Introduction and Applications
The HDM-4 Model

• Analytical tool for engineering and economic assessment of
  - road investments and maintenance
  - transport pricing and regulation

• Physical and economic relationships derived from extensive research on road deterioration, the effects of maintenance activities, and vehicle operation and user costs
International Collaboration

• 1969-1995 – HDM-III
  - Collaborative international studies
    World Bank & MIT, LCPC, TRRL, UNDP
  - Governments of Kenya, Brazil, Caribbean, India
  - $20 million data collection in
    4 field studies

• 1995-2005 – HDM-4 version 1.0 to 1.3
  - International sponsors, PIARC
  - Redesign of functions and software
  - Focus on road agency usage

• 2006-> HDM-4 version 2.0
  - HDMGlobal International Consortium
    responsible for management as sales
HDM-4 Version 1.0 to 1.3 Implementation Coordination

• In 1998 The World Road Association (PIARC) took responsibility for coordinating the international implementation of the Highway Development and Management System (HDM-4)

PIARC Web: http://hdm4.piarc.org
Email: piarc.hdm4@ibm.net
Fax: 33-1+49 00 02 02
HDM-4 Version 2.0
HDMGlobal Management

• HDMGlobal is an international consortium of academic and consultancy companies that have formed a partnership for the future management of HDM 4. This will be a five-year concession awarded by PIARC commencing June 2005 with exclusive rights for its distribution.

• At the center of consortium is the Highway Management Research Group a UK based association of the University of Birmingham, Atkins and Scott Wilson in partnership with; TRL Ltd also of the UK, ARRB Transport Research Ltd from Australia, ENPC and Scetauroute from France, and ICH of Chile.
The HDM4Global distributor role is to:
• sell the software license and deliver HDM-4 on CD-ROM
• deliver updates on disk or by internet download
• provide first contact support

Website: http://civ-hrg.bham.ac.uk/isohdmd/

E-mail: presses.ponts@mail.enpc.fr or sales@hdmglobal.com.
The HDM-4 Products on CD ROM

- HDM-4 software
- Case study data sets
- HDM Series documents
HDM-4 Series Collection
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<th>Standard</th>
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* per capita GNI of less than USD3,255 equivalent per year
Minimum System Requirements

- Pentium P100 processor (or equivalent)
- 32MB of RAM
- 30MB of hard disk space (for program and documentation)
- 50MB of hard disk space (for storage of run-data)
- Windows 95/98 or NT 4 with Service Pack 6a installed
HDM-4 Technical Improvements

- Pavements
  - Wider range of flexible pavements
  - Rigid pavements
  - More maintenance types
  - Drainage effects
  - Freezing climates effects
- Road Users
  - New vehicle types
  - Characteristics of Modern Vehicles
  - Non-motorized traffic
  - Congestion effects
  - Accidents
  - Emissions & Energy consumption
HDM-4 Software Improvements

- Windows 95/98/NT Environment
  - Easy to use
  - Different levels of input data
- Three Application Modules
  - Project Evaluation
  - Network Programme Evaluation
  - Network Strategic Planning Evaluation
- Better interface with Pavement Management Systems
The HDM Computer Programs

Fortran

- HCM 1970
- HDM-II 1975
- HDM-III 1985
- HDM-III PC 1989
- HDM-Q PC 1995

Clipper / DOS

- HDM Manager 1.0 1991
- HDM Manager 2.0 1993
- HDM Manager 3.0 1995
- HDM Manager 3.2 1999
  Limited Distribution

Windows 95/98/NT

- HDM-4 1.0 2000
- HDM-4 1.3 2002
- HDM-4 2.0 2006
Comparison of Road Agency Alternatives

- Standards / Alternatives
- Policies / Strategies
- Norms / Options

- Paved road alternatives, e.g.:
  - overlay at specified condition or time
  - reseal first and overlay later
  - reconstruct at specified condition or time
  - do nothing or do minimum (patching)
  - widen pavement at specified time or V/C
  - improve alignment or add lane

- Unpaved road alternatives, e.g.:
  - grading every 180 days
  - upgrade to paved standard at time or condition
Evaluation of Alternatives

- Economic evaluation
- Technical evaluation
- Institutional evaluation
- Financial evaluation
- Commercial evaluation
- Social evaluation
- Environmental evaluation
Transport Benefits

- Reduce vehicle operating cost
- Savings in time of passengers and cargo
- Reduction of accidents
- Stimulate regional development
- Increase the comfort and convenience
- Better national integration
- National security
- Greater self-sufficiency
- Equal distribution of income
- Prestige of the country
The Beginning, 1969

- More than 10,000 million dollars are spent on the highway sector each year in developing countries. The cost borne by the road-using public for vehicle operation are typically 8 to 10 times greater.

