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Government of Uttar Pradesh, India

UTTAR PRADESH STATE ROADS PROJECT  
Under IBRD Loan No. 4684-IN

Technical Assistance for Implementation of Institutional Reforms in the Road Sector of Uttar Pradesh

REPORT ON ESTABLISHING ROAD MAINTENANCE MANAGEMENT SYSTEM (RMMS) FEATURING RATIONAL PRIORITISATION ON TECHNO-ECONOMIC CRITERIA, AND APPLY TO CORE NETWORK MAINTENANCE MANAGEMENT (FINAL)

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LEA Associates South Asia Pvt. Ltd., India  
in association with

Ministry of Transportation of Ontario, Canada
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<th>Full Form</th>
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<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
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<tr>
<td>ADT</td>
<td>Average Daily Traffic</td>
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<td>AE</td>
<td>Assistant Engineer</td>
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<td>BB</td>
<td>Benkelman Beam</td>
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<td>BCR</td>
<td>Benefit Cost Ratio</td>
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<td>BMS</td>
<td>Bridge Management System</td>
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<tr>
<td>BOOT</td>
<td>Build Own Operate Transfer</td>
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<tr>
<td>BOT</td>
<td>Build Operate Transfer</td>
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<tr>
<td>CBO</td>
<td>Community Based Organisation</td>
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<td>CBR</td>
<td>California Bearing Ratio</td>
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<tr>
<td>CE</td>
<td>Chief Engineer</td>
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<td>CEO</td>
<td>Chief Executive Officer</td>
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<td>CCR</td>
<td>Central Road Fund</td>
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<td>CRRI</td>
<td>Central Road Research Institute</td>
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<td>CSR</td>
<td>Civil Service Reforms</td>
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<td>DAO</td>
<td>Divisional Account Officer</td>
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<tr>
<td>DASP</td>
<td>Diversified Agriculture Support Program</td>
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<td>DBC</td>
<td>Dense Bitumen Concrete</td>
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<td>DPR</td>
<td>Detailed Project Report</td>
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<td>DRDA</td>
<td>District Rural Development Authority</td>
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<tr>
<td>EC</td>
<td>Executive Committee</td>
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<tr>
<td>EE</td>
<td>Executive Engineer</td>
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<tr>
<td>E-in-C</td>
<td>Engineer in Chief</td>
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<tr>
<td>FWD</td>
<td>Falling Weight Deflectometer</td>
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<tr>
<td>FYRR</td>
<td>First Year Rate of Return</td>
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<td>GC</td>
<td>Governing Council</td>
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<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GNP</td>
<td>Gross National Product</td>
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<td>GO</td>
<td>Government Order</td>
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<td>GOI</td>
<td>Government of India</td>
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<td>GoUP</td>
<td>Government of Uttar Pradesh</td>
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<td>GSDDP</td>
<td>Gross State Domestic Product</td>
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<tr>
<td>HDM</td>
<td>Highway Design Model</td>
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<tr>
<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<td>HQ</td>
<td>Head Quarter</td>
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<td>HR</td>
<td>Human Resource</td>
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<td>HRD</td>
<td>Human Resource Development</td>
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<td>HRM</td>
<td>Human Resource Management</td>
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<tr>
<td>IBRD</td>
<td>International Bank for Reconstruction and Development</td>
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<tr>
<td>IDS</td>
<td>Institutional Development Strategy</td>
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<td>IDSP</td>
<td>Institutional Development And Strengthening Plan</td>
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<tr>
<td>IRC</td>
<td>Indian Road Congress</td>
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<td>IRI</td>
<td>International Roughness Index</td>
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<td>IRR</td>
<td>Internal Rate of Return</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
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<tr>
<td>ISAP</td>
<td>Institutional Strengthening Action Plan</td>
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<td>ILO</td>
<td>International Labour Organisation</td>
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<tr>
<td>JE</td>
<td>Junior Engineer</td>
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<tr>
<td>LRP</td>
<td>Location Reference Points</td>
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<tr>
<td>LRS</td>
<td>Location Reference System</td>
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<tr>
<td>MDR</td>
<td>Major District Roads</td>
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<tr>
<td>MES</td>
<td>Monitoring and Evaluation System</td>
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<tr>
<td>MLA</td>
<td>Member of Legislative Assembly</td>
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<tr>
<td>MMS</td>
<td>Maintenance Management System</td>
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<tr>
<td>MOST</td>
<td>Ministry of Surface Transport</td>
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<tr>
<td>MoSRTH</td>
<td>Ministry of Shipping, Road Transport &amp; Highways</td>
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<td>MoRTH</td>
<td>Ministry of Road Transport and Highways</td>
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<td>MoEF</td>
<td>Ministry of Environment and Forest</td>
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<tr>
<td>M&amp;E</td>
<td>Monitoring and Evaluation</td>
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<tr>
<td>MIS</td>
<td>Management Information System</td>
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<tr>
<td>MSS</td>
<td>Mixed Seal Surface</td>
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<tr>
<td>NABARD</td>
<td>National Bank of Agricultural and Rural Development</td>
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<td>NITHE</td>
<td>National Institute for Training of Highway Engineers</td>
</tr>
<tr>
<td>NH</td>
<td>National Highway</td>
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<tr>
<td>NHAI</td>
<td>National Highways Authority of India</td>
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<td>NOIDA</td>
<td>New Okhla Industrial Development Authority</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Maintenance</td>
</tr>
<tr>
<td>PAC</td>
<td>Public Accounts Committee</td>
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<tr>
<td>PCC</td>
<td>Project Coordinating Consultant</td>
</tr>
<tr>
<td>PCI</td>
<td>Pavement Condition Index</td>
</tr>
<tr>
<td>PCU</td>
<td>Passenger Car – equivalent Unit</td>
</tr>
<tr>
<td>PICUP</td>
<td>Pradeshya Industrial &amp; Investment Corporation of UP</td>
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<tr>
<td>PMS</td>
<td>Pavement Management System</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
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<tr>
<td>PRI</td>
<td>Panchayat Raj Institution</td>
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<tr>
<td>PSP</td>
<td>Private Sector Participation</td>
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<tr>
<td>PWD</td>
<td>Publics Works Department</td>
</tr>
<tr>
<td>RAP</td>
<td>Resettlement Action Plan</td>
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<td>RES</td>
<td>Rural Engineering Services</td>
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<tr>
<td>RIDF</td>
<td>Rural Infrastructure Development Fund</td>
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<td>RIS</td>
<td>Road Information System</td>
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<td>RMMS</td>
<td>Road Maintenance Management System</td>
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<td>RoMDAS</td>
<td>Road Measurement and Data Acquisition System</td>
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<td>RoW</td>
<td>Right of Way</td>
</tr>
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<td>RSPEU</td>
<td>Road Safety Planning and Engineering Unit</td>
</tr>
<tr>
<td>RSC</td>
<td>Road Safety Cell</td>
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<tr>
<td>R&amp;R</td>
<td>Resettlement and Rehabilitation</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>SDBC</td>
<td>Semi Dense Bitumen Carpet</td>
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<tr>
<td>SE</td>
<td>Superintending Engineer</td>
</tr>
<tr>
<td>SH</td>
<td>State Highway</td>
</tr>
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<td>SHA</td>
<td>State Highway Authority</td>
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<tr>
<td>SNP</td>
<td>Structural Number Parameter</td>
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<tr>
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<td>Special Purpose Vehicle</td>
</tr>
<tr>
<td>SQL</td>
<td>Standard Query Language</td>
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<td>State Road Fund</td>
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<td>State Road Project-II</td>
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<td>TA</td>
<td>Technical Assistance</td>
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<tr>
<td>ToR</td>
<td>Terms of Reference</td>
</tr>
<tr>
<td>UP</td>
<td>Uttar Pradesh</td>
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<tr>
<td>UPRNN</td>
<td>Uttar Pradesh Rajkiya Nirman Nigam</td>
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<tr>
<td>UPSBC</td>
<td>Uttar Pradesh State Bridge Corporation</td>
</tr>
<tr>
<td>UPSIDC</td>
<td>Uttar Pradesh State Industrial Development Corporation</td>
</tr>
<tr>
<td>UPSRTC</td>
<td>Uttar Pradesh State Road Transport Corporation</td>
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<tr>
<td>UPSRP</td>
<td>Uttar Pradesh State Road Project</td>
</tr>
<tr>
<td>UPSSHA</td>
<td>Uttar Pradesh State Highway Authority</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UPMMS</td>
<td>Uttar Pradesh Maintenance Management System</td>
</tr>
<tr>
<td>VOC</td>
<td>Vehicle Operating Cost</td>
</tr>
<tr>
<td>VR</td>
<td>Village Roads</td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
<tr>
<td>WBM</td>
<td>Water Bound Macadam</td>
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</table>
1. INTRODUCTION

