International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-4 Issue-3, February 2015

Determination of Optimum Maintenance and Rehabilitation Strategies for Urban Semi Dense Bituminous Surface and Premix Carpet Roads

Pardeep Kumar Gupta, Rajeev Kumar

Abstract-: ***The road traffic has increased manifolds during the post-independence in India. The traffic axle loading may be much heavier than the specified limit in many cases. As a result of which, the existing road network has been subjected to severe deterioration leading to premature failure of the pavements. There is a dire need of developing a meaningful approach towards implementing the maintenance and rehabilitation schemes of the road network. In such a scenario, development of the effective pavement management strategies would furnish useful information to ensure the compatible and cost- effective decisions so as to keep the existing road network intact. The optimum maintenance and rehabilitation strategies applied in this study would be useful in planning pavement maintenance strategies in a scientific manner and ensuring rational utilization of limited maintenance funds. Once this strategy for urban road network is implemented and made operational; this would serve as window to the other urban road network of different regions.***

Index – Introduction, Methodology Used, Application of Methodology, Conclusion & Recommendation

I. INTRODUCTION

1.1 Background

Road Transport is vital for India's economy. The roads deteriorate considerably without the timely and proper maintenance which can lead to dwindled reliability of transport system and thereby increasing the number of accidents and increased user cost. The Rehabilitation and reconstruction cost will multiply to a great extent if maintenance work is not given proper heed at right time, road maintenance is, therefore, such a indispensable feature of transportation system, the absence of which will lead to ultimate repair cost, road user cost and a lot of discomfort to the road user. It requires a scrupulous planning, gigantic funds and meticulous construction techniques to keep the good road network. India has a road network of over 46, 89, 842 km in 2013, the second largest road network in the world. As of 2008, 49 percent i.e. about 2.1 million km Indian roads were paved. Total urban road length recorded in India is about 3, 04,327 km. urban road constitute nearly 7 percent of the total road length network in India. Preservation of existing urban roads has become a major activity for all level of government. Deteriorating urban roads and reduced funding are a major problem for the local government. Funds designated for pavement must, therefore, be used as effectively as possible.

Manuscript published on 28 February 2015.
* Correspondence Author (s)
Dr. Pardeep Kumar Gupta, Assoc. Prof., Chandigarh, India.
Rajeev Kumar, PhD Student, Chandigarh, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

1.2 Inadequacies of Present Road Infrastructure

The growth of road network, both in terms of capacity and quality has not kept pace with the significant growth in demand for transport in India. That is why the current road infrastructure of India has to cope with serious inadequacies as mentioned below:

1.2.1 Poor Quality of Roads

In spite of having such a big network of roads, the quality of roads is still not up to the mark. The existing road network has aged, leading to appearance of different kind of distresses viz. cracking, raveling and potholing on the surface. These distresses, under the combined action of traffic and environmental factors have been continuously growing to the extent of severity because of the lack of timely upkeep and maintenance. More than 50 percent of different categories of roads are in very bad conditions.

1.3 Road Maintenance Management

1.3.1 Necessity of Road Maintenance Management

The lack of road maintenance have caused irreparable damage to economic growth rate, since the poorly maintained roads cause delay, road accidents and higher vehicle operating costs. Any neglect of maintenance activity is self defeating as one Rupee spent on maintenance saves 2 to 3 Rupees in vehicle operating cost [MORT&H 2013e]. Also such neglect of maintenance accelerates the process of deterioration leading to the higher cost of rehabilitation and reconstruction.

1.3.2. Consequences of poor maintenance timings:

The consequences of poor maintenance timings are shown in Figure 1.1. If proper and timely maintenance measures are not taken, the pavement condition deteriorates very rapidly from 'good' to 'poor' during a very short span of pavement life, causing the requirement of 4-5 times more fund for rehabilitation of the pavement. If maintenance and rehabilitation is performed during the early stages of deterioration, before a sharp decline in pavement condition, over 75% of the maintenance costs can be avoided [shahin 1994].

© Copyright: All rights reserved.

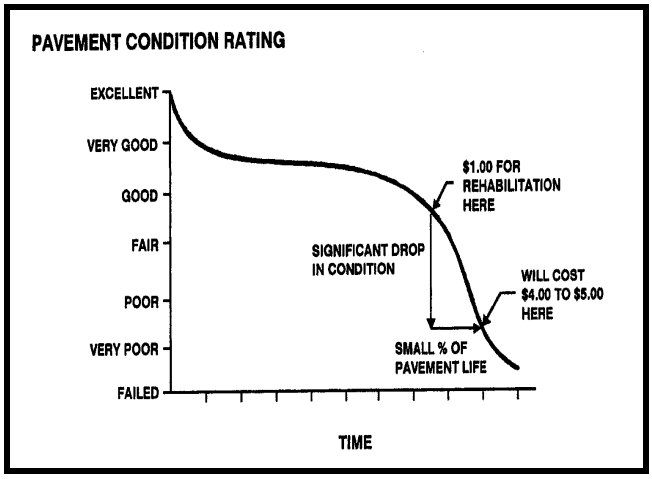

Figure 1.1 Consequences of Poor Maintenance Timings [Shahin 1994]

II. METHODOLOGY USED

2.1 Identification of Urban Road Network

The identification and selection of different categories of roads of various sectors of Panchkula Distt., Haryana has been made. The whole road network comes under the jurisdiction of HUDA (Haryana Urban Development Authority) which can exercise the good control over the study related activities, being the only agency. The following urban road network of Panchkula has been considered for the study:

Semi Dense Bituminous Concrete (SDBC) Roads

- **Road-R4:** 5.5m wide road from B-road leading to Dispensary Sector-16 to parking of booths with 25mm SDBC top layer
- **Road-R5:** 5.5m wide road from Sector dividing road of Sector 16-17 to parking of Sector 16 with 25mm SDBC top layer
- **Road-R6:** 5.5m wide road with 25mm SDBC top layer near roundabout of sector 16-17-8-9, Panchkula.

