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THE ROLE OF HDM-4 IN DEVELOPING PAVEMENT MAINTENANCE MANAGEMENT SYSTEMS (PMMS) FOR THE PATIALA CITY ROAD NETWORK

Amritpal Singh
Engineer, Civil Construction Division, Punjab Mandi Board, Patiala, Punjab (India)
amritpal2012@gmail.com

Annu
Assistant Professor, Civil Engineering Department, MM Engineering College, Maharishi Markarndeshwar University, Mullana-Ambala (India)
annubalhara91@gmail.com

ABSTRACT
A study has been carried out on Patiala city road network to provide a powerful system for the analysis of pavement management and investment strategies for the maintenance of the huge urban road network. The Highway Development and Management-4 (HDM-4) software has been used for strategy and program analysis of 52 road sections of Patiala city, out of which 5 manageable pavement sections on the basis of various characteristics are discussed in detail. The HDM-4 tool provides the deterministic approach in data input and processing also utilizes data on existing road condition, traffic volume and composition to predict road.

Keywords
HDM-4, pavement maintainance management system highway, urban roads.

1. INTRODUCTION
The Highway Development and Management-4 (HDM-4) software is a decision making tool for checking the engineering and economic viability of the investments in road projects. The HDM-4 system assists in effective investment choice at all management levels. Generally the factors associated with both economic and equity consideration in road project investment decisions are also said to be difficult to isolate, measure in their respective units and predict over a long term. The HDM-4 develops and implements pavement maintenance management system to make consistent decisions on maintenance, rehabilitation or reconstruction of road pavements. The HDM-4 model can be used both for strategic planning and programming of road works requiring different levels of input data. For planning purposes, an evaluation of road classes is typically conducted characterizing representative road classes with aggregate data of traffic and road condition. For programming purposes, which require more precise data and the definition of homogenous road sections, the HDM-4 user has the option of evaluating the homogenous road sections individually or evaluating road classes characterized by the homogenous sections data.

OBJECTIVES: The objective of the study is to develop a Pavement Management Maintenance System (PMMS) for Patiala city urban roads. The scope of work Include comprehensively the following:

- To develop the PMMS methodology
- To decide Funding policies for competing needs; for example, Feeder roads versus main roads
- To calculate Road User charges for setting up road funds
- To calibrate the pavement deterioration models of HDM-4 using the collected data from the urban roads
- To validate models using data collected from field
- To evaluate impact of axle load limits
- To evaluate pavement design
- To predict pavement maintenance and rehabilitation standards.

2. METHODOLOGY
2.1 Identification of Patiala Urban Road Network
The prime step in developing the pavement management system is to identify the urban road network. In the current study, selected urban road network consist of total road length of 15.60 Km, comprises of 5 numbers of segments. The selected segments are within the boundaries of Patiala city as shown in layout in Fig. 1.

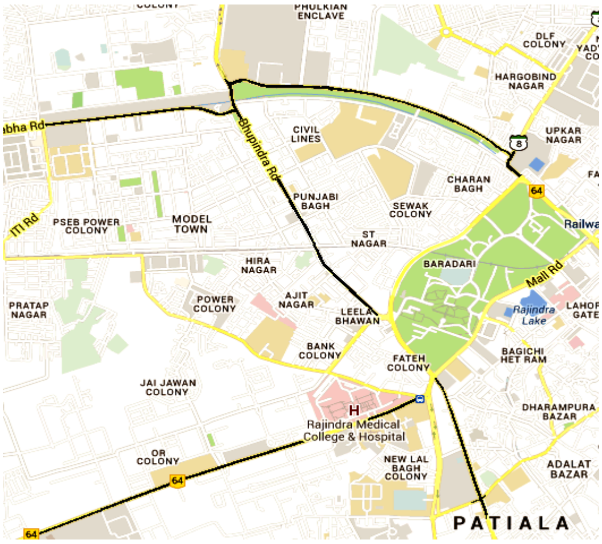

Fig.1. Layout plan of selected 5 numbers of segments

The above urban road network is selected on the basis of different characteristics. The selected pavement segments are quite homogenous within themselves but these are differentiated from each other in traffic, pavement and geometry. The selected segments of roads are denoted with “Urban Road No.” and “Section Name” for their easy identification, as shown in Table 1.