1.1 BACKGROUND

Road maintenance programming in PWD is based on the Road Development Policy (1998) and the PWD Maintenance Manual for Road (1974).

As per the UP Road Development Policy (1998) the period for renewal of various categories of roads is fixed. Accordingly, 1/3rd length of National Highways, 1/5th length of State Highways, 1/6th length of MDRs and 1/8th length of ODRs and village roads require to be renewed every year. This policy does not consider the actual condition of the road and the impact that any change in cycle might have to the economy and network status. Decision makers having a lack of any analysis tools, are not aware of any adverse impacts resulting from the increase in the cycle which, in practice, is actually happening. The current practice is not based on need, i.e. pavement condition, and so, this cannot address any need to improve the overall condition of the network.

The distribution of the routine maintenance fund, as per the PWD Maintenance Manual for Roads (1984), is based on fixed percentages for different routine maintenance activities, such as; patching, shoulders, drainage, roadside clearance, signs, guard rails, slip clearance, bridge maintenance, diversions, etc. The actual needs in terms of local conditions and maintenance status, may well be considerably different.

Collection of the required network level data and the establishment of a Maintenance Management System (MMS) for the rational prioritisation of road maintenance and improvements, based on techno-economic criteria, is one of the main tasks for the improvement of maintenance management.

In order for a MMS to be established to fulfil the above objectives, it should be able to:

- Provide information on the road network to assist in the decision making process
- Undertake network level analysis for the preparation of long-term strategic plans and policy for road maintenance management
- Prepare a prioritised multi-year work programme for road maintenance and improvement
- Estimate and prioritise routine maintenance based on road condition and other factors

1.2 PRESENTATION AND DISCUSSION

The tentative framework for an MMS and the resource requirement was presented to PWD on 28th June 2006. All the issues raised at the time of presentation, during the subsequent discussions, and thereafter in meetings with PWD officers, have already been addressed and incorporated within this report.
1.3 REFERENCE

Data required for MMS is discussed in Working Paper 34/1 Re-establishing Road, Bridge and Traffic Data Collection Process (July 2006). .

Working Paper # 2/1 on Engagement of IT Expertise to Enhance Computerisation and IT Training Action (June 2006) has been referred where appropriate.
2. CURRENT STATUS

2.1 DATABASE SYSTEMS

2.1.1. dROAD 5.0 database

dROAD 5.0 (DOS version) was used as the platform for the PWD central database, implemented in 1994-96 under the ‘Four State Pavement Management System’ project. However, this system is no longer functioning in PWD. Both the software and the database were not available for review. The ‘data dictionary’ indicated that most of the important data required for HDM-4 analysis was included in the database.

Software providers, Deighton Associates Ltd (Canada) have advised that the DOS version is no longer supported/available. PWD will therefore have to procure the latest dTIMS CT version and upgrade the database if there is a decision to continue with this system.