Premix Carpet (PC) Roads

- **Road-R7:** 5.5m wide road along Ghaggar from plot no. 146 to plot no. 801 with 25mm thick Premix Carpet top layer in sector 26, Panchkula.
- **Road-R8:** 5.5m wide road with 25mm PC top layer from plot no. 209 to 234 and plot no. 95 to plot no. 119 in Sector 26, Panchkula.
- **Road-R9:** 5.5m wide road with 25mm PC top layer between sector 24 and 26 from plot no. 922 to plot no. 1019 onwards in sector 26, Panchkula.

2.2 Types of Data Collected

The process of data collection has been categorized into the following four types:

- Road Network Data
- Vehicle Fleet Data
- Maintenance and Rehabilitation Works Data
- Cost Data

Table 2.1 Details of Identified Urban Road Network

Name of Road	Description of Road	Soil Type	Terrain	Rainfall In mm (Annual)	Temp. In 0c	Traffic
Road-R4	25mm SDBC road from B-road to Dispensary in Sec 16	Loamy Sand Soil	Plain	1057	-1to43	Low
Road-R5	25mm SDBC road from sector dividing road 16-17 to parking in Sec 16	Loamy Sand Soil	Plain	1057	-1to43	Low
Road-R6	25mm SDBC road near roundabout 16-17-8-9	Loamy Sand Soil	Plain	1057	-1to43	Low
Road-R7	25mm PC road along Ghaggar in Sector 26	Loamy Sand Soil	Plain	1057	-1to43	Low
Road-R8	25mm PC road from P.No. 209 to 234 and 95 to 119 in sec 26	Loamy Sand Soil	Plain	1057	-1to43	Low
Road-R9	25mm PC road from P.No.922 to 1019 in sector 26	Loamy Sand, Soil	Plain	1057	-1to43	Low

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

2.3 ROAD NETWORK DATA COLLECTION

2.3.1 General

The data has been obtained from the secondary sources such as the past records of concerned division of Haryana Urban Development Authority (HUDA). The data has been gathered from the selected pavement sections by carrying out the field studies. The data related to the type of soil, terrain, traffic (volume and axle load data), pavement composition and climate has also been gathered through field studies.

2.3.1.1 Road network surveys: The road network surveys is categorized into the following two types

- Primary Survey -- Field data collection
- Secondary Survey – Inventory data collected from HUDA offices

The following secondary data has been obtained from various divisional offices of the HUDA in-charge of construction and maintenance of the respective sections of the selected roadway network.

- Year of original construction and its specification
- Crust thickness of each pavement layer
- Maintenance inputs and its norms
- Traffic details for the last 5 years
- Year of strengthening and its specification
- Year and specifications of last renewal course
- Temperature and rainfall data for the last 5 years
- The road network data collection in the field is categorized under the following heads:
- Inventory data
- Functional evaluation
- Evaluation of pavement material

2.3.2 Inventory Data

The details of Inventory data about the selected pavement section is given below:
Name and Category of road
Carriageway width
Shoulder width
Drainage conditions
Surface type and thickness
Pavement layer details
The above data has been gathered from the visual inspection of the pavement section and from the in-charge of construction and maintenance records of the concerned highway division of HUDA (Haryana Urban Development Authority).

2.3.3 Functional evaluation

Functional evaluation of pavements pertains to road data collection of surface distresses e.g. raveled are and pothole area.

2.3.3.1 Surface distress measurements: The type and extent of distress developed at the surface were observed based on the visual inspection. The distresses developed were also measured in quantitative terms.

- **Measurement of raveled area:** The raveling is usually seen in thin surface dressing e.g. seal coat, premix carpet etc. The affected area was measured by making rectangle having raveling inside and then it was expressed as percentage of total pavement area.
- **Measurement of pothole area:**
- **One pothole unit = 0.1sq.m**

The minimum diameter of pothole unit is 150mm and minimum depth is 25mm has been considered.

2.3.4 Evaluation of Pavement Materials

2.3.4.1 Field evaluation: The test pits of suitable size were dug up at suitable locations in all pavement sections. The following tests were conducted and the observations were taken.

- Thickness of the most recent surfacing course and old surfacing courses
- Thickness of base and sub-base courses
- Field dry density and field moisture content of the soil sub grade

The representative sub grade soil samples were collected from the test pits for marking the characterization of materials in the laboratory.

2.3.4.2 Laboratory evaluation: The evaluation of the subgrade soil samples collected from the field was done in laboratory conforming to the Indian Standard specifications.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Table 2.2Laboratory Test Results of Collected Sub grade Soil Samples on All Pavement Sections of the Selected Roads

Name of the Road	Optimum Moisture Content (%)	Atterberg Limits (%)			CBR In %	
		LL	PL	PI	Un-soaked	Soaked
Road-R4	12.0	16	12	4	7.22	4.75
Road-R5	13.0	18	13	5	6.99	4.43
Road-R6	14.0	19	16	3	7.01	4.61
Road-R7	14.0	15	12	3	6.82	4.54
Road-R8	13.0	17	13	4	6.23	4.11
Road-R9	13.0	16	12	4	6.69	4.32

2.3.5 Road Network Database

All road network data items which are required to be defined for each pavement section are given in the Table 2.3 to 2.5. All these items are stored in the road network database developed for the identified road network.

