Maintenance of Roads in Pakistan

NHA’s Perspective

BY

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Islamabad

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بِسْمِ اللَّهِ الرَّحْمَنِ الَّرَحِيمِ

In the Name of Allah, the Most Gracious, the Most Merciful
ROAD NETWORK OF PAKISTAN AND ITS IMPORTANCE
### ROAD TRANSPORT DATA COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>UNIT</th>
<th>1947</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL ROADS</td>
<td>KM</td>
<td>50,367</td>
<td>260,000 +</td>
</tr>
<tr>
<td>REGD VEHICLES</td>
<td>NO</td>
<td>30,577</td>
<td>5,000,000 +</td>
</tr>
<tr>
<td>REGD TRUCKS/TRAILERS</td>
<td>NO</td>
<td>800</td>
<td>184,000</td>
</tr>
<tr>
<td>NATIONAL HIGHWAYS &amp;</td>
<td>KM</td>
<td>NIL</td>
<td>11,485</td>
</tr>
<tr>
<td>Motorways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD DENSITY</td>
<td>KM/KM²</td>
<td>0.06</td>
<td>0.32</td>
</tr>
</tbody>
</table>

### ROAD DENSITY COMPARISON

<table>
<thead>
<tr>
<th>Countries</th>
<th>Road Length / Sq. Km. of Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>3.07</td>
</tr>
<tr>
<td>France</td>
<td>1.72</td>
</tr>
<tr>
<td>Hungary</td>
<td>1.70</td>
</tr>
<tr>
<td>UK</td>
<td>1.62</td>
</tr>
<tr>
<td>Italy</td>
<td>1.04</td>
</tr>
<tr>
<td>India</td>
<td>1.00</td>
</tr>
<tr>
<td>Spain</td>
<td>0.68</td>
</tr>
<tr>
<td>USA</td>
<td>0.65</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.32</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.23</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.20</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.17</td>
</tr>
<tr>
<td>China</td>
<td>0.15</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.08</td>
</tr>
</tbody>
</table>
MODAL SHARE
PAKISTAN TRANSPORTATION MODE

IMPORTANCE OF MAINTENANCE OF ROADS
Life Cycle Cost Analysis

The Costs, Involved during the Design Life of any Pavement, may be Broadly Categorised into Following Three Types.

- Construction Cost
- Maintenance Cost
- Road User Costs

Components of Total Road Transport Costs in the Economy

- Fuel Consumption
- Oil Consumption
- Tyres Wear & Tear
- Parts Replacement
- Vehicle Depreciation
- Travel Time
- Accidents
Key Statistics from Emerging Countries

• Transport sector is 5 to 10 per cent of GDP.
• Every Rupee not spent on maintenance increases transport costs by Four Rupees.
• Transport fuels and machinery account for 40% of import bill.

Is This we want on our Roads

Definitely - Not
The Impacts of Road Maintenance

The effects of road maintenance can be assessed in terms of the various impacts:

- Level of service (road condition)
- Socio economic impacts
- Road user costs
- Accident levels and costs
- Road administration costs
SOME CHALLENGES

Over Loaded Truck
PERCENTAGE OF FREIGHT VEHICLES BY COMPOSITION

OVERLOADED PERCENTAGE

<table>
<thead>
<tr>
<th>TRUCKS 2 &amp; 3 AXLES</th>
<th>TRUCKS 4, 5 &amp; 6 AXLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Load Limits</td>
<td>30% 60%</td>
</tr>
<tr>
<td>Overloaded</td>
<td>70% 40%</td>
</tr>
</tbody>
</table>
Pavements

**Definition**

- The structure of road which actually carries the traffic loads is called *Pavement*.
Pavement Purpose; A Broad Definition

- Load support
- Smoothness
- Drainage

Pavement Performance

- Functional Performance
  - Providing Users a safe and comfortable Ride
  - Consists of
    - Ride Quality
    - Surface Friction
    - Other factors (Noise, Geometrics etc)

- Structural Performance
  - Ability to withstand traffic and environmental loadings
Pavement Types

- Flexible Pavement
  - Bituminous pavements
  - Called "flexible" since the total pavement structure bends (or flexes) to accommodate traffic loads

- Rigid Pavement
  - Portland cement concrete (PCC) pavements
  - Called “rigid” since PCC’s high modulus of elasticity does not allow them to flex appreciably

- Composite Pavements
  - Portland cement concrete (PCC) over HMA pavements
  - HMA Over PCC Pavements

Flexible Pavement

- Structure
  - Surface course
  - Base course
  - Subbase course
  - Subgrade
Types of Flexible Pavement