Table 1. Selected Urban Roads

S. No.	Urban road No.	Section Name	Description
1	PUR – 1	PUR – 1 [Km 0.00-2.00]	Dukhniwaran sahib – Thapar University
2	PUR – 2	PUR – 2 [Km 2.00-5.00]	Thapar University – Nabha road
3	PUR – 3	PUR – 3 [Km 5.00-7.60]	Thapar University – Leela Bhawan
4	PUR – 4	PUR – 4 [Km 7.60-13.60]	Rajindera Hospital – Sangrur Road
5	PUR – 5	PUR – 5 [Km 13.60-15.60]	Fountain Chownk – Mohindera College

2.2 Data Collection and Database Management

The important aspect in data collection is to collect as little as possible that will provide the necessary management information. It is necessary to ensure that the minimum data collected provides information regarding riding quality, surface distress, road inventory, traffic characteristics and pavement strength.

In the software system, the data collection is classified under following four categories:

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

2.2.1 Road Network data

The road network data includes the locational data that describes the position and geometry of the pavement section, and the attribute data, which describes the road characteristics or inventory associated with it. As per the requirements of HDM-4, data collection was carried out which included the collection of past data of roads from local PWD B & R and Municipal Departments. The data regarding type of pavement, traffic density, Date of last surfacing and maintenance record (if any) were provided by these departments. The urban road data was collected from site as follows:

- Functional evaluation
- Inventory data
- Structural evaluation
- Examination of pavement material

Functional evaluation of pavements involves the collection of road data relevant to surface distress (crack area, raveled area, pothole area), rut depth, surface roughness etc. The extent and type of distress developed in quantitative terms were visually inspected and measured, in addition to the visual recording of the pavement surface condition. The information on type of shoulder, width, and condition, and drainage etc. was also recorded.

- **Measurement of crack area -** A number of test sections of length 30 m were chosen for cracking and raveling measurements for each pavement section. The affected area was marked in the form of rectangular figures. In case of single longitudinal and transverse cracks, the crack length was measured and the effective width of the crack was taken as 6 mm. Thus crack area was expressed as percentage of total pavement area. It was observed that in majority of cases the percentage of wide crack area was found to be approximately one-fourth of the total crack area.

- **Measurement of ravelled area -** Ravelling is the loss of material from wearing surface. This distress type is associated with thin surfacing, such as, surface dressing, seal coat and premix carpet. The affected area was measured by taking into account area enclosed in regular geometric shapes such as, rectangle, triangle etc. and then it was expressed as percentage of total pavement area.

- **Measurement of pothole area –** The pot holes were measured in square meters and then it was converted into volumes of standard pot holes for HDM-4 software.

- **Rut depth measurements -** The rut depth measurements were taken with a 2 m straight edge, at all deflection points under the wheel path i.e. at a distance of 0.9 m from the pavement edge in case of double lane carriageway, and maximum value of rut depth was noted down at each point of 30 m interval.

- **Roughness measurements:** The pavement roughness was measured on each segment with 'Roughometer', towed by the mini truck, as per the standard procedure. The instrument was run at a constant speed of 32 km/h. The observations were taken on the outer wheel paths in both directions, at a distance of 0.9 m from the edges.

2.2.2 Inventory Data

The inventory data contains the following details about the selected pavement segments: Name of road, category of road, carriageway and shoulder width, drainage conditions, surface type and thickness, pavement layer details etc. These details were collected from visual inspection of the pavement segments, as well as from the construction and maintenance records of the Government departments.