Table 2.3 Inventory Data of All Selected Urban Road Sections

Name of Road	Description of Road	Flow Type	Carriage -way Width	AADT	AADT Year	Length of Road (km)
Road-R4	25mm SDBC road from B-road to Dispensary in Sec 16	Two Way	5.5m	1,823	2014	0.110
Road-R5	25mm SDBC road from sector dividing road 16-17 to parking in Sec 16,PKL	Two Way	5.5m	2,240	2014	0.090
Road-R6	25mm SDBC road near roundabout 16-17-8-9,PKL	Two Way	5.5m	1980	2014	0.085
Road-R7	25mm PC road along Ghaggar in Sector 26,PKL	Two Way	5.5m	1,124	2014	0.920
Road-R8	25mm PC road from P.No. 209 to 234 and 95 to 119 in sec 26,PKL	Two Way	5.5m	1,296	2014	0.790

© Copyright: All rights reserved.

Road-R9	25mm PC road from P.No.922 to 1019 in sector 26,PKL	Two Way	5.5m	1,404	2014	1.243

Table 2.4 Observed Condition Data on All Pavement Sections of Urban Road network

Name of the Road	Condition Year	Raveled Area (%)	Pothole (No./km)
Road-R4	2013	4.12	2.84
Road-R5	2013	3.87	2.40
Road-R6	2013	3.62	2.68
Road-R7	2013	3.10	2.03
Road-R8	2013	3.20	1.84
Road-R9	2013	3.50	1.70

Table 2.5 Pavement Data Collected from All Sections of Urban Road Network

Name of The Road	Surfacing Material Type	Current Surface Thickness (mm)	Previous Surface Thickness (mm)	Last Construction Year	Previous Last Construction Year
Road-R4	SDBC	25	25	4/2009	5/2002
Road-R5	SDBC	25	25	4/2009	5/2002
Road-R6	SDBC	25	25	4/2009	5/2002
Road-R7	PC	25	25	9/2007	5/2002
Road-R8	PC	25	25	9/2007	5/2002
Road-R9	PC	25	25	9/2007	5/2002

2.4 VEHICLE FLEET DATA

2.4.1 Categories of Vehicle

A typical traffic flow on all types of urban road in India consists of both Motorized (MT) and Non-Motorized (NMT) vehicles. Both MT and NMT vehicles have been taken into account in this study.

2.4.2 Traffic Volume Counts

Traffic surveys were conducted manually for 24 hours round the clock for a week by engaging the sufficient number of enumerators. A separate count station was established for each individual road. The vehicles not covered under the representative vehicles defined above were suitably clubbed with the vehicles similar to them in composition and speed.

2.4.3 Vehicle Growth Rate

The average annual growth rate of vehicles in India has been taken as per the latest code of IRC-37, July'2012.The traffic compositions and annual growth rates have been assumed to be applicable to all different roads in the urban road network under study.

2.5 MAINTENANCE AND REHABILITATION WORKS

2.5.1 Serviceability Levels for Maintenance

The attempts are being made all over the world to develop standards for maintenance quality level for which roads are to be maintained to achieve the requisite level of comfort, convenience and safety to the road users. The maintenance of roads should be kept upto such a level that the vehicle operating costs and accident costs are minimized. Environmental concerns are also being given due weightage to reduce the level of exhausts from road traffic.
Maintenance serviceability level is a qualitative rating of the effectiveness of a road in terms of operating conditions such as traffic volume, speed, comfort and safety. It is proposed to divide the maintenance activities into three maintenance levels which are denoted as level 1, 2 and 3. The suggested serviceability levels and the permissible levels of surface defects based on the measurement of roughness, cracking, rutting etc. are shown in Table 2.7 [MORT&H(2013)].

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Table 2.6 Grouping of Roads as per Maintenance Serviceability level

Serviceability Level	Traffic Volume (AADT)	Name of Roads
High (Level 1)	More than 10000	********** ********
Medium (Level 2)	5,000 – 10,000	********** ********
Low (Level 3)	Less than 5,000	Road-R4,Road-R5,Road-R6 Road-R7,Road-R8,Road-R9

Table 2.7 Intervention Levels for Urban Roads

Sr.No.	Serviceability Indicator	Serviceability Levels		
		Level 1 (Good)	Level 2 (Average)	Level 3 (Acceptable)
1	Roughness by Bump Integrator (max. permissible) Equivalent IRI*	2000mm/km 2.8m/km	3000mm/km 4.0m/km	4000mm/km 5.2m/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- 20mm (max. permissible)	5mm	5-10mm	10-20mm

Source: ORT&H(2013
*As per Odoki and Kerali[2000]

2.6 COST DATA

2.6.1 Cost of Maintenance and RehabilitationWorks

The cost of various items pertaining to Maintenance and Rehabilitation works has been considered as per HSR Item/Description (Haryana Schedule rates) of HUDA (Haryana Urban Development Authority) as shown in Table **2.8.**

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Table 2.8 Cost Data for Maintenance and Rehabilitation Works

Sr. No.	Type of Maintenance & Rehabilitation Work	*Cost per sq.m (2014-15)
1	Tack Coat	14.50
2	Crack sealing	140.00
3	Potholing patching for PC surface	210.00
4	Potholing patching for BC surface	245.00
5	Patch repair for PC surface	210.00
6	Patch repair for BC surface	245.00
7	Rutting and undulation repair	310.00
8	Single Bituminous Surface Dressing(25mmSBSD)	143.00
9	Double Bituminous Surface Dressing(25mmDBSD)	285.00
10	Premix carpet (25mmPC)	211.00
11	Semi Dense Bituminous Concrete (25mmSDBC)	228.20
12	Bituminous Concrete (40mm BC)	340.00
13	Dense Bituminous Macadam (50mmDBM)	392.00
14	Bituminous Macadam (50mmBM)	298.00
15	Mill and Replace with 50mmBM+25mmPC	584.00
16	Mill and Replace with 50mmBM+40mmBC	713.00