- In Europe and North America:
  - high traffic volumes
  - high values attached to travel time savings
  - relatively abundant capital resources

- In developing countries:
  - traffic levels often much lower
  - values given to travel time savings are far lower
  - acute shortage of financial resources
Pavement Management Approaches

- Crisis-oriented approach: highway facilities are operated with little or no maintenance until obstructions occur, then extensive restoration and reconstruction work is needed.

- Condition-responsive/financial approach: physical standards are set in relation to:
  a) perceived technical requirements,
  b) acceptable service levels,
  c) received budget.

- Technical-economic efficiency approach: functional and technical standards are selected to minimize total road transport costs to society.
Basis for Investment Decisions – Technical-economic Efficiency

- Current Condition
- Deterioration Prediction
- Remaining Service Life

- Current Condition
- Deterioration Prediction
- Maintenance Effects
- Vehicle Operating Costs

Worst First?

Overall Index

Terminal Life or Condition Limit?

Benefits to Society?
Total Society Costs

= ROAD AGENCY COSTS
  Construction
  Maintenance

+ ROAD USER COSTS
  Vehicle operation
  Passenger and cargo time
  Accidents
Total Society Costs

- Road User Costs
- Road Agency Costs
- Improve Standard
Minimizing Consumption of Resources

Consumption of Resources \( \times \) Unit Costs = Total Society Costs
Financial & Economic Unit Costs

- Financial Prices
  - Market Prices

- Economic Prices
  - Shadow Prices
  - Social Prices

Do not reflect the real scarcity value of the inputs

Developing Countries
- Government Controls
- Taxes
- Subsidies
- Regulations
- Rapid Inflation
- Overvaluation of Domestic Currency
Primary Features of HDM-4

• Simulates deterioration and maintenance of paved and unpaved roads, in physical condition and quantities, for strategies defined by the user

• Simulates road user costs (speeds and consumption of physical resources)

• Determines time-streams of road agency, road user costs, and net benefits

• Computes economic indicators
Road User Costs Model

- Road Geometry, Condition
- Driver, Traffic Flow
  - Vehicle Characteristics
    - SPEED
      - Fuel & Lubricants
      - Tire
      - Maintenance Parts & Labor
      - Crew Time
      - Depreciation & Interest
      - Passenger & cargo time
Paved Road Deterioration Model

Moisture, Temperature Aging

Traffic, Loading

Pavement Materials, Thickness

Cracking

Ravelling

Potholing

Rutting

Roughness
Vehicle Operating Costs

VOC per vehicle-km ($)

Roughness (IRI)

Car
Truck
Articulated Truck
HDM-4 Limitations

• The model accepts but does not perform network traffic assignment

• Limited estimation of environmental impacts such as air or noise pollution, and not costed internally

• Only partially applicable to urban traffic conditions – through acceleration variance

• Option for evaluating cement blocks and cobblestone pavements not yet implemented
HDM-4 Applications

- Project Justification
- Program Formulation
- Maintenance Needs Forecasting
- Network Analysis
- Technical Standards
- Vehicle Policies
Project Justification

A Gravel Road

Current Policy
- Gravel resurfacing when thickness of gravel is less than 50mm
- Routine maintenance
- Grading every 90 days

Proposed Project
- Upgrade the road to a paved standard
- After the upgrading, routine maintenance, patching 100% of the potholes, and resealing when damaged area > 20%
Comparison of Alternatives

- Evaluation Period = 20 years
- Discount rate = 12.00%

<table>
<thead>
<tr>
<th>Length (km)</th>
<th>Construction Costs</th>
<th>Road User Costs</th>
<th>Total Costs</th>
<th>Net Present Value</th>
<th>Internal Rate of Return (%)</th>
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<td>26.2</td>
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Is the project economically justified?
Program Formulation