2.1.2. Management Information System (MIS)

As part of the computerisation of PWD business processes, a Management Information System (MIS) was developed by TCS in 2002. The MIS included the following 12 modules:

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<tbody>
<tr>
<td>1.</td>
<td>Planning</td>
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<td>2.</td>
<td>Budget</td>
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<td>3.</td>
<td>Establishment (HR)</td>
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<tr>
<td>4.</td>
<td>Bridge</td>
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<tr>
<td>5.</td>
<td>Court cases and litigation</td>
</tr>
<tr>
<td>6.</td>
<td>Complaints and grievances</td>
</tr>
<tr>
<td>7.</td>
<td>Work monitoring</td>
</tr>
<tr>
<td>8.</td>
<td>Execution</td>
</tr>
<tr>
<td>9.</td>
<td>Accounts</td>
</tr>
<tr>
<td>10.</td>
<td>World bank</td>
</tr>
<tr>
<td>11.</td>
<td>Electrical and mechanical</td>
</tr>
<tr>
<td>12.</td>
<td>Architecture (information about buildings)</td>
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</table>

The acceptance testing of MIS was carried out up to Feb 2003, however, the system was never implemented due to various contractual issues. For more details, reference should be made to Working Paper No 2/1 on Engagement of IT Expertise to Enhance Computerisation and IT Training Action (June 2006).

The Planning module of MIS has data tables for storing road inventory, condition and traffic data. The tables created were based on the existing data collection practice of PWD and so they do not necessarily match with the proposed improved data collection practice given in Working paper # 34/1 Re-establishing Road, Bridge and Traffic Data Collection Process (July 2006).

Review of MIS has shown that the Planning modules do not have the functionality to maintain neither a linear nor spatial location referencing system. The system cannot therefore be used for managing road related data (inventory, condition, traffic) that requires linear referencing. Hence, this cannot be used as a Road Information System (RIS) for MMS purposes. It is therefore proposed to include RIS (specifically focused on road maintenance management) as a part of
MMS development. Data transformation routines will need to be developed to transfer summarised data from RIS to the Planning Module of MIS.

2.2 GEOGRAPHIC INFORMATION SYSTEM (GIS)

GIS implementation in PWD is still at a preliminary stage. The available GIS base map, used for digitising different types of maps, lacked accuracy. With the curves/lines on the map being identified based on road definition only, there is limited use of this base map for both query and display of information available on the road database.

It is therefore important to start developing a new base map for the road network that is managed by PWD. The base map can be prepared by digitising roads based on 1:50,000 scale topographical maps although it is preferable to collect the GPS co-ordinates of the centreline of the road using a GPS receiver.

To minimise the volume of work, only the roads included in the core network should be digitized in the first phase - national highways, state highways and major district roads. It is preferable that each road segment in the base map is defined based on the position of the kilometre stone, in order that the required information is generated with reasonable speed and accuracy.

2.3 MAINTENANCE MANAGEMENT SYSTEM (MMS)

2.3.1. dTIMS Based Pavement Management System

The Pavement Management System (PMS) was developed for PWD in 1996 as part of the Four States PMS project. HDM pavement deterioration and vehicle operating cost models, calibrated to Indian conditions, were built in to the dTIMS v. 5 software platform. Necessary training was given to UP PWD staff in order to implement the system. The analyses were carried out for some 8,000 kms of road in order to prepare a prioritised work programme.

None of the software programme files, nor the PMS setup and analyses output, are currently available.

2.3.2. DHV Road Manager

DHV Road Manager, developed as part of a road maintenance management study, was used by the consultant in 2002 and 2006 for the preparation of a 5 year maintenance programme. The system was handed-over to PWD but was never used for any programming purposes thereafter.

The installation disk for the Road Manager software was obtained, but the software could not be installed on the Consultant’s computer in order that they might review the system. The issue was referred to the DHV (Holland), but neither updated software nor the manuals have been made available.

A review of the long-term maintenance programme for the core-network (prepared by DHV under the PCC project, March 2006) shows that there is inconsistency with regard to the network conditions generated by the DHV Road Manager Works programme. The condition status of the road network shows a significant backlog, whereas the treatments are applied
mainly from the year 2008. The visual condition data has been stated as having been collected using an incorrect format. This has been blamed, by the consultants, for both the poor analysis results and subsequent works programme.

The following conclusions on the capability of DHV Road Manager have been identified based on the various reports available which contain information on the software:

- The generation of the works programme is based on a condition assessment of the network
- The system does not support techno-economic and lifecycle analysis
- Economic parameters such as Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR), First Year Rate of Return (FYRR) can not be generated using the software
- A limited number of reports are available and any modifications, if required, can only be done with the help of the software suppliers, for a fee.

In conclusion, DHV Road Manager does not fulfil all the requirements of a comprehensive MMS system for PWD, as recommended by Road Maintenance Study (2000).
3. FRAMEWORK FOR MMS DEVELOPMENT

3.1 OVERALL FRAMEWORK - CORE ROAD NETWORK (approx. 45,000 km)

Based on a review of the existing systems, PWD capabilities and, the requirement of improved maintenance management practices, a tentative framework for the proposed UP Maintenance Management System for the core road network (UPMMS-Core) has been developed and is shown in Figure 3.1.

Figure 3.1: Proposed UP Maintenance Management System (UPMMS-Core)

A brief description of each module is given below.
3.2 OVERALL FRAMEWORK- NON-CORE ROAD NETWORK (approx. 78,000 km)

Based on the review of the existing systems, PWD capabilities and requirements of the improved maintenance practices, a tentative framework for the proposed UP Maintenance Management System for the non-core road network (UPMMS-Non Core) has been developed. (Illustrated in Figure 3.2)

Figure 3.2: Proposed UP Maintenance Management System (UPMMS-Non Core)

3.3 ROAD INFORMATION SYSTEM (RIS)

The Road Information System (RIS) database is the central part of any Maintenance Management System (MMS) and should:

- Manage the Location Referencing System
- Function as a data repository for network level planning data
- Have the ability to process data to the required format, based on information needs
• Easily access the required information for any particular section and/or structure on the road network

• Generate information (in the form of reports/graphs) that can assist in the decision making process.