*All Costs are in Indian Rupees, Source: HSR Item/Description

2.7 Pavement Deterioration Models

2.7.1 Raveling Initiation Model

IRV = Kvi CDS2 * 10 RRF * EXP [-0.156 * YAX]
Where,
IRV = Time to raveling initiation, in years
YAX = Annual number of axles of all vehicle classes in the analysis year, millions/lane
RRF = Raveling retardation factor due to maintenance (default value = 1.0)
CDS = Construction defects indicator for bituminous surfacing
Dry (brittle) = 0.5, Normal = 1.0, Rich (soft) =1.5
Kvi = calibration factor

2.7.2 Raveling Progression Model

dARV = Kvp(1/RRF)(1/CDS2)[{(0.6 + 3.0*YAX)*0.352* δtv + SRV0.35}1/0.35 – SRV]
where,
dARV = Change in area of raveling during analysis year, in % of total carriageway area
SRV = Min {ARVa, (100 – ARVa)}
ARVa = Area of raveling at the start of the analysis year, in %
δtv = Fraction of analysis year in which raveling progression applies
RRF = Raveling retardation factor due to maintenance (default value = 1.0)
CDS = Construction defects indicator for bituminous surfacing
Dry (brittle) = 0.5, Normal = 1.0, Rich (soft) =1.5
Kvp = Calibration factor

2.7.3 Potholing Initiation Model

$$IPT = Kpi\ 2.0 * \left[\frac{(1+0.05*HS)}{(1+1*CDB)(1+0.5*YAX)(1+0.01*MMP)}\right]$$

Where,
IPT = Time between the initiation of wide cracking or raveling and the initiation of potholing
HS = Total thickness of bituminous surfacing
CDB = Construction defects indicator for bituminous surfacing
Dry (brittle) = 0.5, Normal = 1.0, Rich (soft) =1.5
MMP = Mean monthly precipitation, in mm/month (avg. value = 80mm)
YAX = Annual number of axles of all vehicles classes in the analysis year, in millions/lane
Kpi = Calibration factor

2.7.4 Potholing Progression Model

$$dNPTi = Kpp * ADISi \left[\frac{(1+1*CDB)(1+10*YAX)(1+0.005*MMP)}{(1+0.08*HS)}\right]$$

where,
dNPTi = Additional number of potholes per km derived from distress type iADISi = Percent area of wide cracking at the start of the analysis year or
Percent area of raveling at the start of the analysis year or numbers of existing potholes per km at the start of the analysis year.
CDB = Construction defects indicator for the base
(0 = no defects, 1 = some defects, 1.5 = several defects)
MMP = Mean monthly precipitation, in mm/month (avg. value = 80mm)
HS = Total thickness of bituminous surfacing
YAX = Annual number of axles of all vehicles classes in the analysis year, In millions/lane
Kpp = Calibration factor
Source: Odoki et al(2000).

2.8 CALIBRATION OF PAVEMENT DETERIORATION MODELS

The calibration of pavement deterioration models has been done with the help of actual field data by different methods and equipment used.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

The number of data sets as given in Table 2.9 has been considered for calibration purposes. All the data values are within the defined limits of respective distress model.

Table2.9 Data Sets for Calibration of Pavement Deterioration Models

Name of the Road	YAX (millions)	YE4 (AMSA)	AGE3 (Years)	HS (mm)	ADISi (potholes)	MMP (mm)
Road-R4	0.624	0.0053	4	25	2.64	88.083
Road-R5	0.893	0.007	4	25	2.20	88.083
Road-R6	0.788	0.0061	4	25	2.48	88.083
Road-R7	0.201	0.00594	6	25	1.83	88.083
Road-R8	0.212	0.00612	6	25	1.64	88.083
Road-R9	0.249	0.00647	6	25	1.50	88.083

Table2.10 Calibration Factors Obtained for Pavement Deterioration models

Model Description	Road-R4	Road-R5	Road-R6	Road-R7	Road-R8	Road-R9
Raveling Initiation Model	0.22	0.23	0.26	0.26	0.24	0.28
Raveling Progression Model	0.4	0.27	0.33	0.88	0.69	0.57
Pothole Initiation Model	0.33	0.28	0.35	0.26	0.3	0.26
Pothole Progression Model	0.23	0.25	0.22	0.26	0.24	0.22

The calibration factors obtained in this study for various deterioration models are: Raveling Initiation (Kvi) = 0.237 (average) and 0.26 (average), Raveling Progression (Kpp) = 0.33 (average) and 0.71 (average), Potholing Initiation (Kpi) = 0.32 (average) and 0.27 (average), Potholing Progression (Kpp) = 0.23 (average) and 0.24 (average), It shows that the initiation of different pavement distresses i.e. raveling and potholing start appearing on the pavement surface a lot earlier than what is predicted by the pavement deterioration model. In other words, the initiation of all types of distresses is faster for urban road test stretch. The rate of raveling initiation (Kvi) = 0.237 (average) is faster by 76.3% on urban road test stretch. The rate of progression of raveling (Kpp) = 0.33 (average) is slower by 67% on urban road test stretch.

2.9 VALIDATION OF PAVEMENT DETERIORATION MODELS

2.9.1 General

The validation of calibrated pavement deterioration models is very important before putting them to use to ascertain whether the calibration has been authenticated or not. The validity of the calibrated pavement deterioration models has been checked to test the efficacy of these models. The distresses predicted by the calibrated deterioration models were compared with those actually observed on the selected pavement sections to prove the validity of these models.

