DEVELOPMENT OF PAVEMENT MAINTENANCE MANAGEMENT SYSTEM FOR HIGH SPEED ROAD CORRIDORS USING STATE-OF-ART TECHNOLOGIES

K. Sitaramanjaneyulu and Pradeep Kumar
CSIR - Central Road Research Institute, New Delhi
ksitaramcrri@yahoo.co.in & pkumar.crri@nic.in

ABSTRACT

Development of good road infrastructure and its efficient management is very important for economic and social development of any country. The benefits from the investment in road sector are indirect, long term and not immediately visible. A pavement which is not protected and maintained deteriorates fast and the society has to pay heavily for an inefficient and ill preserved road network. Over the years, as the nation's economy started growing, users expectations and demand for better levels of service from roads have also been increasing. This situation demanded multi lane roads for high speed and better surface conditions for good riding at safe roads. Thus the available resources for maintenance shall be spent judiciously on scientific basis.

Pavement maintenance management systems have developed globally using advances in data collection and computing technologies. But most of the tools have been developed keeping in view the requirements of a particular highway agency, and the conditions prevailing in a particular country or a geographical region. Hence, these tools lack universal acceptance and applications.

CSIR-Central Road Research Institute has successfully completed a research study and developed Pavement Maintenance Management System (PMMS) for high speed road corridors towards judicious allocation and prioritization of maintenance tasks/funds. This paper describes the methodology adopted for the development of PMMS for high speed road corridors, which includes details of type of data collected, hardware and software tools used for collecting and managing the data and integration to PMMS software.

1. INTRODUCTION

A pavement is a structure whose condition changes with the passage of time due to the combined effects of its structural adequacy; traffic composition (volume) and loading characteristics of traffic; environment and the maintenance inputs provided. The failure of a pavement structure is generally due to the internal damage caused by traffic loads, within an operational environment, over a period of time. The process of accumulation of damage is called deterioration and it increases with time. The incremental effect of pavement deterioration can be observed by conducting periodical performance studies. The performance data obtained from the field studies, for each section, are important and form major inputs for determining the calibration factors of pavement deterioration models which are inbuilt into Highway Development and Management tool (HDM-4).

The use of software tools based on global positioning systems-GPS, and geographic information systems-GIS have benefited the PMMS development and implementation effort. State-of-art equipment technologies such as automated road survey system and weight-in-motion system have provided accurate and timely collection of time series performance data on the selected road sections.

The range of calibration factors, obtained for various pavement deterioration models of HDM-4, have been used as inputs to run HDM-4 software for development and analysis of maintenance strategies of high speed corridors.

2. OBJECTIVE OF THE STUDY

The overall objectives of the study was to develop a management system towards making logical decisions about the budget requirements and allocation of funds thereof for maintenance of pavements and bridges, based on optimal life cycle costs. Flexible as well as Rigid Pavements and Bridges involving network of high speed road corridors were included within the scope of this study.(1)

3. SELECTION OF SECTIONS ON HIGH SPEED CORRIDORS

The parameters covered for development of study section matrix primarily include the whole range of pavement's structural composition, environment, temperature, moisture and traffic conditions prevailing in the country. The major parameters covered in development of study section matrix are number of lanes (2- two way hilly, 2- one way, 3- one way), traffic volume-commercial vehicle per day (low, medium, high), terrain classification (plain, rolling, hilly), pavement condition-total surface distress (good, fair, poor), moisture classification (semi-arid, sub humid, humid) and temperature classification (tropical, sub-tropical hot, sub-tropical cool) for both Flexible and rigid pavements **(2).** A total of 55 road sections (each min. 500m to max. 1000m length) spread over length and breadth of the country with varying pavement thickness, traffic volume and loading, surface type, environmental conditions etc. have been selected on Golden Quadrilateral, North-South & East West Corridors and Ahmedabad-Vadodara, Mumbai-Pune, Delhi- Gurgaon & Noida-Greater Noida Expressways, these corridors/expressways were considered as high speed road corridors. Locations of the selected sections are shown in figure-1.

