Overview of HDM-4

Henry Kerali

Lead Transport Specialist

The World Bank
Transport and Development

- Transport sector is vital for economic & social development
- Roads constitute largest component of transport
- Roads require a balance of:
  - Maintenance (or Preservation)
  - Development (or Improvement)
- Objective of Road Management
  - Consistent and Rational Policy Objectives
  - Sufficient and Reliable Funding
  - Effective Procedures & Management Tools (e.g. HDM-4)
In many developing and emerging economies, actual expenditure on road preservation and maintenance is between 25 ~ 60% of need.
HDM-4 Concept

- Predicts road network performance as a function of:
  - Traffic volumes and loading
  - Road pavement type and strength
  - Maintenance standards
  - Environment / Climate

- Quantifies benefits to road users from:
  - Savings in vehicle operating costs (VOC)
  - Reduced road user travel times
  - Decrease in number of accidents
  - Environmental effects
Road Management

Purpose:

To optimise the overall performance of the network over time in accordance with POLICY OBJECTIVES and within budgetary constraints.

Typical objectives:

- Minimise transport costs
- Preserve asset value
- Provide and maintain accessibility
- Provide safe and environmentally friendly transport
Road Management Functions

- Planning
  - Setting standards and policies
  - Long term estimates of expenditure
- Programming
  - Medium term work programmes
- Preparation
  - Detailed project design and work packaging
- Operations
  - Implementation of works in field
### Role of HDM-4

<table>
<thead>
<tr>
<th>Management Function</th>
<th>HDM-4 Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Strategy Analysis</td>
</tr>
<tr>
<td>Programming</td>
<td>Programme Analysis</td>
</tr>
<tr>
<td>Preparation</td>
<td>Project Analysis</td>
</tr>
</tbody>
</table>
HDM-4 Applications

- Road sector policy studies
- Strategic planning of road network development, improvement & maintenance
- Determination of funding requirements
- Preparation of multi-year road work programmes
- Economic appraisal of individual road projects
- Research studies
  - Road pricing
  - Vehicle regulations
  - Pavement design standards
Standards & Policies

• Road pricing
  - road use costs (to define fuel levies)
  - congestion charges
  - weight-distance charges

• Vehicle regulations
  - axle load limits
  - energy consumption, vehicle emissions & noise

• Engineering Standards
  - sustainable road network size
  - pavement design and maintenance standards
Strategy Analysis

Strategy analysis is concerned with the analysis of entire road networks to determine funding needs and/or to predict future performance under budget constraints.

Objectives:

- Determine budget allocations for road maintenance and improvement
- Prepare for work programmes
- Determine long term network performance
- Assess impact on road users
- Forecast scenarios of revenues & available budget
- Assess current condition of assets
- Forecast traffic demands (from road network plan)
- Evaluate impact of strategies on performance and costs - using predictive model
- Optimize strategies under alternative budget scenarios - maximize NPV for each scenario
- Determine multi-year program allocations & performance
Strategic Analysis Approach

Road Network

Matrix

Revenues, Sector budgets → Resource Constraints → Development Candidates → Preservation Evaluation

Optimal Strategy under Budgetary Constraints

Optimization Module
Budget Allocation

- Routine maintenance needs based on road lengths under each category of roads
- Recurrent maintenance needs based on pavement surface condition
- Periodic maintenance needs based on economic indicators
- Improvement needs based on economic indicators
## Maintenance Budget ($m)

<table>
<thead>
<tr>
<th>Region</th>
<th>Primary Roads</th>
<th></th>
<th>Secondary Roads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexible</td>
<td>Gravel</td>
<td>Flexible</td>
<td>Gravel</td>
</tr>
<tr>
<td>North</td>
<td>45.9</td>
<td>18.7</td>
<td>34.5</td>
<td>21.8</td>
</tr>
<tr>
<td>East</td>
<td>34.6</td>
<td>13.5</td>
<td>24.9</td>
<td>11.8</td>
</tr>
<tr>
<td>South</td>
<td>52.1</td>
<td>21.0</td>
<td>45.0</td>
<td>21.8</td>
</tr>
<tr>
<td>West</td>
<td>27.2</td>
<td>20.4</td>
<td>19.5</td>
<td>12.3</td>
</tr>
</tbody>
</table>
Effect of budget levels

Primary Roads

Average Roughness (IRI)

Target = 3.5 IRI

Annual Budget

- $10m
- $15m
- $20m

Budget Levels:
- $20m
- $15m
- $10m

Years:
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
Road Network Performance

Budget Allocations

- Feeder Roads: $30m/yr
- Secondary Roads: $35m/yr
- Primary Roads: $20m/yr

Average Roughness (IRI)

- 2003: 3.0
- 2004: 4.0
- 2005: 5.0
- 2006: 6.0
- 2007: 7.0
- 2008
- 2009

Graph showing the budget allocations and average roughness over the years.
Optimal budget requirements
Programme Analysis

Concerned with the preparation of single or multi-year road work and expenditure programmes under specified budget constraints.

- Objective: prioritise candidate road projects in each year within annual budget constraint
- Annual budgets obtained from strategic maintenance plan
Procedure.