The pavement condition data on all sections of the road network was collected by the starting of the year 2013 with the help of various equipments and methods. The pavement condition data was once again collected around the starting of the year 2014 with help of same equipment and methods so as to ascertain the status of the annual progression of distresses during the year 2013- 14. The two types of deterioration models which have been validated are

- Raveling progression model
- Pothole progression model

2.9.2 Raveling Progression Model

The observed values of raveling area around the starting of the year 2014 for the selected untreated pavement sections have been compared with those predicted by the raveling progression model as shown in the Table 2.11. These values have been plotted against each other as shown in figure 2.1 to determine the correlation between them.

Table 2.11 Variability between Observed and Predicted Raveling Values

Name of the Road	Observed Raveling Area in %	Predicted Raveling Area in %	% Variability
Road-R4	4.82	05.63	16.8
Road-R5	10.78	14.34	33.0
Road-R6	16.37	20.56	25.6
Road-R7	5.62	06.45	14.7
Road-R8	12.46	18.37	47.4

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Road-R9	19.11	23.08	20.7

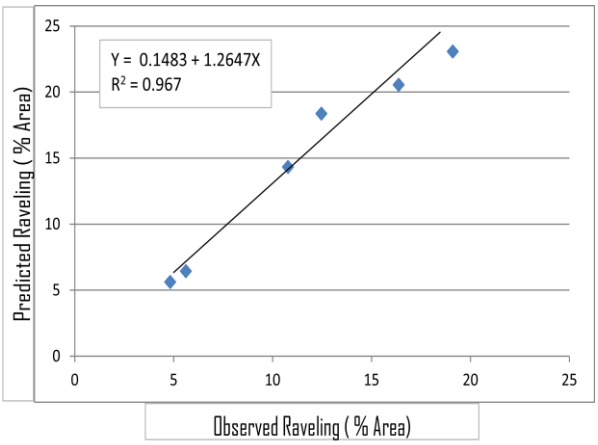

Figure 2.1 Observed V/S Predicted Raveling (% Area)

2.9.3 Pothole Progression Model

The observed number of standard pothole units around the starting of the year 2014 for the selected untreated pavement sections have been compared with those predicted by the pothole progression model as shown in the Table 2.12. These values have been plotted against each other as shown in figure 2.2 to determine the correlation between them.

Table 2.12 Variability between Observed and Predicted Pothole Units

Name of the Road	Observed Pothole Units (number)	Predicted Pothole Units (number)	% Variability
Road-R4	3	5	66.7
Road-R5	4	6	50.0
Road-R6	6	8	33.3
Road-R7	7	11	57.1
Road-R8	11	14	27.3
Road-R9	14	20	42.8

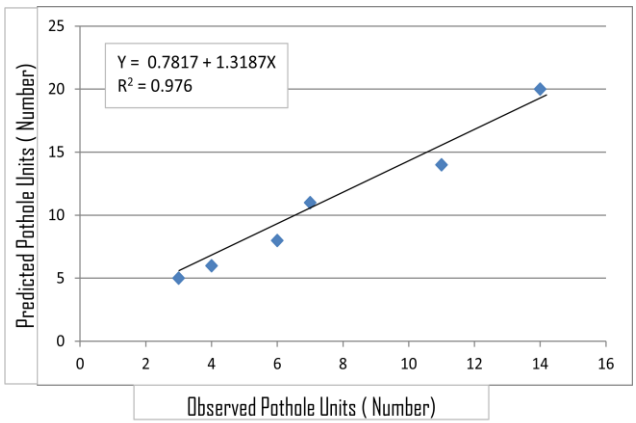

Figure 2.2 Observed V/S Predicted Pothole Units (Number)

2.9.4 The 't' Test

The 't' test has been performed to find out the significance of difference between the observed and predicted distress values in response to various deterioration models. The calculated 't' values (t_{cal}) for both the pavement deterioration models have been compared with tabulated 't' values for a level of significance of 5% ($t_{0.05}$) as shown in the Table 2.13. From this test, it is inferred that $t_{cal} < t_{0.05}$ for both the pavement deterioration models. Therefore, the difference between the observed and predicted distress values is not significant at 5% level of significance. Hence, it is maintained that both the pavement deterioration models can be used for prediction of distresses and for the development of maintenance management strategies for the selected urban road network.

Table 2.13 The't' Test for Observed and Predicted Distress Values

Distress Modeled	Calculated 't' Value (tcal)	Degree of Freedom	Tabulated 't' Value (t0.05)	Comparison of tcal v/s t0.05
Raveling	0.92	10	2.228	tcal < t0.05
Potholing	0.49	10	2.228	tcal < t0.05

2.9.5 Conclusion on Validation of Models

The calibrated pavement deterioration models have been validated by comparing the value of distresses predicted by the respective model with those actually observed in the field. A variation of 14.7 to 47.4 percent for raveling and 27.3 to 66.7 percent for potholing units has been obtained. The above variations are bound to exist for such complex phenomena of pavement behaviour under varied conditions of traffic loading, climatic and other conditions. The regression analysis has been carried out correlation equations has been framed for the given distress parameters. The R2 (coefficient of determination) values for raveling and potholing have been obtained as 0.967and 0.976 respectively. Since R2 values depict good agreement between observed and predicted distress values. Hence, it is concluded that the above models can be used for prediction of distresses and the development of maintenance management strategies for selected urban road network. The 't' test has been carried out to find out the difference between the observed and predicted distress values with regard to all deterioration models. The calculated 't' values (tcal) for all models have been compared with tabulated 't' values at 5% level of significance (t0.05). On the basis of comparison, the conclusion has been made that the difference between the observed and predicted distress values is not significant for all deterioration models. The above statistical data justifies the efficacy of the calibrated pavement deterioration models for the urban road network. Hence, it is concluded that the above deterioration models can be used for prediction of distresses and the development of maintenance management strategies for the identified urban road network.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

III. APPLICATION OF METHODOLOGY

The main purpose of this study is to appraise the economic benefits arising out of investing in maintenance and rehabilitation of the road network at the appropriate time as compared with carrying out minimum routine maintenance annually. The use of calibrated pavement deterioration models for the selected pavement section is illustrated in this study. Applicable maintenance and rehabilitation activities, and the corresponding intervention levels are defined, and the timing of selected M&R activities are calculated. The optimum M&R strategy is finalized on the basis of economic viability of the project. The analysis period is defined by a start year (i.e. current year 2015) and the duration of 8 years (i.e. 2015-2022).