- Dense-graded
- Open-graded
- Gap-graded

Flexible Pavement – Construction
Flexible Pavement Types

- Flexible Pavement
  - Hot Mix Asphalt Surface
    - With Granular Unbound Base
    - With Stabilised (Bound) Base
    - Full Depth HMA
  - Bituminous Surface Treatment
    - With Granular Base
      - Single Surface Treatment
      - Double Surface Treatment
      - Triple Surface Treatment

Rigid Pavement

- Structure
  - Surface course
  - Base course
  - Subbase course
  - Subgrade
Types of Rigid Pavement

- Jointed Plain Concrete Pavement (JPCP)
  - Top View
  - Side View

Types of Rigid Pavement

- Jointed Reinforced Concrete Pavement (JRCP)
  - Steel Mesh 0.1 to 2.0 % of Cross sectional Area
  - Joint Spacing 7.5 to 30 m
  - Slab Thickness: 150 to 400 mm
  - Granular stabilized base
Types of Rigid Pavement

- Continuously Reinforced Concrete Pavement (CRCP)

Design Parameters

- Subgrade
- Loads
- Environment
Maintenance Alternatives

- Routine Maintenance
- Resurfacing
- Recycling
- Restoration
- Reconstruction

Types of Distresses in Flexible Pavements

A. Cracking
   1. Fatigue Cracking
   2. Block Cracking
   3. Edge Cracking
   4. Longitudinal Cracking
   5. Reflection Cracking at Joints
   6. Transverse Cracking

B. Patching and Potholes
   7. Patch Deterioration
   8. Potholes
Types of Distresses in Flexible Pavements

C. Surface Deformation
   9. Rutting
   10. Shoving

D. Surface Defects
   11. Bleeding
   12. Polished Aggregate
   13. Raveling

E. Miscellaneous Distresses
   14. Lane-to-Shoulder Dropoff
   15. Water Bleeding and Pumping

FATIGUE CRACKING

- Occurs in areas subjected to repeated traffic loadings (wheel paths).
- Can be a series of interconnected cracks in early stages of development.
- Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters (m) on the longest side, characteristically with a chicken wire/alligator pattern, in later stages.
- Must have a quantifiable area.
FATIGUE CRACKING; Severity Levels

- **LOW**
  An area of cracks with no or only a few connecting cracks; cracks are not spalled or sealed; pumping is not evident.

- **MODERATE**
  An area of interconnected cracks forming a complete pattern; cracks may be slightly spalled; cracks may be sealed; pumping is not evident.

- **HIGH**
  An area of moderately or severely spalled interconnected cracks forming a complete pattern; pieces may move when subjected to traffic; cracks may be sealed; pumping may be evident.
BLOCK CRACKING

- A pattern of cracks that divides the Pavement into approximately rectangular pieces.
- Rectangular blocks range in size from approximately 0.1 m² to 10 m².
LONGITUDINAL CRACKING

- Cracks predominantly parallel to pavement centerline. Location within the lane (wheel path versus non-wheel path) is significant.
REFLECTION CRACKING (At Joints)

- Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements.
TRANSVERSE CRACKING

- Cracks that are predominantly Perpendicular to pavement centerline.

Note: Rate entire crack at highest level present for 10% or more of total crack length.

Damage type 6, Low severity

TRANSVERSE CRACKING
POTHOLES

- Bowl-shaped holes of various sizes in the pavement surface. Minimum plan dimension is 150 mm.
RUTTING

- A rut is a longitudinal surface depression in the wheel path. It may have associated transverse displacement.
SHOVING

- Shoving is a longitudinal displacement of a localized area of the pavement surface. It is generally caused by braking or accelerating vehicles, and is usually located on hills or curves, or at intersections.
- It also may have associated vertical displacement.
RAVELING

- Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. Raveling ranges from loss of fines to loss of some coarse aggregate and ultimately to a very rough and pitted surface with obvious loss of aggregate.
Maintenance Principles

Treatments, Triggers and Resets

Decay in Condition (DETERIORATION)

Condition Improvement (RESET)

Minimum Acceptable Standard (TRIGGER)

Treatment Applied

ROAD CONDITION

EXCELLENT

POOR

TIME
**Deterioration Management**

- **ASSET CONDITION**: EXCELLENT, POOR
- **TIME**: ORIGINAL DECAY, OPTIMAL CONDITION BAND, OPTIMAL RENEWAL STRATEGY
- **Maintenance Treatments**

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**Requirement - Optimization to Minimize Total Transportation Cost (TTC)**

- **COSTS**
  - Optimum Maintenance
  - Total Transport Costs
  - Road User Costs
  - Maintenance Costs
  - Construction Costs

**MAINTENANCE LEVEL**
Means of Maintenance

An ideal system for the maintenance should be based on some scientific basis and all the data required should be collected on some standards.

For decision making process, many countries have developed Pavement Management System (PMS) according to the their need.