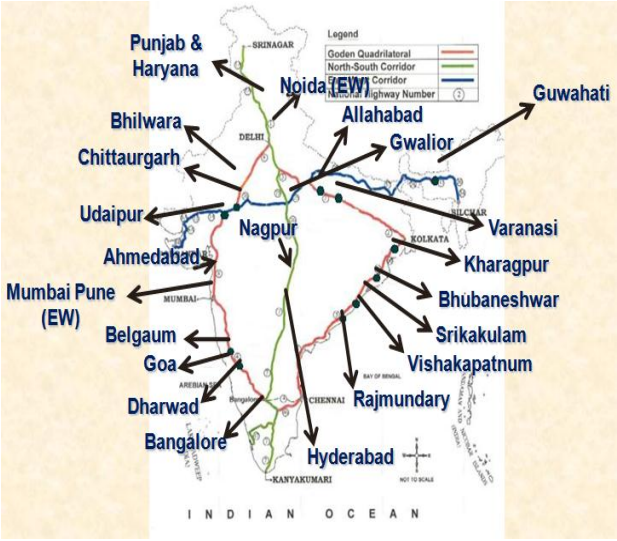

FIGURE 1 Locations of Sections Identified Under the Study

4. PERFORMANCE OBSERVATIONS ON SELECTED SECTIONS SELECTED UNDER THE STUDY

The various observations/measurements (Three times with one year interval) on the selected road sections for collecting periodic pavement performance data required for calibration and validation of pavement deterioration models of HDM-4 are given below **(3)**:

- Pavement crust for each section is being taken by digging a test pit having size 1.2m X 1.2m size. Field densities of each layer (subgrade, sub base and base course) are being measured using sand replacement method for knowing the compaction level of these layers. Bulk Density in case of bituminous Layers (binder course and surface/wearing course), are being measured using cores extracted for the purpose.
- The thickness of Pavement Quality Concrete (PQC) and Dry Lean Concrete (DLC) are being measured by taking out cores. The properties of concrete mix i.e. modulus of elasticity and modulus of rupture etc. are also being determined in the laboratory using the cores extracted.
- Benkelman Beam Deflection Technique have been used to measure the deflections and in turn the structural strength of the flexible pavements.
- Functional Condition, inventory details and geometrics data for both flexible and rigid pavement sections have been collected using Automated Road Survey System.
- Pavement Surface distress measurements are carried out by physically measuring all individual distresses to find out the type, extent and severity of different distresses. The distresses were measured in terms of the percentage of affected area with respect to total surface area.
- Historical data for each pavement sections such as construction (year and specification), strengthening (year and specification), resurfacing and preventive treatment (year and specification), if any, are being collected from the concerned Engineer-in-charge during field observations.
- Traffic surveys (motorized and non-motorized vehicles) were carried out for two consecutive days (48 hours) round the clock by engaging skilled enumerators.
- Axle loads survey, using weigh-in-motion system, were carried out two times during the course of study for a period of one day (24 hours) round the clock i.e. once in the beginning of first series of observation (i.e. Ist observation) and the other one at the time of last series of observation (i.e. IIIrd observation).
- Information related to environmental condition such as highest flood level, temperature during the last year, depth of water table, average rainfall per year etc. was collected during the time of each observations, form the concerned engineer-in-charge. In the case of rigid pavements, in addition to the above data, freezing index, temperature index and average number of days in which temperature was greater than 32^{o} C etc. was also collected separately.

5. USE OF STATE-OF ART EQUIPMENT FOR DATA COLLECTION

5.1 Automated Road Survey System

The Survey vehicle system used under this study, is based on the latest techniques utilizing Laser, Global Positioning System and Video image processing tools. The inventory data collected include measurements of Gradient (Percent, rise and fall), Cross slope (percent), Horizontal curvature (degree/km), Pavement surface roughness (International Roughness Index in m/km), Rut Depth (mm), Pavement surface texture (mm) and GPS coordinates (X, Y, Z) viz. longitude, latitude & altitude etc. Photo-1 shows a view of measurement of road inventory and pavement condition using automated road survey system on NH-08.