2.2.3 Examination of Pavement Materials

The examination of pavement materials of the existing pavement section was carried out in the laboratory. The detailed examination in the laboratory was done on the soil samples in accordance with the Indian Standard specifications. The following tests were carried out for each soil sample: Atterberg's limits (Liquid limit and Plastic limit), CBR, Proctor density and optimum moisture content.

2.2.4 Road Network Database

All urban road network data items, which are required to be specified for each pavement section, are given in the Tables 2(a) to 2(d). All these data items situated in the road network database created in HDM-4. This road network database has been named as 'Patiala Urban Road Network', for all future references and uses.

Table 2(a). Urban Road Network - Basic Data

Section ID	Section Name	Link Name	Speed Flow Type	Traffic Flow Pattern	Climate Zone	Section Length (km)	Carriage-way Width (m)	Motorized AADT	AADT Year
PUR – 1	PUR – 1 [Km 0.00-2.00]	Dukhniwaran sahib – Thapar University	Two Lane Standard	Inter-city	North India - Plains	2.00	7.0	4,450	2012
PUR – 2	PUR – 2 [Km 2.00-5.00]	Thapar University – Nabha road	Two Lane Standard	Inter-city	North India - Plains	3.00	7.0	4,370	2012
PUR – 3	PUR – 3 [Km 5.00-7.60]	Thapar University – Leela Bhawan	Two Lane Standard	Inter-city	North India – Plains	2.60	7.0	4,990	2012
PUR – 4	PUR – 4 [Km 7.60-13.60]	Rajindera Hospital – Sangrur Road	Two Lane Standard	Inter-city	North India – Plains	6.00	7.0	5,280	2012
PUR – 5	PUR – 5 [Km 13.60-15.60]	Fountain Chownk – Mohindera College	Two Lane Standard	Inter-city	North India - Plains	2.00	7.0	4,860	2012

Table 2(b). Urban Road Network – Lab Test Results of Subgrade soil

Section Name	Optimum Moisture Content (%)	Atterberg Limits (%)			CBR (%)	
		LL	PL	PI	Un-soaked	Soaked
PUR – 1 [Km 0.00-2.00]	7.40	23	18	5	10.3	7.2
PUR – 2 [Km 2.00-5.00]	7.65	24	16	4	9.7	6.9
PUR – 3 [Km 5.00-7.60]	8.90	29	19	9	9.7	6.8
PUR – 4 [Km 7.60-13.60]	9.26	22	17	6	9.8	6.7
PUR – 5 [Km 13.60-15.60]	7.69	26	18	8	10.1	7.1

-Table 2(c). Urban Road Network - Condition Data

Section Name	Condition Year	Rough- ness IRI (m/km)	Cracking Area (%)	Ravelled Area (%)	Potholes (no./km)	Edge Break (m^2/km)	Rut Depth (mm)	Texture Depth (mm)	Skid Resistance (SCRIM)	Benkelman Beam deflection (mm)	Adjusted structural Number of pavements
PUR – 1 [Km 0.00-2.00]	2012	2.4	2	1	1	0	2	0.6	0.40	0.42	4.46
PUR – 2 [Km 2.00-5.00]	2012	2.7	1	1	2	0	3	0.5	0.50	0.46	4.38
PUR – 3 [Km 5.00-7.60]	2012	3.1	3	0	2	2	2	0.4	0.40	0.58	4.29
PUR – 4 [Km 7.60-13.60]	2012	3.9	2	2	2	0	4	0.7	0.40	0.39	3.29
PUR – 5 [Km 13.60-15.60]	2012	2.6	4	3	1	2	3	0.3	0.50	0.43	4.12

