation activities to be carried out on all road sections and the corresponding timing for the same. A year wise listing of the applicable M&R activities, will also serve the purpose to a great extent. Table 5 shows a list of M&R activities to be carried out under M&R option 'Alternative1', on all road sections in the very first year of analysis, i.e. year 2007 itself. The corresponding work quantities involved alongwith the financial costs involved are also shown in Table 5.

Table 4 - Predicted pavement condition for the road section DUR-11

Year	Motorized Traffic (AADT)	ESAL (millions/ E lane)	Condition Time	Pavement Type	Average Structural Number	Roughness IRI (m/km)	Cracking Areas (%)			Ravelled Area (%)	Potholes		Rutting		Texture Depth (mm)	Skid Resistance (SFC50)
							All Structural	Wide Structural	Total Cracking		No. per km	Area %	Mean Rut Depth (mm)	Std. Dev of Rut Depth		
2007	42175	0.98	Before works	AMAP	4.85	4.64	12.4	6.52	12.4	13.64	4	0	8.2	4.69	0.5	0.49
			After works	AMAP	4.85	4.61	5.89	0	5.89	13.64	0	0	8.2	4.69	0.5	0.49
2008	45619	1.03	Before works	AMAP	4.86	4.74	10.71	0	10.71	43.1	0	0	8.4	4.74	0.5	0.48
			After works	AMAP	4.86	4.74	10.71	0	10.71	43.1	0	0	8.4	4.74	0.5	0.48
2009	49358	1.08	Before works	AMAP	4.83	4.89	17.88	0	17.88	78.74	3	0	8.61	4.78	0.5	0.47
			After works	STAP	4.83	4.89	0	0	0	0	0	0	8.61	4.78	0.7	0.47
2010	53417	1.13	Before works	STAP	5.04	5.01	0	0	0	2.22	0	0	8.8	4.82	0.22	0.46
			After works	STAP	5.04	5.01	0	0	0	2.22	0	0	8.8	4.82	0.22	0.46
2011	57824	1.19	Before works	STAP	5.04	5.11	0	0	0	14.96	0	0	9	4.86	0.12	0.45
			After works	STAP	5.04	5.11	0	0	0	14.96	0	0	9	4.86	0.12	0.45
2012	62610	1.25	Before works	STAP	5.03	5.23	0	0	0	46.36	0	0	9.19	4.89	0.1	0.44
			After works	STAP	5.03	5.23	0	0	0	46.36	0	0	9.19	4.89	0.1	0.44
2013	67808	1.32	Before works	STAP	5.03	5.36	1.15	0	1.15	81.25	3	0	9.39	4.92	0.1	0.43
			After works	STAP	5.03	5.36	1.15	0	1.15	81.25	0	0	9.39	4.92	0.1	0.43
2014	73456	1.38	Before works	STAP	5.03	5.52	6.28	0	6.28	93.71	6	0.01	9.59	4.95	0.1	0.41
			After works	STAP	5.03	5.52	6.28	0	6.28	93.71	0	0	9.59	4.95	0.1	0.41
2015	79594	1.45	Before works	STAP	5.01	5.75	18.31	6.1	18.31	81.68	8	0.01	9.79	4.98	0.1	0.4
			After works	STAP	5.01	5.64	0	0	0	0	0	0	9.79	4.98	0.7	0.4
2016	86265	1.53	Before works	STAP	5.21	5.77	0	0	0	6.21	0	0	9.99	5	0.16	0.38
			After works	STAP	5.21	5.77	0	0	0	6.21	0	0	9.99	5	0.16	0.38

Table 5 - Road works summary for the year 2007

Road Section	Works Description	Code	Economic Cost (Rs.)	Financial Cost (Rs.)	Work Quantity (sqm)
Kasturba Gandhi Marg	Crack Sealing	CRKSL	17,041.9	20,450.3	852.09
Sardar Patel Marg	Crack Sealing	CRKSL	15,961.4	19,153.6	798.07
Thimmaya Marg	Crack Sealing	CRKSL	1,152.0	1,382.4	57.60
Carriappa Marg	Double Surface Dressing	DBSD	1,200,000.0	1,440,000.0	16,000.00
Barrar Square – Narayana	Patching	PATCH	29.3	34.7	0.77
	Crack Sealing	CRKSL	31,036.0	37,243.2	1,551.80
Peera Garhi – Vikas Puri	Double Surface Dressing	DBSD	1,680,000.0	2,016,000.0	22400.00
Kingsway Camp – Dhaka	Patching	PATCH	29.9	35.4	0.79
	Crack Sealing	CRKSL	31,036.0	37,243.2	1,551.80
GTB Hospital – Tahirpur	Crack Sealing	CRKSL	20,049.3	24,059.1	1,002.46
Maharajpur Check Post	Crack Sealing	CRKSL	25,373.3	30,447.9	1,268.66
Bhairon Road	Crack Sealing	CRKSL	23,713.6	28,456.3	1,185.68
Nehru Place – Chirag Delhi	Double Surface Dressing	DBSD	1,275,000.0	1,530,000.0	17,000.00
S.A. Road	Single Surface Dressing	SBSD	633,600.0	763,2100.0	14,400.00

5.3 Unconstrained Works Programme

If sufficient budget is available, an unconstrained works programme can be taken up for the total analysis. Table 6 gives an unconstrained works programme list, giving details of the optimum M&R alternatives for the candidate pavement sections, corresponding financial costs involved and the cumulative budget requirements for the analysis period of 10 years, which will be of the order of 26.8 million Indian Rupees.