PHOTO 1 Measurement of Road Inventory and Pavement Condition Using Automated Road Survey System on NH-08

5.2 Weigh-In-Motion System

The axle load survey were conducted on the study sections using Weigh-In-Motion (WIM) System. The entire data collected from the field was analyzed for the computation of Vehicle Damage Factor (VDF). VDF values have been computed for different vehicle classes individually and also a single VDF for the road has been calculated after combining all types of commercial vehicles. Photo-2 shows axle load survey using WIM system on one of the selected road section of NH-02.

PHOTO 2 Axle Load Survey Using WIM on NH-2

6. DEVELOPMENT OF PMMS

Pavement Maintenance Management System has been developed in two steps. In the first step data management and information system has been developed and in the second step management system for maintenance planning has been developed for the study road corridors.

6.1 Development of Data Management and Information System

Data Management and Information System has been developed for the study road network covering Golden Quadrilateral, North-South & East West Corridors, Ahmedabad-Vadodara, Mumbai-Pune, Delhi Gurgaon & Noida-Greater Noida Expressways.

The database has been created using Hawkeye Processing Tool Kit Software. The database includes spatial as well as non-spatial data for the road corridors collected using Automated Road Survey System. Data Viewer software has been used to manage and view the database and attribute information for each of the road corridor **(4).**

Figure-2 and 3 shows the typical screenshots of the developed database showing a view of the GIS map generated for a road section on Kolkata to Delhi Corridor and Road Information System showing all data along with GIS Map and Right-of-Way Images respectively using the Data viewer software.

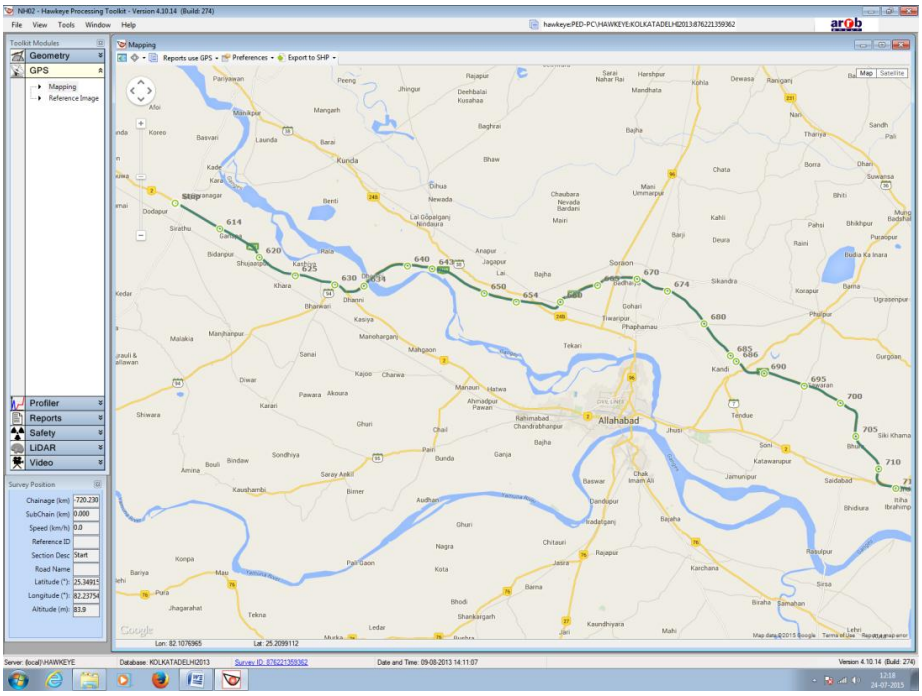

FIGURE 2 A View of the GIS Map Generated for a Road Section (Kolkata-Delhi Corridor)

FIGURE 3 A View of Road Information System showing all Data along with GIS Map and Right-of Way Images

Hawkeye processing tool kit software which has been used for processing of road inventory and pavement condition data, also include one module for export to HDM-4, which has been used to generate the HDM-4 input files for the respective corridors. Figure-4 shows a typical view of the HDM-4 input file generated for the road section on Kolkata to Delhi Corridor.