In Pakistan, Different agencies are using various PMS varying from excel sheets to state of art Models like HDM-4

NETWORK ANALYSIS PROCESS

Main components include:
- Forecasting of Revenue Generation/Investment Statement
- Road and Bridge Distress Survey
- Roughness Measurement Survey
- Strength Evaluation Survey
- Traffic Survey
- Historical Data
- Performance Standards
- Feedback from Stakeholders
- Treatment Rules
Data Collection
Data Collection

Following Data is collected each year

- Pavement Condition Data
- Traffic Data
- Falling Weight Deflecto-meter Data
- Roughness Data
- Profilo-graph Data
- Economic Data for Traffic Fleet
- Revenue Data From Toll Plazas
Pavement Condition Data

Pavement Distress type, Extent and Severity is recorded for EACH KM of the every Road. The Data is Collected by WINDSHEILD SURVEY.

Following Distresses with measuring units are identified for Data Collection

- Cracking (%age of length effected & Crack Width)
- Rutting (Length of Rutted Portion & Rut Depth)
- Potholes (Number of Potholes in KM)
- Ravelling (%age of length effected & Disintegration Type)
- Edge Step (%age length effected & Depth)
- Erosion from Original Edge (%age length effected & Depth)
- Drainage Condition (Performance Indicator)
# PAVEMENT CONDITION SURVEY FORM

<table>
<thead>
<tr>
<th>Damage Type</th>
<th>Km 1</th>
<th>Type</th>
<th>Km 2</th>
<th>Type</th>
<th>Km 3</th>
<th>Type</th>
<th>Km 4</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage 1</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
<td>6.0</td>
<td>7.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Damage 2</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
<td>6.0</td>
<td>7.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

**Note:**
- Damage 1: Description of Damage 1
- Damage 2: Description of Damage 2

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**Critical Notes:**
- Critical note 1
- Critical note 2

---

**File Info:**
- Date: 3/17/2012
- Filed By: [Signature]

---

**Survey Details:**
- Surface: [Description]
- Width: [Width]
Traffic Data

- 24 Hours Classified Traffic Counts at Chosen Stations is Carried Out.
- Traffic Data is also Retrieved from NTRC, NHA, NH&MP and Other Highway Consultants.
- This Data is, then, Sorted for Different Analysis.
- Axle Load Data is Collected from NH&MP and NHA Weigh Stations.
- Axle Load Studies by NTRC, RAMD and JICA Japan are also consulted.

FWD Data

- FWD data is collected by NHA itself.
- KUAB Falling Weight Deflectometer is used to collect the data.
**STIFFNESS CONCEPT**

Wheel load

WEAK
Poor load spreading

Subgrade

Compressive stress on subgrade

STIFFNESS CONCEPT

Wheel load

STRONG
Good load spreading

Falling Weight Deflectometer

\[ h \]

\[ m \]

\[ k \]
FWD Deflection Basin

FWD Machine
Pavement Roughness Data

- Pavement Roughness Data is Collected by ROMDAS Bump Integrator Unit & Profilograph.

- The BI unit gives the number of bumps, it received from the pavement, which were, then, converted to IRI values.

- IRI is a standard to measure the smoothness of the Pavement and measures Pavement Roughness in terms of the number of mm per Km that a vehicle receives during its operation.
Front bar with 13 roughness lasers (16 kHz) and 2 texture lasers (64 kHz)

HDM-4 APPLICATION
PRIORITIZATION CYCLE

Analysis Tools
- Project
- Program
- Strategy

Central Data Bank
- Data Managers
- Road Network
- Vehicle Fleet
- Road Works
- HDM Config.

APPLICATION OF HDM MODEL

ANNUAL BUSINESS PLAN

BUDGET
The Highway Design and Maintenance Standards Model (HDM-4), Developed by the World Bank, has been Used for over two Decades to Combine Technical and Economic Appraisals of Road Projects, to Prepare Road Investment Programmes and to Analyze Road Network Strategies.
Vehicle Fleet

Vehicle Fleet is Developed by Considering Different Types of Vehicles which are Using the Road Network in Pakistan. Following Data is Provided for 12 Type of Vehicles:

- Type & Class of Vehicle
- Physical Characteristics
- Utilisation of Vehicle
- Specifications of Tyres
- Axle Loading and Spacing
- Vehicular Resources
- Time Value
- Fuel & Lubrication Pricings
# Economic Costs of Motorcycles & Cars

## Description

<table>
<thead>
<tr>
<th>Description</th>
<th>M.Cycle</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Honda 70</td>
<td>Honda 125</td>
</tr>
</tbody>
</table>

## Basic Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>M.Cycle</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine (cc)</td>
<td>70</td>
<td>125</td>
</tr>
<tr>
<td>Gross Vehicle Weight (kg)</td>
<td>129</td>
<td>1587</td>
</tr>
<tr>
<td>Number of Airs</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Types of Tyres</td>
<td>270 - 18.8PR</td>
<td>155/80 BR 13 X (X)</td>
</tr>
<tr>
<td>Seats</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Usage</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hours Driven per year</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Average Speed (km/hr)</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Kilometers Driven per year</td>
<td>12000</td>
<td>12000</td>
</tr>
</tbody>
</table>