- Use specified standards to screen network & identify candidate projects, e.g.
  - road sections which exceed specified condition
  - roads with inadequate capacity
  - pavements which need strengthening
  - upgrade pavements with high traffic volumes
**Procedure**

- Determine maintenance or improvement options
- Specify budget limits & periods
- Optimise using selected objective
- Produce optimal list of projects for budget period
## Work Programme Output

<table>
<thead>
<tr>
<th>Priority Rank</th>
<th>Road Section</th>
<th>Length (km)</th>
<th>Province or District</th>
<th>Type of Road Work</th>
<th>Scheduled Year</th>
<th>Cost $m</th>
<th>Cumulative S$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N1-2</td>
<td>20.5</td>
<td>2</td>
<td>Resealing</td>
<td>2003</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>2</td>
<td>N4-7</td>
<td>23.5</td>
<td>7</td>
<td>Overlay 40mm</td>
<td>2003</td>
<td>10.9</td>
<td>16.3</td>
</tr>
<tr>
<td>3</td>
<td>N2-5</td>
<td>12.5</td>
<td>5</td>
<td>Reconstruct</td>
<td>2003</td>
<td>8.6</td>
<td>24.9</td>
</tr>
<tr>
<td>4</td>
<td>R312-1</td>
<td>30</td>
<td>4</td>
<td>Widen 4 lane</td>
<td>2003</td>
<td>31.4</td>
<td>56.3</td>
</tr>
<tr>
<td>5</td>
<td>R458-3</td>
<td>36.2</td>
<td>3</td>
<td>Overlay 60mm</td>
<td>2003</td>
<td>16.3</td>
<td>72.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>N4-16</td>
<td>32.1</td>
<td>6</td>
<td>Reconstruct</td>
<td>2004</td>
<td>22.8</td>
<td>22.8</td>
</tr>
<tr>
<td>2</td>
<td>R13-23</td>
<td>22.4</td>
<td>4</td>
<td>Overlay 40mm</td>
<td>2004</td>
<td>9.7</td>
<td>32.5</td>
</tr>
<tr>
<td>3</td>
<td>N521-5</td>
<td>45.2</td>
<td>2</td>
<td>Widen 4 lane</td>
<td>2004</td>
<td>41.3</td>
<td>73.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>N1-6</td>
<td>30.2</td>
<td>4</td>
<td>Resealing</td>
<td>2005</td>
<td>8.2</td>
<td>8.2</td>
</tr>
<tr>
<td>2</td>
<td>N7-9</td>
<td>17.8</td>
<td>3</td>
<td>Overlay 60mm</td>
<td>2005</td>
<td>9.2</td>
<td>17.4</td>
</tr>
<tr>
<td>3</td>
<td>F2140-8</td>
<td>56.1</td>
<td>1</td>
<td>Reconstruct</td>
<td>2005</td>
<td>34.9</td>
<td>52.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Project Appraisal

- **Project types**
  - New construction, upgrading
  - Reconstruction, resealing
  - Widening, lane addition
  - Non-Motorised Transport lanes

- **Economic indicators**
  - Net Present Value (NPV)
  - Economic Rate of Return (ERR)
  - Benefit Cost Ratio (BCR), NPV/C
  - First Year Rate of Return (FYRR)
## Economic Decision Criteria

<table>
<thead>
<tr>
<th></th>
<th>NPV</th>
<th>IRR(^3)</th>
<th>NPV/C</th>
<th>FYRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project economic validity</td>
<td>V.Good</td>
<td>V.Good</td>
<td>V.Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Mutually exclusive projects</td>
<td>V.Good</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Project timing</td>
<td>Fair</td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Project screening (^1)</td>
<td>Poor</td>
<td>V.Good</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Under budget constraint (^2)</td>
<td>Fair</td>
<td>Poor</td>
<td>V.Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>

### Notes:

1. check for robustness to changes in key variables (sensitivity analysis)
2. with incremental analysis
3. IRR may be indeterminate with NONE or MANY solutions.
Project Level Outputs

- Sensitivity analysis results
  - Scenario analysis
  - Road condition indicators
  - Road user cost details
  - Energy & emissions
HDM-4 as a Decision Support Component of Road Management Systems
Components of a Road Management System

- Data Collection
- Database
- Decision Support
- Management Information

Inventory Condition Structures Traffic Furniture Unit Costs Standards

RDBMS (RIMS)

Life Cycle Analysis (HDM-4)

Standard & Custom Reports
Management Information

Starting point in implementation

“Must be relevant to the decision-making process with little or no further processing”

Determine:

- Purpose/use of the management information
- Correspondence with management structure
- Key reports to be produced by Decision Support system
- Reports Formats
Decision Support System

- Transparency of analysis
- Life cycle analysis capable of:
  - Short, Medium & Long term analyses
  - What-if analysis, Performance indicators
- Management **must** understand analysis framework
- Availability of local technical expertise
- Default data sets

HDM-4
HDM Technology Set

Knowledge Base

Models

Software
Conclusions – Why HDM-4?

- Transparency of analysis
- Economic analysis capable of:
  - Short, Medium & Long term analyses
  - What-if analysis
- Internationally accepted analysis framework
- Availability of technical expertise
- Local calibration
Web sites:

http://hdm4.piarc.org
http://www.bham.ac.uk