RIS should also be;

• Able to manage the shifting of location referencing data when there is a change in road definition

• Flexible enough to ‘grow’ with time

• Able to create customised reports

Changes in chainage, and the distance from the start of the road, due to changes in the alignment, following the construction of a new bridge, is illustrated in Figure 3.3. RIS should have the ability to automatically update the location references of the data.

Figure 3.3: Need for Updating Location Referencing

The software platform used for RIS should be flexible enough to be easily customised by the User (Advanced) in regard to any new requirements identified during system implementation. This could significantly reduce the system refinement cost if the software programmer is not required for minor improvements to the system.

Although GIS is not a mandatory requirement for establishing a MMS but with its ability to display information in thematic maps is a very useful supplementary tool for data presentation. Inbuilt GIS within RIS could help to quickly access available information in the database; generate thematic maps for reporting, and/or for data validating purposes.
3.4 PAVEMENT MANAGEMENT SYSTEM (PMS)

3.4.1. Overview

The Pavement Management System (PMS) module can help in decision making on the optimal use of available funds for the road maintenance. Strategic level analysis is used to predict long-term funding requirements and to define appropriate levels of service. Programme level analysis can help to prepare optimised multi-year work programmes. The optimised work programme can be used to identify candidates for a preliminary works programme with the final programme being prepared based on field verification and comments from Divisions and other relevant authorities.

3.4.2. Level of PMS Analysis

Two different levels of PMS are considered for implementation within PWD:

- Simplified PMS
- Advanced PMS

A Simplified PMS should be used for tentative assessment of maintenance needs (in terms of type of treatment, cost and quantities). A decision tree, based on predefined maintenance standards should be used for this purpose. There would be no optimisation ability required in the Simplified PMS as the primary objective will be to just identify need/backlog.

Advanced PMS will generally be based on deterioration predictions, life-cycle analysis and economic optimisation. Economic optimisation, used in advance PMS, is generally based on the minimisation of total transport costs and/or maximisation of condition/improvement.

HDM-4 software (promoted by PIARC) is one of the most widely used analytical tools specifically developed for PMS implementation. Using road network traffic data, it can simulate the deterioration of the road pavement and assign required treatments based on predefined work standards. The benefits are calculated based on improvement in the condition of the road following the application of a treatment. Optimisation should be undertaken based on incremental benefit-cost ratio (BCR). The software has the flexibility to be configured easily to local conditions by providing calibrated values for various parameters used in the analysis.

Another option is to use generic software platforms, such as HIMS, dTIMSCT, Confirm TNG etc., to ‘build-in’ HDM (or locally developed) road deterioration, works intervention effects and road user cost models. This approach was followed while implementing the Four State PMS in 1994-1996. Although the system is more flexible in such a case, special expertise is needed for any further refinement to the system. Such a capability is not available within PWD.

It is therefore recommended to use HDM-4 as the analysis tool for PMS, with the interface for both the Simplified PMS and for HDM-4 being provided by generic software, such as HIMS, dTIMSCT etc.
It is recommended to use HDM-4 as the analytical tool for PMS. Generic software, such as HIMS, dTIMSCT etc., is recommended for use as the interface for both Simplified PMS and for HDM-4.

### 3.4.3. Using Generic Platform for Simplified PMS- Non Core roads

Generic PMS can be used to identify the work needs (in terms of location, quantum of work and cost involved) based on a decision tree.

<table>
<thead>
<tr>
<th>Category</th>
<th>Treatment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve</td>
<td>Realignment</td>
<td>Necessary improvement in horizontal and vertical alignment when road is re-categorized to higher level</td>
</tr>
<tr>
<td></td>
<td>Widening</td>
<td>Capacity improvement to cater increasing traffic condition</td>
</tr>
<tr>
<td></td>
<td>Strengthening</td>
<td>Strengthen weak pavement structure to accommodate increased loading condition</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation</td>
<td>Rehabilitate badly deteriorated road (which can not be maintained by resurfacing or overlays)</td>
</tr>
<tr>
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<td>Resurfacing</td>
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<tr>
<td>Routine Maint</td>
<td>Patching, cleaning drains, maintain line marking, signs and signal etc</td>
<td>Includes general maintenance to delay the deterioration process and keep road safe to travel</td>
</tr>
</tbody>
</table>

Please refer to Figure 3.4 for an example of such decision tree.

As the decision tree requires to be based specifically on PWD policy and local maintenance practices, the software platform should allow easy configuration, and modification when required, to enable the system to generate the required output.
3.4.4. Using HDM-4 as Analytical Tool for PMS

3.4.4.1. HDM-4 workspace Customisation

As stated earlier HDM-4 workspace should be customised for local conditions and maintenance practices. Work standards in HDM-4 require to be identified based on best practices (existing and proposed) within PWD. A level one calibration, based on a desktop study of pavement deterioration models, will be required. Similarly, the cost parameters used for vehicle operating costs will need to be identified/updated. Vehicle fleet parameters can be updated based on information available for HDM-4 from other states.
3.4.4.2. HDM-4 Interface

HDM-4 requires that data be prepared in a special format based on homogeneous sections and, hence, an interface (See Figure 3.5) is required to prepare HDM-4 input data from the data available in RIS.

**Figure 3.5: Functions of HDM-4 Interface**

Homogeneous sectioning includes the breaking of a road into relatively similar sections so that the same treatment can be applied to whole section. The criteria used for the breaking up of sections should be based on parameters that are the most sensitive in relation to the output of the analysis. Value change, deviation and range are some of the criteria that could be used to break the section.