Table 2(d). Urban Road Network - Pavement Data

Section Name	Surfacing Material Type	Current Surface Thickness (mm)	Previous Surface Thickness (mm)	Last Construction Year	Last Rehabilitation Year	Last Surfacing Year	Last Preventive Treatment Year
PUR – 1 [Km 0.00-2.00]	Bituminous Concrete (BC)	40	25	2002	2011	2011	2011
PUR – 2 [Km 2.00-5.00]	Bituminous Concrete (BC)	40	25	2003	2009	2009	2009
PUR – 3 [Km 5.00-7.60]	Semi Dense Bituminous Concrete (SDBC)	25	25	2005	2005	2011	2011
PUR – 4 [Km 7.60-13.60]	Bituminous Concrete (BC)	40	25	2004	2004	2008	2008
PUR – 5 [Km 13.60-15.60]	Semi Dense Bituminous Concrete (SDBC)	25	25	2001	2009	2009	2009

2.2.5 Maintenance and Rehabilitation Works Data

Maintenance serviceability level is a qualitative rating of the effectiveness of a road network in terms of operating conditions such as traffic volume, speed, comfort and safety. Accordingly, for maintenance purposes, it is proposed to divide the maintenance programme into three maintenance levels, which are identified as level 1, 2, and 3.

Table 3. Maintenance Serviceability Levels For Pavements

Sl. No.	Serviceability Indicator	Serviceability Levels		
		Level 1	Level 2	Level 3
1.	Roughness by Bump Integrator (max. permissible) Equivalent IRI	2000 mm/km 2.8 m/km	3000 mm/km 4.0 m/km	4000 mm/km 5.2 m/km
2.	Potholes per km (max. number)	Nil	2-3	4-8
3.	Cracking and patching area (max. permissible)	5 per cent	10 per cent	10-15 per cent
4.	Rutting – 20 mm	1.0 per cent	1.5 per cent	2.5 per cent
5.	Skid number (minimum desirable)	50 SN	40 SN	35 SN

Table 4. Division Of Pavement Sections Into Maintenance Serviceability Levels

Serviceability Level	Traffic Volume (AADT)	Pavement Sections
High (Level 1)	More than 10000	NIL
Medium (Level 2)	5000 – 10000	PUR – 4
Low (Level 3)	Less than 5000	PUR – 1, PUR – 2, PUR – 3, PUR – 5

In the present study, standards of Level 3 have been selected for carrying out the network level PMS analysis. However, for the purpose of project level PMS analysis, it is proposed to divide all pavement sections included in the selected highway network into three serviceability levels; High, Medium, and Low on the basis of volume of traffic carried by them at present, as shown in Table 4. The heavily trafficked pavement sections shall be maintained as per Level 1 standards, medium trafficked as per Level 2 standards and lesser trafficked as per Level 3 standards.

3. RESULTS AND DISCUSSIONS

The road user cost (RUC) data is one of the most important in the life-cycle cost analysis of pavements. The road user cost is composed of three main components :(i) Vehicle Operating Cost (VOC) (ii)Time Cost

(iii) Accident Cost. VOC is defined as the price the user has to spend to move the vehicle per unit distance. Time cost involves monetary value of the time of passengers spent on travelling and the time taken by cargo in transit. The accident cost involves costs of human life and property, which is very difficult to quantify in monetary terms. Hence this cost is not included in the analysis.

3.0. Determination of remaining life of pavement sections

This case study presents the methodology of determining Remaining Service Life (RSL) of some selected pavement sections of the highway network. RSL of a pavement section is defined as the time left in years, till it will become imperative to reconstruct the pavement, provided no amount of maintenance or rehabilitation works are carried out in the intervening period.

3.0.1. Input data: The input data for this study is included in the 'Urban road Network' and 'Urban Vehicle Fleet' databases as defined earlier. An optimum analysis period of 10 years is selected considering the fact that almost all pavement segments will become candidates for reconstruction in the next ten years in the absence of any other maintenance or rehabilitation measure.

3.0.2. Specify alternatives: Since the purpose of this study is to determine the time period before reconstruction of the pavement is due, only one Maintenance & Rehabilitation (M&R) alternative is defined for each of the selected pavement section. The condition responsive M&R alternative named as 'Do Nothing Up to Reconstruction' is defined along with intervention criteria.