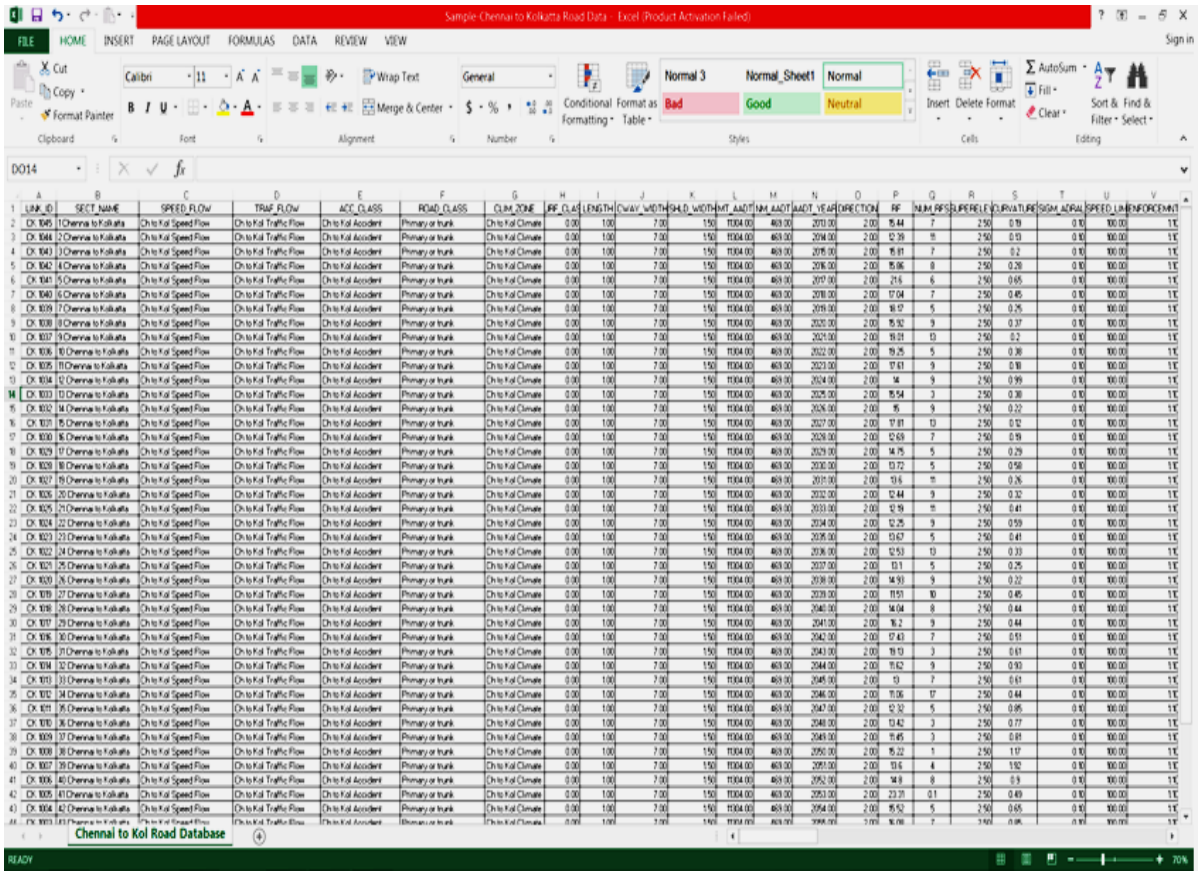

FIGURE 4 A Typical View of HDM-4 Input File Generated Using Hawkeye Processing Tool Kit Software