**Figure 3.6: Example of Homogeneous Sectioning**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Asphalt</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>2250</td>
<td>4500</td>
</tr>
<tr>
<td>Carriageway</td>
<td>single</td>
<td>dual</td>
</tr>
<tr>
<td>Roughness (IRI)</td>
<td>4.0 5.5</td>
<td>7.0 4.5</td>
</tr>
<tr>
<td>Homogeneous Lengths</td>
<td>H1 H2</td>
<td>H3 H4</td>
</tr>
</tbody>
</table>

At the time of automatic homogenous sectioning some sections may be too short and others too long. Manual refinement of the sections may therefore be needed before it can be considered as the analysis section for use in the development of a works programme. A typical interface for manual refinement of sectioning is illustrated in Figure 3.7. A ‘strip-map’ display of the data for different parameters can also help in the process.
3.5 ROUTINE MAINTENANCE MANAGEMENT SYSTEM (RMMS)

RMMS is used for estimating maintenance cost based on actual condition and calibrated performance standards. This approach, which allows informed decisions to be made, is better than the approach followed by PWD Maintenance Manual for roads (1984), whereby funds are distributed over different maintenance activities based on fixed percentages. The ongoing refinement of performance standards would need to be based on the achievements derived from maintenance funding.

It is important that the maintenance works undertaken on each road section are recorded. This functionality can be built into an RMMS module or this can be kept in a separate Monitoring and Evaluation System (MES) module.

It is preferable that the same software platform be used for RIS and other modules of MMS and also be implemented for data and process integration as well as data administration. This would therefore reduce the duplication of work in compiling data and also result in less training requirements for end users.
3.6 BRIDGE MANAGEMENT SYSTEM (BMS)

A Bridge Management System can help in the decision making process by providing relevant information to decision makers. This can be based on the data available within the database or specific analysis undertaken to determine the maintenance and rehabilitation needs.

4. RESOURCES REQUIREMENT FOR MMS

4.1 INSTITUTIONAL DEVELOPMENT

4.1.1. MMS Core Team – Key personnel

To ensure that the system is sustainable, it is essential that a skilled data management and analysis team is in place. The key personnel that could be included in the team are given in Figure 4.1.

Figure 4.1: Data Management and Analysis Team

Given that the data collection will require a considerable amount of time, the formation of such a team could be divided into two phases:

- Phase 1 – Creation of data collection and management team
- Phase 2 – Creation of data analysis team

Please refer to Annexure 1 for a job description for the key personnel of the team.

As these jobs are quite specific in nature, it is important that the personnel are recruited in time and are given proper training. It is recommended that all the Assistant Engineer level personnel be sent for an HDM-4 training course, organised by CRRI, in order to develop a basic understanding of maintenance planning based on techno-economic principles.

The positions identified for Phase 1 should be recruited immediately, if the data collection process, is to start as soon as possible. The positions identified for Phase 2 should be recruited...
after some six months, if PWD is to implement MMS. It is envisaged that by this time sufficient data should be available for the required customisation of RIS, PMS and RMMS modules for local UP conditions.

4.1.2. Training Requirement

Key personnel involved in the Maintenance Management System (MMS) implementation will require basic training in:

- Data collection principles and methods
- Maintenance planning based on techno-economic analysis
- General user training on all software used in MMS.

The 2-week HDM-4 training course regularly conducted by CRRI, could be useful for the personnel involved in MMS. Such training would provide an overall understanding of data requirements and the basic principles followed for optimal maintenance planning.

4.2 SOFTWARE AND DATABASE REQUIREMENTS

Various modules are required to be implemented as part of MMS. The functionalities required are specific and it is not considered practical (financially, technically and from a sustainability perspective) to develop the software in-house using local consultants. It is therefore recommended to procure ‘off the shelf’ software allowing configuration to satisfy specific local requirements. Using the same software platform for RIS and other MMS components would also be cost effective, and be less problematical for data integration and transfer.

The MMS should operate using Standard Query Language (SQL) and latest generation relational database management system (e.g. Microsoft, Sybase, Access, Oracle etc.)

Software platform to be used for RIS should:

- Have a linear as well as a spatial location referencing system, capable of managing historical data and changes in network definition.
- Store data references based on linear and spatial referencing systems
- Have the ability to generate specific reports, graphs and maps through data query procedures
- Process data to the required format compatible to HDM4 and/or other prioritisation software
- Transfer data to a different section definition
- Flexible enough to be easily refined in the future

Software platform to be used for MMS should:

- Be ‘off the shelf’ software with a well established help-desk and technical support arrangements
• Should have an in built RIS, PMS, RMMS and HDM-4 (version 2) interface module available or a software platform flexible enough to be built on

• Be flexible enough to be easily customisable to the requirements of PWD

• Be able to create homogeneous sectioning and transfer the data as required

• Have an interface to GIS thematic mapping

Examples of ‘off the shelf’ software platforms that fulfil the above requirements and are currently available include:

• dTIMS CT (distributed by Deightons Associate Limited, Canada)

• HIMS – Asset Management System (distributed by HIMS Ltd, New Zealand)

The DOS version of dROAD and dTIMS was implemented in the Four States PMS Implementation project in 1994-96. The HIMS software platform has recently been used to develop a maintenance management component as a part of the Gujarat Road Management system - GRMS

HDM-4 software will also need to be procured as the analytical tool of PMS.

| Action Required | PWD should initiate the procurement of the software, and the services to customise the system as a part of MMS development. It should be noted that the resources required for procurement and local customisation of ‘off the shelf’ software is not included in this contract. |

4.2.1. Number of Licenses

The number of licenses for the generic software platform, or for HDM-4, cannot be determined at this stage. These issues will need to be reviewed once the structural re-organisation of PWD has been approved and the RMMS software has been selected.
5. LOCATION OF MMS/GIS UNIT

The MMS / GIS Unit will report to the Policy and Planning Unit but will also have considerable interaction with the MIS Unit. Although GIS is not a mandatory requirement for establishing a MMS but with its ability to display information in thematic maps is a very useful supplementary tool for data presentation.
6. **ACTION PLAN FOR MMS ESTABLISHMENT**

As mentioned earlier, most of the MMS off the shelf softwares comes in-built with the database. This database needs to be configured based on core infrastructure plan at the client’s location. Therefore, PWD should assess the scale of application and the planned infrastructure related to connectivity before going for procurement. An action plan for establishment of MMS together with RIS has been proposed below.

