A tool for investigating road investment choices

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Sponsors:
- World Bank
- Dept for International Development
- Asian Development Bank
- SNRA & Others

In progress since 1993 comprising
- technical studies (1993~1997)
- software development and testing (1996~1999)
- PIARC leading the implementation phase (1999 ~ )
Objectives:

Economic basis for selecting investment alternatives

Road standards

Pavement standards

Alignments
Objectives:

Minimise Road Agency and Road User Costs

Non-motorised transport facilities

Traffic congestion

Vehicle emissions

Travel times

Transport costs

Road accidents
Predicts road network performance as a function of:

- Traffic volumes and loading
- Road pavement strength
- Maintenance and improvement standards
- Environment

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 Maintenance & Improvement

- Affects long term pavement performance
- Funding requirements depend on specified maintenance standards & unit costs

![Diagram showing the relationship between roughness, rehabilitation, maintenance standard, and pavement performance over time or traffic loading.](image)
Road User Effects

- Vehicle operating costs
  - fuel, oil, tyres, parts consumption
  - vehicle utilisation & depreciation
- Travel time
  - passengers
  - cargo
- Road accidents
- Energy consumption
- Vehicle emissions & noise
Impact of Road Condition

<table>
<thead>
<tr>
<th>Road Condition (IRI)</th>
<th>Good</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pickup/utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Truck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rickshaw</td>
<td></td>
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</tr>
</tbody>
</table>
EXOGENOUS BENEFITS AND COSTS

- Due to other road related investments
  - diversion routes, bridge repair, slope stabilisation, etc.
- Development benefits
  - agricultural, commercial, industrial, etc.
- Accessibility benefits
- Environmental impacts (pollution, ecological)
- Social & resettlement impacts
The Role of HDM-4 in Road Management
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
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
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
## Road Network Matrix

### Length of Roads (km)

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Cond.</th>
<th>Flexible Pavement</th>
<th>Gravel Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>Med.</td>
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<tr>
<td><strong>Trunk</strong></td>
<td>G</td>
<td>76</td>
<td>283</td>
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<tr>
<td></td>
<td>F</td>
<td>485</td>
<td>762</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>911</td>
<td>420</td>
</tr>
<tr>
<td><strong>Feeder</strong></td>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td>G</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P</td>
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</table>
### Expenditure Strategy Analysis

#### Long term budget forecasts

<table>
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<tr>
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<th>4</th>
<th>5</th>
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<tr>
<td>Maintenance</td>
<td>128</td>
<td>133</td>
<td>135</td>
<td>135</td>
<td>136</td>
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<tr>
<td>Rehabilitation</td>
<td>99</td>
<td>77</td>
<td>79</td>
<td>83</td>
<td>86</td>
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<td>Improvement</td>
<td>56</td>
<td>88</td>
<td>87</td>
<td>91</td>
<td>90</td>
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<td>Development</td>
<td>45</td>
<td>78</td>
<td>66</td>
<td>36</td>
<td>49</td>
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<tr>
<td>Bridges</td>
<td>34</td>
<td>37</td>
<td>40</td>
<td>39</td>
<td>40</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>362</strong></td>
<td><strong>413</strong></td>
<td><strong>407</strong></td>
<td><strong>384</strong></td>
<td><strong>401</strong></td>
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</tbody>
</table>
Effect of budget levels

Primary Roads

Average Roughness (IRI)

Target = 3.5 IRI

Annual Budget

$10m

$15m

$20m

2000 2001 2002 2003 2004 2005 2006
Optimal budget requirements

US $ m/year

2000 2001 2002 2003

- Development
- Improvement
- Periodic
- Routine
Pavement condition by road class (2001)
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
## Work Program

<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>
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<tr>
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<td>4</td>
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<tr>
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<td>N4-16</td>
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<td>3</td>
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<td>Reconstruct</td>
<td>2002</td>
<td>34.9</td>
<td>52.3</td>
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</table>
Project Appraisal

Project types

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

Calculated economic indicators

- Net Present Value (NPV)
- Economic Rate of Return (ERR)
- Benefit Cost Ratio (BCR)
- First Year Rate of Return (FYRR)
Project Level Outputs

- Sensitivity analysis results
  - Scenario analysis
  - Road condition indicators
  - Road user cost details
  - Energy & emissions
Multi Criteria Analysis
Multi Criteria Analysis

- Method: Analytic Hierarchy Process (AHP)
- Criteria – defined/selected by the user
- Relative weights: user-defined for the criteria selected
- Determine the Performance indices for each road investment alternative
- Calculate ranking vectors (or scores) for the investment alternatives
Criteria Considered

- **Economic**
  - Road Agency Cost
  - Road User Cost
  - Net Present Value

- **Safety**

- **Environmental**

- **Delay due to congestion (VCR)**

- **Comfort (riding quality)**

- **Energy use**

- **Social concerns (can be disaggregated at the micro level analysis)**

- **Political concerns**
Social/Political Concerns

Rating of the net effect of each alternatives (PI)

1. Major dissatisfaction
2. Minor dissatisfaction
3. Indifference
4. Minor satisfaction
5. Major satisfaction
Application Levels

- **Strategic planning** – using the scores to:
  - Determine total needs for different road categories (primary, secondary, feeder, urban)
  - Allocate budget between road classes
  - Allocate budget between regions
  - Allocate budget between works types

- **Work programming** – prepare multi year work programmes under budget constraints using the ranking vectors calculated

- **Project analysis** – for each road section select investment alternatives with the highest score
Optimal budget allocations

US $ m/year.

- Primary
- Secondary
- Feeder

HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT
# Work Program

<table>
<thead>
<tr>
<th>Rank</th>
<th>Priority Road</th>
<th>Length (km)</th>
<th>Province or District</th>
<th>Road Work</th>
<th>2000 Cost $m</th>
<th>2001 Cost $m</th>
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<td>1</td>
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<td>0.217</td>
<td>R.M.</td>
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<td>R.M.</td>
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<td>R.M.</td>
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<td>R.M.</td>
<td>0.202</td>
<td>RECON</td>
</tr>
</tbody>
</table>

Note: RM = Routine Maintenance
Implementation
Some Country Experience

- Russia
- Bangladesh
- Armenia
- Estonia
- Slovenia
- Papua New Guinea
- Thailand
- Brazil
- Tanzania
- Zimbabwe

- Australia
- New Zealand
- Sweden (benchmark)
- South Africa
- Finland
- Fiji
- Namibia
- Ukraine
- Lebanon
- Czech Republic
- Scotland
- Malaysia
- Ghana
Conclusions

- HDM-4 is based on a well established economic analysis framework
- Models derived from large scale field experiments conducted world-wide
- International standard tool for road sector planning and management
- Provides a common framework for analysis of road management options
- International technical support behind HDM-4