3.1 Pavement Sections of Selected Roads:

The Road-R9 of the identified urban roads network Panchkula have been selected for this present study. The Road-R9 comprises of a Premix carpet (PC) and lies between sector 24 and sector 26 of Panchkula. This road is considered as a light trafficked route since the surrounding area is still under developing phase of construction. A lot of construction activities are coming up in the developing sectors. Pavement condition characteristics such as raveled area and pothole area are recorded at the time of data collection. It is very essential that to enable pavement condition to be modeled through the analysis period, condition data must be specified for a date prior to the start of the analysis period i.e start year 2015.The last reconstruction (50mmBM+25mmPC) of the pavement section of Road9 was done in Nov,2007. The total traffic plying on the identified pavement section of the roads is collected in terms of AADT. The annual growth of traffic has been taken as per 5percent (IRC-37,2012).

3.2 Proposed M&R strategies:

The maintenance and rehabilitation strategies applicable to the pavement section have to be put forward in advance. The five M&R strategies depicted in the Table 3.1 are considered for this study. The first strategy i.e. 'Base Alternative' makes the provision of minimum routine maintenance till up to the time when the reconstruction of the pavement section becomes inevitable. Four other alternative M&R strategies, namely Alternative 1, Alternative 2, Alternative 3, and Alternative 4, which comprehend resealing, resealing plus overlay, overlay, and mill & replace type of maintenance works respectively, have also been mentioned in this study.

Table 3.1 Proposed M&R Strategies and Intervention Level of Road-R9

M&R Strategy	Works Standards	Description of Work	Intervention Level
Base Alternative	Routine Maintenance	Patching Work	Scheduled annually
Alternative 1	Resealing	Provide 25mm DBSD	Total damaged area > 15% of the total area
Alternative 2	Resealing + Overlay	Provide 25mm DBSD Provide 25mm PC	Total damaged area > 15% of the total area
Alternative 3	Overlay	Provide 25mm PC	Total damaged area > 15% of the total area
Alternative 4	Mill and Replace	Remove 65mm Surfacing and provide 40 mm BM+25 mm BC	Total damaged area > 30% of the total area

The selected pavement section of Road-R9 belongs to low serviceability level (Level3). So, the applicable maintenance standards and the appropriate intervention level based on the serviceability indicators have been mentioned for these pavement sections. All the maintenance standards mentioned here are applicable from the first year of the analysis period i.e. year 2015.

3.3 Project analysis: During the set up of the project analysis, Base Alternative is established with respect to which the economic analysis is to be undertaken and a discount rate of 10% is specified. While doing execution of project analysis, Alternative1, Alternative2, Alternative3 and Alternative4 are compared with the Base Alternative. As a result of this operation, the pavement deterioration reports, and the maintenance & rehabilitation works reports are created for all M&R strategies considered above. These two types of reports are mentioned in the following sections.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

3.4 Pavement deterioration: The deterioration summary report of the pavement sections of Road-R9 as obtained distresses i.e raveling and potholing show annual progression over the analysis period, with respect to deterioration models. These deterioration models have already been suitably activated as per the local conditions. The annual progression of all types of distresses is varying under different M&R strategies.

3.5 Description of works: The different work items resulting from application of all the defined M&R strategies (as triggered by the respective intervention parameters), and timings of their application, are given in the M&R works under alternative M&R strategies over the analysis period of 8 years is shown in the Table 3.2, 3.3, 3.4 and 3.5. Pavement report in Table 3.6. This works report shows description of the works that would be implemented in each year of the analysis period (2015-2022), under each M&R strategy. The cost associated with each work item is also shown in this report. The total cost to be incurred by the highway agency on maintenance management of the pavement section under each alternative M&R strategy, is computed over the whole analysis period of 8 years, and the same is also shown in this works report.

Table 3.2 Deterioration Summary Report of the Pavement Section of Road-R9 for Alternative1

Year	AADT	YAX (ma/yr.)	Raveled Area (%)	No. of Potholes	Treatment Option
2015	1475	0.262	05.70	1.25	DBSD(25mm)
2016	1548	0.275	00.00	0.00	****
2017	1626	0.288	11.24	2.52	****
2018	1707	0.303	33.24	5.11	DBSD(25mm)
2019	1792	0.318	00.00	0.00	****
2020	1882	0.333	13.02	2.89	****
2021	1976	0.351	41.40	6.79	DBSD(25mm)
2022	2075	0.368	00.00	0.00	****

Table 3.3 Deterioration Summary Report of the Pavement Section of Road-R9 for Alternative2

Year	AADT	YAX (ma/yr.)	Raveled Area (%)	No. of Potholes	Treatment Option
2015	1475	0.262	05.70	1.25	PC(25mm)
2016	1548	0.275	00.00	0.00	****
2017	1626	0.288	15.15	2.56	DBSD(25mm)
2018	1707	0.303	00.00	0.00	****
2019	1792	0.318	12.38	3.13	****
2020	1882	0.333	31.98	6.73	DBSD(25mm)
2021	1976	0.351	00.00	0.00	****
2022	2075	0.368	14.56	3.44	****

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Table 3.4 Deterioration Summary Report of the Pavement Section of Road-R9 for Alternative3