Table 6.1: Main Activity and Responsibility for Establishment of MMS

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description of Activities</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Constitute MMS core staff</td>
<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>Review existing road maintenance management practices in PWD (Part of Report 24)</td>
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</tr>
<tr>
<td>4</td>
<td>Review existing and planned IT infrastructure for PWD and state (Part of Report 13)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Prepare Generic specification for MMS</td>
<td></td>
</tr>
<tr>
<td>6</td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td>Compare the generic UP-PWD specification of MMS with those provided by suppliers and make initial selection</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Visit to a road agency using similar software program to evaluate the effectiveness of the system</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Off-the-shelf software procurement and installation</td>
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</tr>
<tr>
<td>10</td>
<td>Obtain inventory and condition data from the zones</td>
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</tr>
<tr>
<td>11</td>
<td>Configuration of MMS database and application to PWD requirements</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Prepare customized reports</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Procurement of HDM4 software</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Training on use of HDM4</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Configuration of HDM-4 workspace for local conditions</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Training on use of MMS</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Testing and evaluation</td>
<td></td>
</tr>
</tbody>
</table>

Once the MMS has been implemented in two divisions for the core network (2000 km approx.), a review will be undertaken and recommendations on further refinements will be provided.
7. CONCLUSIONS and RECOMMENDATIONS

The PWD should establish an MMS / GIS Unit which reports to the Policy and Planning Unit. In selecting a MMS software program, PWD should;

"....... try to adopt Commercial Off-the-Shelf (COTS) software wherever possible. Custom developed applications have often proved difficult and expensive to sustain."\(^1\)

It should also be a program that is fully supported by the supplier. This software program should be able to develop a prioritised list of roads for maintenance on the core road network.

A much simpler type of program will be required for the non-core network.

Four copies of the World Bank paper accompany this Report together with four copies of the details obtained regarding suitable software suppliers. All of the programs developed by the software suppliers link to HDM-4.

It is strongly recommended that before making any purchase the PWD visit at least one other organisation currently using the selected software program. This will enable the PWD to obtain first hand information regarding the application and use of the software from a user, and not the supplier. Such a visit will also enable the PWD to determine the effectiveness of the system in developing their annual maintenance budget and presentation of same to the Government.

\(^1\) Success Factors for Road Management Systems, World Bank 2006
8. PRESENTATION TO PROJECT STEERING COMMITTEE
Report No. 42: Report on Establishing Road Maintenance management system (RMMS) featuring rational prioritisation on techno-economic criteria, and apply to core network maintenance management

<table>
<thead>
<tr>
<th>PWD Focus Group - G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shri. Rajesh Chandra</td>
</tr>
<tr>
<td>Shri. P.K. Mittal</td>
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<tr>
<td>Shri. R.B.K. Rakesh</td>
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<tr>
<td>Shri. Vishwa Deepak</td>
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<tr>
<td>Shri. N.K. Bishayee</td>
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<tr>
<td>Shri. Arvind Jain</td>
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<tr>
<td>Shri. Ajay Gangwar</td>
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</tbody>
</table>

LEA International Ltd. and LEA Associates South Asia Pvt. Ltd.

<p>| |</p>
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<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Alan Stanbury</td>
</tr>
<tr>
<td>Dr. Nabin Pradhan</td>
</tr>
</tbody>
</table>
Available System

Management Information System (MIS)

• 12 Modules developed in 2002 with MS SQL Back End
• Software developed based on the existing PWD procedures
• Acceptance tested, But Pilot Implementation in 37 Division not done
• Module with Data relevant to requirement for MMS
  – Planning module include road inventory data
  – Bridge module include bridge inventory data

Issues

1. Data stored not based on Linear Location Referencing System required for road related data management
2. Data items included are different from one identified
3. No existing time frame to implement MIS for whole Network

Need to transfer data between MIS and MMS
Available System ....

DHV Road Manager

- Decision tree based treatment assigning tool developed in year 2000
  Software never been operational in PWD. Installation disk available (but software could not be installed properly)
- DHV run analysis using the software & provided report (in 2002 and 2006)
- Issue with the works programme generated in 2006
  (Reason given- Problem with data provided)

Issues:
1. Do Not use Techno-economical criteria for prioritising treatment
2. Not flexible to customisation
Proposed UPMMS for Core Network

SYSTEM MODULES:
- LRM – LOCATION REFERENCE MANAGEMENT
- RIS – ROAD INFORMATION SYSTEM
- PMS – PAVEMENT MANAGEMENT SYSTEM
- RMMS – ROUTINE MAINTENANCE MANAGEMENT SYSTEM
- BMS – BRIDGE MANAGEMENT SYSTEM
- GIS – GEOGRAPHICAL INFORMATION SYSTEM

Network Reference System (LRM)

Planning Database

- Linear Referenced Data
  - Traffic Surveys Data
  - Road & Bridge Inventory Data
  - Pavement History & Strength Data
  - Condition Surveys Data
  - Project Information
  - Specialised Road Survey

- Spatial Reference Data
  - Road Centre Line
  - Remote Sensing
  - Other Spatial Data

Location Reference System (LRM)