## Cost (Rs)

<table>
<thead>
<tr>
<th>Cost</th>
<th>M.Cycle</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Market Price</td>
<td>59000</td>
<td>71000</td>
</tr>
<tr>
<td>Market Price of Tyre</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Market Price of Tyres In vehicle</td>
<td>24000</td>
<td>24000</td>
</tr>
<tr>
<td>Vehicle Market Price without Tyres</td>
<td>50000</td>
<td>68000</td>
</tr>
<tr>
<td>Duty / Tax Ratio</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>Economic Cost Ratio</td>
<td>0.71</td>
<td>0.71</td>
</tr>
<tr>
<td>Economic Cost Of Vehicle Minus Tyre</td>
<td>40166</td>
<td>48706</td>
</tr>
</tbody>
</table>

## Tyre Cost (Rs)

<table>
<thead>
<tr>
<th>Tyre Cost of Tyre</th>
<th>M.Cycle</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Price of Tyre</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Tax Ratio on Tyre</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Economic Cost Ratio</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>Economic Cost per Tyre</td>
<td>435</td>
<td>405</td>
</tr>
</tbody>
</table>

## Vehicle Fleet

- **Vehicle Attributes: Car**
  - Definition: Basic Characteristics
  - Economic Use Costs

## Vehicle Attributes: Car

- **Vehicle Resources**
  - New vehicle: 12000
  - Maintenance labour: 25 per hour
  - Replacement parts: 42 per hour
  - Labour: 50 per hour
  - Lubrication oil: 210 per hour

- **Tree Value**
  - Maintenance labour: 10000
  - Replacement parts: 100 per hour
  - Labour: 50 per hour
  - Lubrication oil: 210 per hour

- **Calculations**
  - All costs should be expressed in the local currency - Pakistan Rupees

- **UI Elements**
  - Calculate: Yes
  - Print Details: Yes
Work Standards

24 Maintenance Standards are Developed and Costing of Each of Them is Carried out. These Standards are Then Imported to HDM-4 for Choosing Best Alternative for any Road Section: Following are Considered for the Formulation of These Standards:

- Desired Service Indicators
- Maximize the Net Present Value
- Maximize the Internal Rate of Return
- Minimize the IRI
- Minimum Cost for Maintaining a Road.

Rate Analysis for All the Maintenance Standard is Carried out in Excel Sheets

Work Standards

Each Maintenance Standard is Associated with Responsive Criteria. And it Triggers when That Criteria is Met. Like

- **Rehabilitation Triggers when** IRI=>5 & Cracked Carriageway =>35 %

Similarly

- **120 mm Structural Overlay Triggers when** 4=< IRI <=5 & Cracked Carriageway =>15 %, <35%
### Work Standards

**Maintenance Standards: Thesis Alternative 1 without Hauler Recycling**

#### Work Standards

- **Name:** [Input Name]
- **Work Code:** [Input Work Code]

#### Work Types

<table>
<thead>
<tr>
<th>Rehabilitation</th>
<th>25 cm w/AR + 13 cm AC</th>
<th>PEHEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Defect</td>
<td>50 mm with B2</td>
<td>25</td>
</tr>
<tr>
<td>Structural Defect</td>
<td>20 mm with B2</td>
<td>50</td>
</tr>
<tr>
<td>Structural Defect</td>
<td>100 mm with B2</td>
<td>100</td>
</tr>
</tbody>
</table>

#### Work Programme

UNCONSTRAINED WORK PROGRAM

**HDM-IV ANALYSIS - 2008**

### Work Programme Unconstrained by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Network</th>
<th>Total</th>
<th>Plate</th>
<th>Sideband</th>
<th>Overhead</th>
<th>Financial Costs</th>
<th>Cumulative Costs</th>
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</thead>
<tbody>
<tr>
<td>2006</td>
<td>12345</td>
<td>1234</td>
<td>5678</td>
<td>9012</td>
<td>3456</td>
<td>7890</td>
<td>12345</td>
</tr>
</tbody>
</table>

### HDM-IV Analysis

- **Total Work:** [Total Work]
- **Plate Work:** [Plate Work]
- **Sideband Work:** [Sideband Work]
- **Overhead Work:** [Overhead Work]

### Financial Costs

- **Total Financial Costs:** [Total Financial Costs]
- **Cumulative Costs:** [Cumulative Costs]

### Summary

- **Study Name:** Work Network 2006-08
- **Run Date:** 08-09-2008
- **Summary:** Fish Slice
End Note

*A Stitch in Time Saves Nine*