Year	AADT	YAX (ma/yr.)	Raveled Area (%)	No. of Potholes	Treatment Option
2015	1475	0.262	05.70	1.25	PC(25mm)
2016	1548	0.275	00.00	0.00	****
2017	1626	0.288	15.15	2.77	PC(25mm)
2018	1707	0.303	00.00	0.00	****
2019	1792	0.318	15.97	2.91	PC(25mm)
2020	1882	0.333	00.00	0.00	****
2021	1976	0.351	17.84	3.07	PC(25mm)
2022	2075	0.368	00.00	0.00	****

Table 3.5 Deterioration Summary Report of the Pavement Section of Road-R9 for Alternative4

Year	AADT	YAX (ma/yr.)	Raveled Area (%)	No. of Potholes	Treatment Option
2015	1475	0.262	05.70	01.25	****
2016	1548	0.275	23.54	02.70	****
2017	1626	0.288	66.52	04.98	Mill&Replace
2018	1707	0.303	00.00	00.00	****
2019	1792	0.318	6.700	02.91	****
2020	1882	0.333	14.90	05.81	****
2021	1976	0.351	29.01	11.96	****
2022	2075	0.368	61.09	25.39	Mill & replace

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Table 3.6 M&R Works Report for Pavement Section of Road-R9

Year	M&R Works				
	Base Alt	**Alt1**	**Alt2**	**Alt3**	**Alt4**
2015	Patching Work	DBSD (25mm)	PC (25mm)	PC (25mm)	****
2016	Patching Work	****	****	****	****
2017	Patching Work	****	DBSD (25mm)	PC (25mm)	Mill & Replace
2018	Patching Work	DBSD (25mm)	****	****	****
2019	Patching Work	****	****	PC (25mm)	****
2020	Patching Work	****	DBSD (25mm)	****	****
2021	Patching Work	DBSD (25mm)	****	PC (25mm)	****
2022	Patching Work	****	****	****	Mill & Replace

Table 3.7 Associated Costs for Pavement Section of Road-R9

Year	Cost of Works				
	Base Alt	**Alt1**	**Alt2**	**Alt3**	**Alt4**
2015	0.1435	1.948	1.442	1.442	****
2016	0.1435	****	****	****	****
2017	0.1435	****	2.357	1.743	4.831
2018	0.1435	2.598	****	****	****
2019	0.1435	****	****	2.112	****
2020	0.1435	****	3.138	****	****
2021	0.1435	3.452	****	2.555	****
2022	0.1435	****	****	****	7.780
Total Cost in Million Indian Rupees	1.148	7.998	6.937	7.852	12.611

3.6 Selection of optimum M&R strategy for pavement section of Road-R9: On the basis of the economic analysis summary presented in Table 3.7, Alternative2 has been selected as the optimum M&R strategy having the minimum agency cost. Therefore, it has been concluded on the basis of above case study that Alternative2 which consists of the application of overlay (25mm Premix Concrete and 25mm Double Bituminous Surface Dressing) at a predefined intervention level (triggered when total damaged area > 15% of the total area), is the optimum M&R strategy for the selected pavement section. The optimum M&R strategies at the project level PMS for other pavement sections included in the 'Urban Road Network' may be determined in a similar manner.

IV. CONCLUSIONS AND RECOMMENDATIONS

The following inferences have been drawn on the basis of this study.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

- An operational optimum maintenance and rehabilitation strategies, aided by adequate indigenous tools is not popular in India for the development of pavement management system for urban road network. Therefore, the pavement deterioration models which are internationally recognized has been selected for use in this study for the urban road network of Panchkula. These models have been chosen because of its global acceptance and large applicability in a number of advanced countries.
- The methodology comprehends: identification and selection of the urban road network, data acquisition, and calibration, validation & activation of pavement deterioration models for Indian conditions.
- The urban road network selected for the present study consists of six roads (Road-R4, Road-R5, Road-R6, Road-R7, Road-R8 and Road-R9) of categories viz. SDBC and PC roads, which are located in different sectors of Panchkula. The SDBC roads (Road-R4, Road-R5 and Road-R6) and PC roads (Road-R7, Road-R8 and Road-R9) are two way type. Since, this urban road network covers different types of traffic and pavement composition, therefore, this network may be considered as the representative urban road network of India.
- As per the current norms for maintenance of roads, all the selected pavement sections of the roads need to be maintained at the low level as traffic carried carried by them is less than 5000AADT.
- The data for vehicle fleet plying on urban road network, maintenance & rehabilitation activities, cost data for various types of maintenance & rehabilitation works and the road user cost data has been gathered from field and relevant government publications. The inventory and pavement condition data in respect of all pavement sections of the selected roads have been gathered through survey works. All the collected data have been utilized for time series prediction of pavement distresses by making use of pavement deterioration models.
- The pavement deterioration models have been calibrated by using periodic data collected on the pavement sections of the identified urban road network. Calibration factors for various raveling deterioration model and potholing deterioration model have been obtained. The calibrated deterioration models have been instrumental in making prediction of different pavement distresses of the identified urban road network. The calibration factors obtained in this study for various deterioration models are: Raveling Initiation (Kvi) = 0.237 (average) and 0.26 (average), Raveling Progression (Kvp) = 0.33 (average) and 0.71 (average), Potholing Initiation (Kpi) = 0.32 (average) and 0.27 (average) & Potholing Progression (Kpp) = 0.23 (average) and 0.24 (average). It shows that the initiation of different pavement distresses i.e. raveling and potholing start appearing on the pavement surface a lot earlier than what is predicted by the pavement deterioration model. In other words, the initiation of all types of distresses is faster for urban test stretch. The rate of raveling initiation (Kvi) = 0.237 (average) is faster by 76.3% on urban test stretch. The rate of progression of raveling (Kvp) = 0.33 (average) is slower by 67% on urban test stretch.
- Validity of the calibrated deterioration models have also been examined to test the efficacy of these models. The validation has been checked by comparing the distress predictions made by these models with the distress values actually observed on the pavement sections of the selected roads. The validation has been undertaken through percentage variability in the observed and predicted values, coefficient of determination (R2), and 't' test. Variability of 14.7 to 47.4 percent for raveling area and 27.3 to 66.7 percent for pothole units have been obtained. These variations are bound to occur for such complex phenomena of pavement behaviour under different conditions of soil type, pavement composition, traffic loading and climatic conditions. The correlation equations have been developed for these distress values and the regression analysis has been done. The Coefficient of Determination (R2) values for raveling and pothole have been obtained as 0.967 and 0.976 respectively. The 't' test has been performed to find out the significance of difference between the observed and predicted distress values. The calculated 't' values for raveling and potholing are 0.92and 0.49 respectively. The tabulated 't' values for raveling and potholing at 5% level of significance are 2.228 and 2.228 respectively. All the calculated 't' values are less than their corresponding tabulated 't' values. This evinces that the difference between the observed and predicted distress values is not statistically significant at 5% level of significance. On the basis of these statistical results, the efficacy of the calibrated deterioration models for the roadway network has been established. Therefore, it is inferred that these deterioration models can be used for prediction of distresses and the development of maintenance management strategies for the urban road network.
- An optimum maintenance and rehabilitation strategy for a pavement section has been determined on the basis of economic viability of the project amongst a number of pre-defined M&R strategies. The M&R strategy consists of overlay (25mm Premix Carpet) at a defined intervention level (activated when damaged area > 15%).
- The optimum maintenance and rehabilitation strategy developed in this study would be useful to the highway agencies in planning pavement management strategies in a scientific manner, and to ensure rational utilization of constrained funds. This strategy can be used by various technical and administrative officials of the highway agencies in making decisions for project level pavement management. Once this methodology for urban road network is implemented and made operational in a few years; this would serve as window to the other urban road network of different regions. Thereafter, similar kind of strategies may be developed for different categories of urban road network.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