3.0.3. Analyse project: The application is run for simulating the pavement condition of the five pavement sections under the defined M&R alternative. No economic analysis is required to be done in this case as there is no other alternative defined for comparison purposes.

3.0.5. Roughness progression: As the limiting value of roughness has been selected as the deciding intervention criterion, the progression of roughness up to the intervention level of IRI>8 shall trigger the reconstruction of the various pavement segments in a particular year as shown in Fig. 2. The reconstruction of the pavement is indicated by a sharp fall in the roughness values.

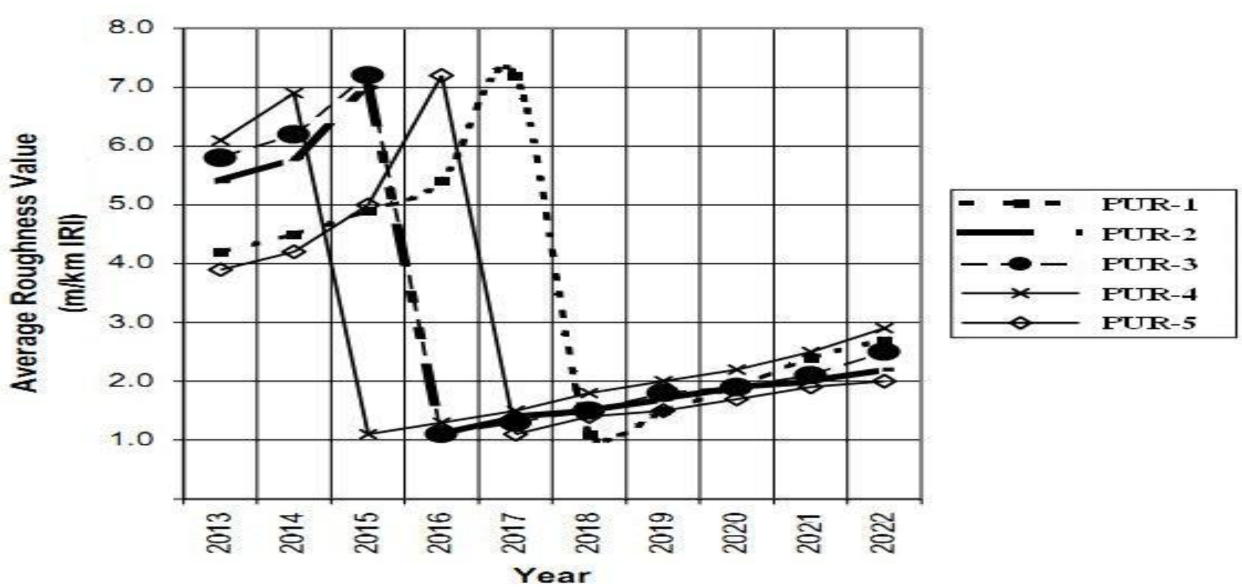

Fig. 2. Roughness progression for all pavement segments

Table 5. Remaining Service Life Of Pavement Sections

Sl. No.	Pavement Section	Reconstruction Year	Remaining Service Life (Years)
1.	PUR – 1	2017	4
2.	PUR – 2	2015	2
3.	PUR – 3	2015	2
4.	PUR – 4	2014	1
5.	PUR – 5	2016	3

It can be concluded from the RSL values shown in the above table that in the absence of any other maintenance activity, all the pavement sections included in this case study will become candidate sections for reconstruction within 1 to 4 years, which is a very costly affair. Hence it may be suggested that these pavement sections should be provided with suitable maintenance and rehabilitation works as they become due.

4. CONCLUSIONS

- The HDM-4 Software is system is future decision making tool for road network management.
- It provides a common framework for analysis of road management options.
- HDM-4 makes provision for a much wider range of upgrading options, pavement types, seal types and other maintenance options.
- One of the most important problems is that HDM-4 is 'Black box'. Even though user found error, they cannot check the problem and modify it. Developer should open the source code to user for better reliable system.

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