Bridge Improvement & Maintenance Programme

Planning Database

- BMS
- HDM4 - PMS

RMMS

GIS

The Diagram shows the integration of various data sets and systems for managing core network infrastructure. The flowchart highlights the systematic approach to project selection, ranking, and maintenance prioritization, ensuring efficient resource allocation and strategic planning.
Proposed UPMMS for Non-Core Network

SYSTEM MODULES:
LRM – LOCATION REFERENCE MANAGEMENT
RIS – ROAD INFORMATION SYSTEM
PMS – PAVEMENT MANAGEMENT SYSTEM
RMMS – ROUTINE MAINTENANCE MANAGEMENT SYSTEM
BMS – BRIDGE MANAGEMENT SYSTEM
GIS – GEOGRAPHICAL INFORMATION SYSTEM

UPSRP

IDS

NETWORK DEFINITION

LOCATION REFERENCE SYSTEM
LRM

PLANNING DATABASE

Simplified BMS

BRIDGE IMPROVEMENT & MAINTENANCE PROGRAMME

Simplified PMS

MANAGEMENT INFO

ROUTINE MAINT. CATEGORISE

FEASIBILITY STUDIES

PROJECT SELECTION & RANKING

RENEWAL (Periodic Maintenance)

IMPROVEMENT PROJECTS

RENEWAL PER SECTION

GEOGRAPHICAL INFORMATION SYSTEM

THEMATIC MAPS

ROAD CENTRE LINE

REMOTE SENSING

OTHER SPATIAL DATA

LINEAR REFERENCED DATA

ROAD & BRIDGE INVENTORY DATA

VISUAL CONDITION SURVEYS DATA

TRAFFIC SURVEYS DATA
RIS - Road Information System

Should

- Manage the Location Referencing
- Store source data related to MMS
- Process and manage data
- Prepare reports graphs to assist decision making
- Able to manage data transformation at the time of change in road definition or road alignment
- Flexible enough to grow with time
- Able to easily create customised reports
Update required: Due to Mistake or Change in Alignment

Requirement: All data attributes also move with Reference
PMS – Pavement Management System

2 Levels Proposed

- Simplified PMS (for non-core road network)
  (For assessment of improvement and maintenance needs in terms of type of works, quantity, cost based on available data)

- Based on HDM-4 (for core road network)
  (For strategic planning, annual and multi-year work programme development based on techno-economic criteria)

Need:

1. Specific Software platform for Simplified PMS Development
2. HDM-4 software and customisation to PWD condition
3. HDM-4 Interface configured to prepare input data for HDM-4
4. System Flexible enough to grow with time
<table>
<thead>
<tr>
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</tr>
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<tbody>
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</tr>
</tbody>
</table>
Preparing Input Data

• Define the Latest Data
• Collate Data from Different Tables
• Define Homogeneous Analysis Section
• Prepare HDM-4 Input Data Table
  – Transfer Source data to Analysis Section and HDM-4 Format
  – Assign the Global Default based on Look-up Table
  – Export table in HDM-4 Format
**Automatic Homogeneous Sectioning**

**Creation of Homogeneous Sections & Data Transfer**

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Example of section based on value change
Refining Auto->Analysis Section - Example

Short Sections removed by double clicking LRP
RMMS – Routine Maint. Mgmt. System

• Distribution Model (Core RMMS)
  (Distribution of work and budget to analysis section based on road condition and performance standard for given category of road)

• Monitoring Maintenance Work (May be part of monitoring system)
  (Recording of consumed resources based on analysis section)

Need:
1. Specific Software platform for RMMS Development
2. Configuration of Software based on PWD Requirement
• Phase 1 – Creation of data collection and management team
• Phase 2 – Creation of data analysis team
Software for MMS

In-house development of the system not feasible due to:

- Development of complicated functionality required will require expertise which is not readily available in market
- Significant time required to start from the scratch
- Software will need continuous bug fixing, testing and refinement

1. Preferable to procure specific off-the-shelf software and configure to PWD Requirements:

2. Analytical Tool -> HDM-4 software (PIARC)

3. Software platform for RIS, PMS, RMMS, MES: Example are
   - dTIMS CT – Old version used for UP PMS (1994)
   - HIMS – Used in Gujarat, compatible to ROMDAS data collection system
Location of MMS / GIS Unit

Director General Works

Policy and Planning Unit

Finance Unit

MMS / GIS

MIS

6 No. Engineers-in-Chief
# Action plan for MMS establishment

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ANNEXURE 1: JOB DESCRIPTION FOR MMS KEY PERSONNEL

These are proposals only: they will need to be reviewed once the PWD re-structuring and staffing re-alignment has been approved and implemented. They are included here as a guide to the likely experience and skills of those required to work in the RMMS/GIS Unit.

1. General Manager - Data Management and Analysis (Superintendent Engineer)

Responsibility
General Manager – Data Management and Analysis will be responsible for managing all the works related to data management and analysis

Tasks
General Manager – Data Management and Analysis will ensure that:
• Data Management and Analysis Section is fully equipped, manned and functioning properly
• Information generated are disseminated to relevant authority
• The objective and task of the Section are well promoted within the organization

Qualification and Experience
General Manager – Data Management and Analysis should have:
• Experience in managing information or system management related work
• Should be graduate (preferably post graduate) degree in engineering, economics or management

2. Manager – Data Collection (Executive Engineer)

Responsibility
Manager – Data Collection and Co-ordination will be responsible for managing Data Collection and Co-ordination unit.

Tasks
Manager – Data Collection and Co-ordination will ensure that:
• Data Collection and Co-ordination Cell is fully equipped, manned and functioning properly
• Data are collected in time and of required quality
• Procure data collection contract and manage the contract

Qualification and Experience
Manager – Data Collection and Co-ordination should have:
• Experience in maintenance work management and planning
• Graduate (preferably post graduate) degree in civil engineering

3. Manager – Database Administration (Executive Engineer)

Responsibility
Manager – Database Administration will be responsible of all information and management systems in the Section are working properly.