REFERENCES

[1] Abaza, K. (2004), "Deterministic Performance Prediction Model for Rehabilitation & Management of Flexible Pavement", International Journal of Pavement Engineering 5(2), 111-121.
[2] Abja, K. A. (2002). "Optimum Flexible Pavement Life-Cycle Analysis Model", ASCE Journal of Transportation Engineering, Vol. 128, No. 6, pp 542-549.
[3] Antonio, A., Picado-Santos, L., and Ferreira, A. (2002). "Optimization Models for Pavement Management: Past Achievements and Current Trends", Proceedings, 3rd International Conference on Decision Making in Urban and Civil Engineering, London, U.K.
[4] Bennet, C.R., and Greenwood, I.D. (2002). "Modelling Road User and Environmental Effects in HDM-4", The Highway Development and Management Series, Volume 7, ISOHDM Technical Secretariat, University of Birmingham, U.K.
[5] CRRI (1994). "Pavement Performance Study on Existing Pavement Sections", Project Sponsored by Ministry of Surface Transport, Government of India, Final Report, Submitted by Central Road Research Institute, New Delhi.
[6] Gedafa, D.S. (2007), "Performance Prediction and Maintenance of Flexible Pavement ", Proceedings of the 2007 Midcontinent Transportation Research Symposium, Ames, Iowa, 2007.
[7] Haas, Ralph, W. Ronald Hudson and Lynne Cowe Falls (2011), "Evolution and Future Challenges for Pavement Management", Proc., 8th Int. Conf. On Managing Pavement Assets, Santiago, Chile
[8] IRC (2012). "Manual on Economic Evaluation of Highway Projects in India", IRC:SP30, Indian Roads Congress, New Delhi.
[9] IRC (2012). "Manual on Economic Evaluation of Highway Projects in India", IRC:SP30, Indian Roads Congress, New Delhi.
[10] IRC (2012). "Guidelines for Strengthening of Flexible Road Pavement Using Benkelman Beam Deflection Technique", IRC:81, Indian Roads Congress, New Delhi.
[11] IRC (2012). "Guidelines for the Design of Flexible Pavements", IRC:37, Indian Roads Congress, New Delhi.
[12] Jain, S.S., Parida, M., and Rawat, M.M.S. (1999). "A Rational Approach for Pavement Management System for Urban Roads", Highway Research Bulletin, No. 61, Indian Roads Congress, pp 69-99.
[13] Martin T (2004), Data Review and Caliberation of HDM-4 Road Deterioration Models ARRBTR Research Report ARR 360 (ARRBTR: Vermont South, Victoria, Australia.
[14] MORT&H (2013c). "Road Development Plan Vision: 2021", Ministry of Road Transport & Highways, Government of India, New Delhi.
[15] MORT&H (2013e). "Updation of Road User Cost Data", Final Report prepared by Central Road Research Institute, for Ministry of Road Transport & Highways, Government of India, New Delhi.
[16] MORTH&H (2013), " Guideline for Maintenance of Primary, Secondary and Urban Roads" , Ministry of Road Transport and Highway, Govt. of India, New Delhi.
[17] Odoki, J.B., and Kerali, H.R. (2000). "Analytical Framework and Model Descriptions", HDM-4 Documentation Series, Volume-4, The World Road Association (PIARC), Paris, France.
[18] Shahin M.Y. (1994). "Pavement Management for Roads, Airports and Parking Lots", Chapman & Hall, London.
[19] Zimmerman, K.A (2010), Linda M. Pierce and James Krstulovich. " Pavement Management Roadmap. Executive Summary." Document publ. By Federal Highway Administration, Washington D.C.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.