5.4 Optimized Works Programme and Prioritization

Just in case, sufficient funds are not available to carry out all the M&R activities as shown in the unconstrained works programme list, the works programme need to be optimized and the M&R activities need to be prioritized each year, depending upon the available budget. In this case, if the budget availability is of the order of Rs. 20 million as against the requirement of 26.8 million over a period of 10 years, the works programme has been optimized with in the available budget and the yearly M&R activities have been prioritized on the basis of NPV/cost ratio. The same has been given in Table 7.

Table 6 - Unconstrained works programme (by year)

Year	Section	Road Class	AADT	Surface Class	Work Description	NPV/Cost	Fin. Cost	Cum. Cost
2007	Carriappa Marg	Urban Road	29197	Bituminous	Asphaltic Concrete 40m	43.217	2.88	2.88
	Peera Garhi - Vikas Puri	Urban Road	23790	Bituminous	Asphaltic Concrete 40m	24.794	4.032	6.912
	Nehru Place - Chirag Delhi	Urban Road	50825	Bituminous	Double Surface Dressing	4.955	1.53	8.442
2009	Bhairon Road	Urban Road	15187	Bituminous	Single Surface Dressing	2.105	0.901	9.343
	Maharajpur Check Post	Urban Road	29741	Bituminous	Double Surface Dressing	1.415	1.89	11.233
2010	S.A. Road	Urban Road	23284	Bituminous	Asphaltic Concrete 25m	24.73	1.901	13.134
	Thimmaya Marg	Urban Road	23284	Bituminous	Single Surface Dressing	5.18	0.763	13.897
	Sardar Patel Marg	Urban Road	42459	Bituminous	Double Surface Dressing	5.039	1.296	15.193
	Kasturba Gandhi Marg	Urban Road	24653	Bituminous	Single Surface Dressing	4.043	0.901	16.094
	GTB Hospital - Tahirpur	Urban Road	11642	Bituminous	Single Surface Dressing	1.144	1.06	17.154
	Kingsway Camp - Dhaka	Urban Road	15066	Bituminous	Single Surface Dressing	0.881	1.484	18.638
2013	Nehru Place - Chirag Delhi	Urban Road	81717	Bituminous	Double Surface Dressing	4.955	1.53	20.168
2015	Barrar Square - Narayana	Urban Road	79593	Bituminous	Asphaltic Concrete 40m	5.366	3.888	24.056
	Maharajpur Check Post	Urban Road	47960	Bituminous	Double Surface Dressing	1.415	1.89	25.946
2016	Bhairon Road	Urban Road	26542	Bituminous	Single Surface Dressing	2.105	0.901	26.847

Table 7 Optimized works programme (by year)

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	Kasturba Gandhi Marg	Urban Road	24653	Bituminous	Single Surface Dressing	4.043	0.901	13.303
	GTB Hospital - Tahirpur	Urban Road	11642	Bituminous	Single Surface Dressing	1.144	1.06	14.363
2013	Nehru Place - Chirag Delhi	Urban Road	81717	Bituminous	Double Surface Dressing	4.955	1.53	15.893
2015	Barrar Square - Narayana	Urban Road	79593	Bituminous	Asphaltic Concrete 40m	5.366	3.888	19.781

6. CONCLUSIONS

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

(i) A methodology has been developed for PMS for a representative Urban Road Network in New Delhi.

(ii) In India, adequate indigenous tools are not available for the development of pavement management system methodology, therefore, internationally recognised Highway Development and Management system (HDM-4) has been selected for use in this study, because of its wider acceptance and applicability in a large number of developing countries.

(iii) The network level pavement management analysis has been carried out using the 'Program Analysis' application module of HDM-4. The life-cycle cost analysis of the selected road network has been carried out, and an unconstrained works programme has been prepared for the defined analysis period of 10 years (i.e. year 2007–2016).

(iv) The total budget requirements for maintenance management of the selected road network comes out to be equal to Rs. 26.8 million. But, since the usual level of fund allocation for the maintenance management of the urban roads is only 75% of the requirements, therefore an optimized and prioritized works programme has been prepared for the available budget of Rs. 20 million.

(v) The prioritization of road sections to be taken up for maintenance management during the analysis period has been done on the basis of decreasing NPV/Cost ratio.

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