Tasks
Manager – Database Administration should ensure that:
• Road Information System (RIS), Pavement Management System (PMS), Routine Maintenance Management System (RMMS) and Geographical Information system (GIS) is working properly
• The cell is fully equipped with the personnel, hardware and software required
• Necessary arrangement is made to procure external services as required

Qualification and Experience
Manager – Database Administration should have:
• Experience in management of information and management system related works
• Graduate (preferably post graduate) degree in information technology or graduate in civil engineering with post graduate study in information technology

4. Manager – Maintenance Management System (Executive Engineer)

Responsibility
Manager – Maintenance Management System will be responsible for managing Maintenance Management System unit.

Tasks
Manager – Maintenance Management System will ensure that:
• Maintenance Management System unit is fully equipped, manned and functioning properly
• The MMS system are functioning properly and that required strategic plan and work programme are generated in timely manner as per annual planning schedule

Qualification and Experience
Manager – Maintenance Management System should have:
• Experience in management of the team working on maintenance planning
• Graduate (preferably post graduate) degree in civil engineering
5. **Assistant Engineer – Data Collection**

**Responsibility**

Assistant Engineer – Data Collection will be responsible for coordinating with all the stakeholders and contractors to ensure that the required data are collected. It is envisaged that two assistant engineers will be working, looking after Eastern and Western part of the UP.

**Tasks**

The tasks of Assistant Engineer – Data could include:

- Planning and budgeting for data collection
- For data to be collected using external service provider:
  - Assist Manager – Data Collection to procure data collection contract
  - Provide necessary orientation/training to the contractor
  - Monitor the progress and quality check
  - Ensure that data received are in electronic format ready to be imported into the database
- Managing the data collection in-house
  - Schedule the timing for data collection
  - Coordinate with relevant personnel for data collection
  - Provide training/refresher course etc. if required
  - Providing the data in the format as required by Data Administration
- Identify any improvement required in data collection procedures etc.

**Qualifications and Experience**

Assistant Engineer – Data Collection should have:

- Experience in road network planning or road maintenance & construction supervision
- Graduate (preferably post graduate) degree in civil engineering
- Knowledge of data collection process and procedures (Preferable)
- High standard of communication skills, ability to maintain good communications with management staff and field support staff

6. **Database Administrator - RIS and GI**

**Responsibility**

Database Administrator- RIS & GIS will be responsible for ensuring that RIS and GIS databases are well administered and working properly.

**Tasks**

The tasks of Database Administrator- RIS & GIS will include:

- Administration of the database, including:
  - User access control
  - Data Entry of all the collected data
Refinement of the database system to accommodate additional requirement based on the recommendation from Asst. Engineer – PMS and Asst. Engineer – RMMS.

Database are properly backed-up and archived

Identify any improvement required in RIS and GIS.

**Qualifications and Experience**

Database Administrator- RIS and GIS should have:

- More than 5 years practical experience in administration of database (preferably related to road)
- Proficiency in operation of commercial GIS software
- Graduate (preferably post graduate) degree in information technology

7. **Assistant Engineer – MMS Analyst**

**Responsibility**

Assistant Engineer – MMS Analyst will be responsible for ensuring that PMS and RMMS applications are in working condition to undertake various analysis required for maintenance management.

**Tasks**

The tasks of Assistant Engineer – MMS Analyst will include:

- Administration of the PMS and RMMS modules of MMS
- Refinement of the PMS application working together with Assistant Engineer - PMS
- Refinement of the RMMS application working together with Assistant Engineer - RMMS

**Qualifications and Experience**

Assistant Engineer – MMS Analyst should have:

- More than 5 years experience in road maintenance planning and programming
- Practical experience in administration of database and/or custom design software
- Working knowledge of using GIS
- Graduate in Civil engineering (with advance training in database management preferable)

8. **Assistant Engineer - PMS**

**Responsibility**

The Assistant Engineer - PMS will be responsible for undertaking analysis using available PMS and HDM-4 system for various tasks related to network level planning and programming process.

**Tasks**

The tasks of Assistant Engineer - PMS will include:
• Undertaking PMS and HDM-4 analysis for development of long-term and medium-term programme, and other specific analysis as required by Planning or Asset Management Division

• Manage ongoing refinement of PMS and HDM-4 system
  o Identification issues related to data requirements for PMS and promote improvements
  o Ongoing refinement of deterioration and road user effects models
  o Update maintenance treatment and define maintenance unit costs
  o Update vehicle operating costs

• Promote use of PMS within the organisation

Qualifications and Experience
Assistant Engineer – PMS should have:
• More than 5 years experience in road maintenance planning and programming
• Graduate in Civil engineering (with advance training in database management preferable)
• Knowledge of economics and basic principle of HDM-4 models.
• Experienced and skilled in the use of the HDM-4 and relevant computer applications

9. Assistant Engineer - RMMS

Purpose
The Assistant Engineer - RMMS is responsible for undertaking analysis using Routine Maintenance Management System (RMMS) to ensure proper distribution of funding for general maintenance work to ensure optimum use of resources.

Tasks
The tasks of Assistant Engineer - PMS will include:
• Undertaking RMMS analysis and estimate routine maintenance budget for each road section
• Manage the data on monitoring of the expenditure and physical progress
• Manage ongoing refinement of RMMS
  o Review the available data and identify the effectiveness of the funding used
  o Improvement in the performance standard use for funding distribution based on the analysis and feedback
  o Identify the sections consuming high maintenance cost and consider for rehabilitation
• Promote use of RMMS within the organisation

Qualifications and Experience
Assistant Engineer – RMMS should have:
• More than 5 years experience in road maintenance planning and programming
• Graduate in Civil engineering (with advance training in database management preferable)
• Experienced and skilled in the use of computer applications