6.2 Development of Management System for Maintenance Planning

6.2.1 Development of Road User Cost Equations for High Speed Road Corridors

A maiden and successful attempt was made towards developing Road User Cost (RUC) Equations covering Four Lane, Six Lane and Eight Lane Divided Inter - Urban Carriageways. For this purpose, appropriate traffic and user cost studies were conducted on national highways and expressways located in the vicinity of six cities namely Delhi, Mumbai, Chennai, Kolkata, Hyderabad and Vijayawada. Fuel consumption studies were also carried out at different locations. Based on the voluminous data collected through such studies, road user cost equations were developed and the same were used for calculation of Vehicle Operation Cost for high speed corridors **(5).**

6.2.2 Calibration of HDM-4 Pavement Deterioration Models and Development of Pavement Maintenance Management System

A successful attempt was made under the present research study for the first time in the country, towards deriving calibration factors for HDM-4 Pavement Deterioration Models for high speed road corridors. To develop an acceptable maintenance management system for any road network, different pavement deterioration models of HDM-4 need to be calibrated as per the local operating / environmental conditions. To obtain these calibration factors, 55 sections spread over length and breadth of the country with varying pavement thickness, traffic volume and loading, surface type, environmental conditions etc. were monitored for three times (at one year interval) for their performance. Based on the 1st and 2nd series of performance observations, calibration factors of HDM-4 pavement deterioration models were developed and the 3rd observation was used for the validation of the calibration factors so developed.

By using developed calibration factors, performance data, one time road inventory data and road user cost models developed under this study, the maintenance management system for high speed road corridors using HDM-4 has been developed.

7. CONCLUSIONS

- The PMMS developed under this study shall assist/enable engineers and decision/policy makers to pre-conceive the requirement of funds for maintenance of road network in order to bring them to a desired level of serviceability.

- The system developed will also assist in minimising wasteful losses occurring every year on account of poorly maintained roads. It will also provide powerful tool to the road authorities in allocating maintenance funds in a rational and judicious/manner and in prioritizing the maintenance tasks/ treatments in view of limited resources.

- The use of state-of-art technologies based on Global Positioning System, Geographical Information System, Laser, WIM, and image processing techniques is the key of success for accurate and timely collection of time series data on the huge road network as covered under this study.

8. RECOMMENDATIONS FOR FUTURE DIRECTION OF RESEARCH/WORK

- The road user cost equations developed under this study needs to be updated on periodic basis (say 10 years) to cover the ever changing dynamics of vehicle technology and the associated increasing cost of operation of vehicles, increasing cost of spare parts, tyre cost, labor charges, depreciation cost and value of travel time.

- To undertake similar research studies for urban roads (Development of Road User Cost Models for Urban Roads) so as to make assessment of Vehicle Operating Cost, Travel Time Cost and Road Crash Cost, covering major metropolitan cities of the country.
- To develop calibration factors of HDM-4 Pavement Deterioration Models by covering characteristics of other categories of roads.

ACKNOWLEDGEMENT

Authors are thankful to the Director, CSIR-Central Road Research Institute, New Delhi-110025, India for his guidance and kind permission to publish this paper. Support of the entire project team at various stages of data collection and analysis during the execution of the project is also acknowledged.

REFERENCES

1. Project proposal on "Development of Management System for Maintenance Planning and Budgeting of High Speed Road Corridors", Central Road Research Institute, New Delhi, 2007.

2. Technical Document on "Methodology for Formulation of Section Matrix" under "Development of Management System for Maintenance Planning and Budgeting of High Speed Road Corridors", Central Road Research Institute, New Delhi, 2009.

3. Technical Document on "Methodology for Field Observations / measurements for Calibration & Validation of Pavement Deterioration Models of HDM-4", under "Development of Management System for Maintenance Planning and Budgeting of High Speed Road Corridors", Central Road Research Institute, New Delhi, 2009.

4. Research Report on Development of Management System for Maintenance Planning and Budgeting of High Speed Road Corridors, Supra Institutional Project, Research Report: CSIR-CRRI-SIP30, Volume-I, Road Module (Part-A), 2014.

5. Research Report on Development of Management System for Maintenance Planning and Budgeting of High Speed Road Corridors, Supra Institutional Project, Research Report: CSIR-CRRI-SIP30, Volume-I, Road Module (Part-B), Traffic Related Aspects, 2014.