A Gravel Road

- Grading every 180 days
- Grading every 90 days
- Grading every 60 days
- Grading every 30 days
- Grading every 15 days
- Grading every 7 days
- Upgrade in 2001
- Upgrade in 2002
- Upgrade in 2003
- Upgrade in 2004
Project Economic Efficiency Frontier

Which is the optimal strategy?
Maintenance Needs Forecasting

A Paved Road in Good Condition

- Routine Maintenance
  Reconstruction when IRI > 11.0

- Routine Maintenance
  Patching 100% of potholes
  Reconstruction when IRI > 11.0

- Routine Maintenance
  Patching 100% of potholes
  12 mm Resealing when damage is > 30%
  Reconstruction when IRI > 11.0

- Routine Maintenance
  Patching 100% of potholes
  4 cm overlay when IRI is > 4.0

- Routine Maintenance
  Patching 100% of potholes
  8 cm overlay when IRI is > 4.0
Roughness Progression

![Graph showing roughness progression over years with different treatment types (BASE, P100, RE30, OS40, OD40).]
Efficiency Frontier

What will be the future maintenance needs?
Network Analysis

- What are the resources needed to maintain and develop the network?

- How should the agency allocate the resources needed?

- What program should be implemented in case of budgetary constraints?
### Budgetary Constraints

#### Road Network

- A.C.
  - L
  - M
  - H

- Resource Constraints

- Optimization Module

- Optimal Program under Budgetary Constraints

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<tr>
<th>Program without Budgetary Constraints</th>
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Diagnostic of the Network Condition

Roughness in 1998

- > 5.0 IRI: 64%
- 3.5 < IRI < 5.0: 8%
- < 3.5 IRI: 28%
Diagnostic of Road User Costs

Typical Road User Costs (Rs/vehicle-km)

Roughness (IRI)

- Car
- Wagon
- Bus
- S. Truck
- M. Truck
- H. Truck
Diagnostic of Agency Costs

Typical Periodic Maintenance Costs

- 30 cm Gran. Base / 25 cm AC
- 30 cm Gran. Base / 20 cm AC
- 30 cm Gran. Base / 15 cm AC
- 25 cm Overlay
- 20 cm Overlay
- 15 cm Overlay
- 13 cm Overlay
- 7.5 cm Overlay
- 5 cm Overlay
- 30 mm TST
- 25 mm DST

Financial Costs (Million Rs/km)
## Diagnostic of Road Classes

### Primary Network

<table>
<thead>
<tr>
<th>Surface</th>
<th>Traffic (ADT)</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Very Poor</th>
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### Solution Catalog per Budget Level

#### Primary Network

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#### Periodic Operations (Billion Rs)

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#### Net Present Value

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Consequences to Society

Society Net Benefits Present Value (Billion Rs)

Periodic Expenditures (Billion Rs/year)
Consequences to the Network

Scenario: 6 Billion Rs per year

Year

Network Condition (%)

Average Roughness (IRI)

- Poor
- Fair
- Good
- Avg. IRI

1998 1999 2000 2001 2002 2003 2004
Consequences to the Agency

Budget Scenarios (Billion Rs per year)

Periodic Expenditures per Period (Billion Rs.)

- Period: Years 7 to 20
- Period: Years 1 to 6
Consequences to the Users

Network Road User Costs (Billion Rs)

Year

1999 2000 2001 2002 2003 2004

Network Road User Costs (Billion Rs)

Savings: 152 Billion Rs

6 Billion Rs per Year Case

Without Project Case
Support Definition of Budget Level

Average Network Roughness (IRI)

Year

1998 1999 2000 2001 2002 2003 2004

Budget Scenarios (Rs B per year)

1.0
2.0
3.0
4.5
6.0

6.0
4.5
3.0
2.0
1.0
### Support for Allocation of Resources

**Works for Scenario: 6 Billion Rs per Year**

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<th>Years 1-6</th>
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## Support for Programming of Works

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<th>Cost (B Rs)</th>
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Technical Standards

What is the optimal traffic threshold for paving?
How much road damage is caused by trucks?