



Introduction to HDM-4

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Transport and Development

- ❊ Transport sector is vital for economic & social development
- ❊ Roads constitute the 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



HDM-4 Objectives .

Economic basis for selecting investment alternatives



Road standards



Pavement standards



Alignments



HDM-4 Objectives ..

Minimize Road Agency and Road User Costs



**Non-motorized
transport facilities**



**Traffic congestion
Vehicle emissions
Travel times**

Transport costs

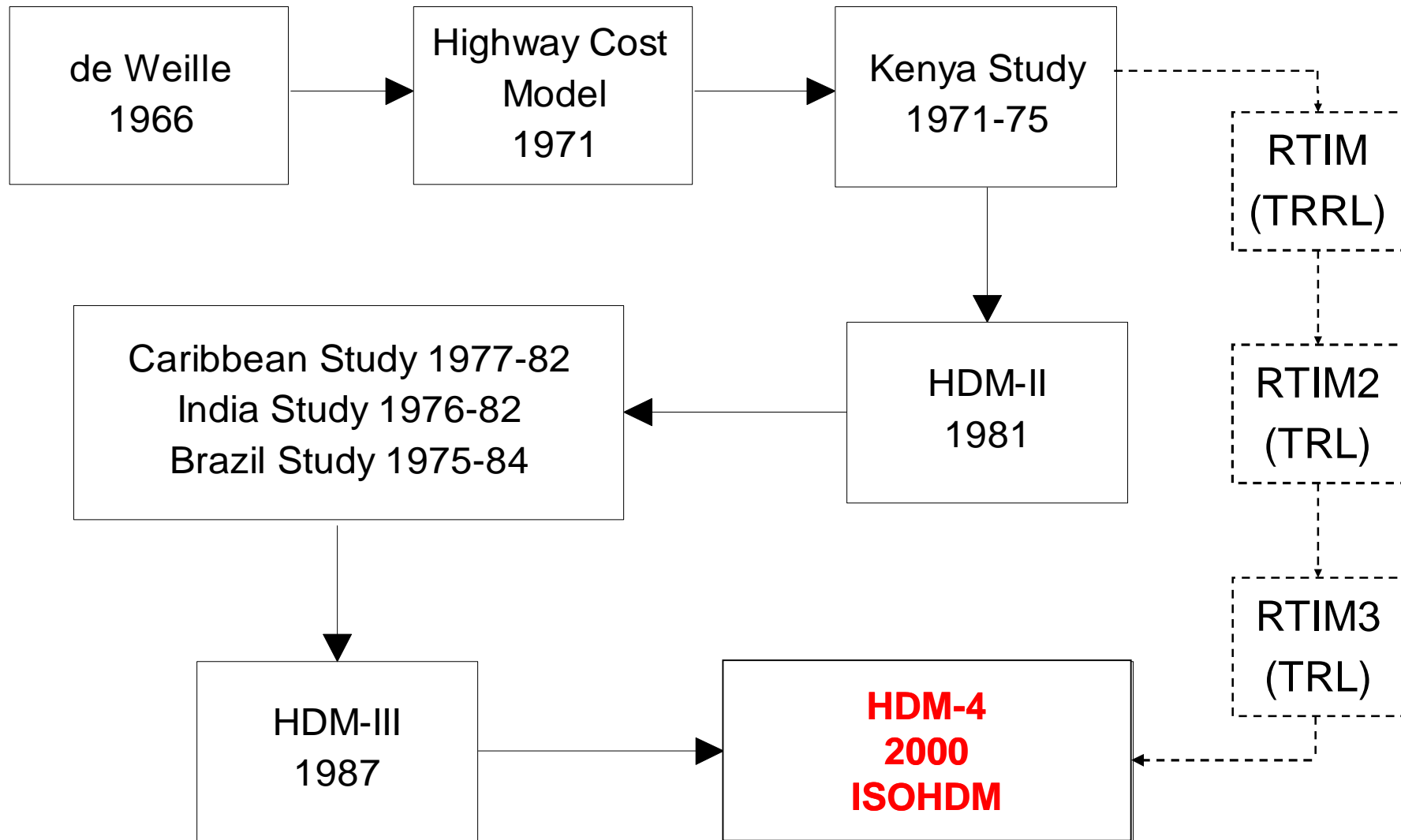


Road accidents





History of the HDM model



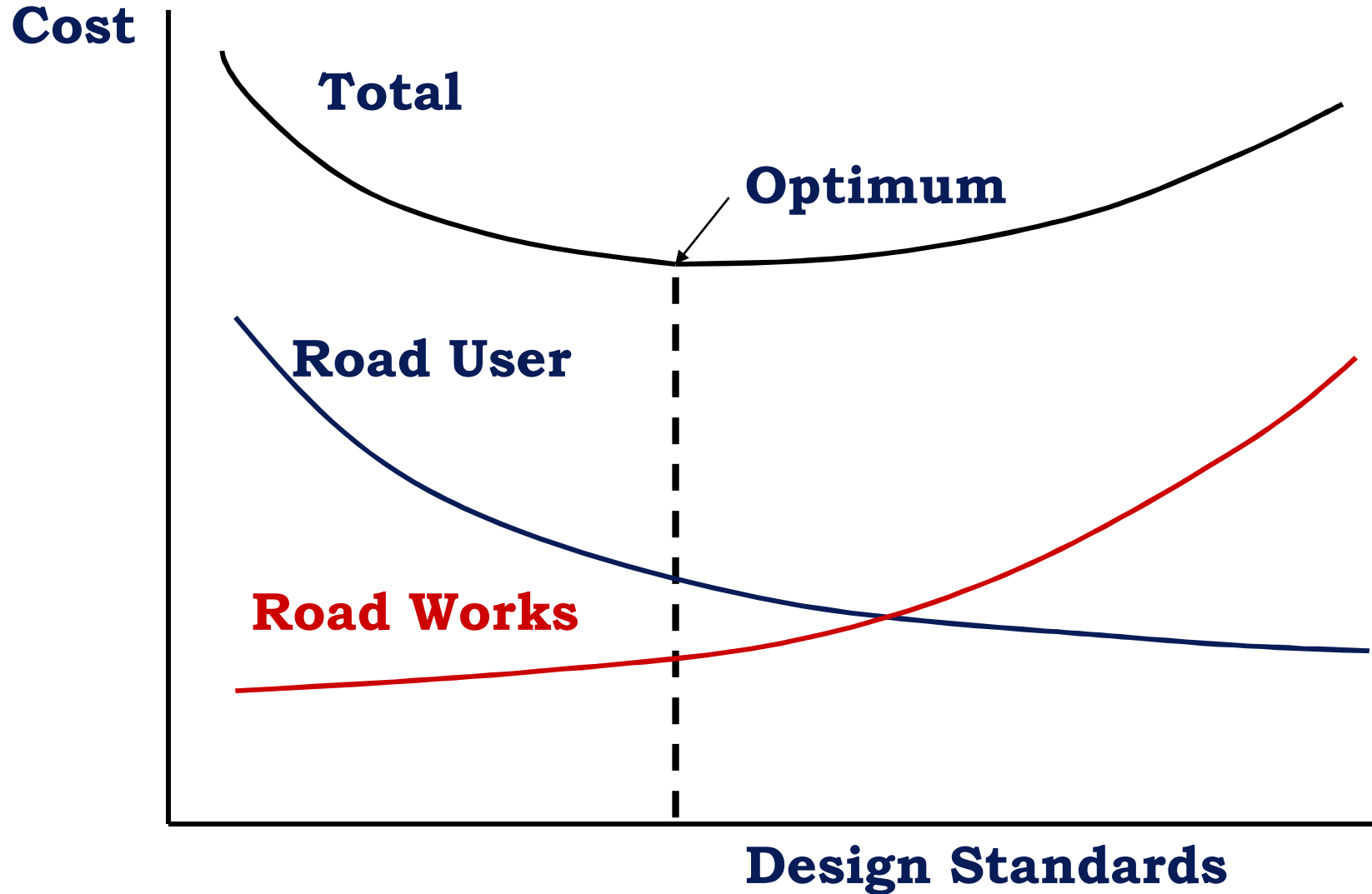


HDM-4 Concept

- 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



Optimum Transport Costs





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



Life Cycle Costs

● Road Agency Costs

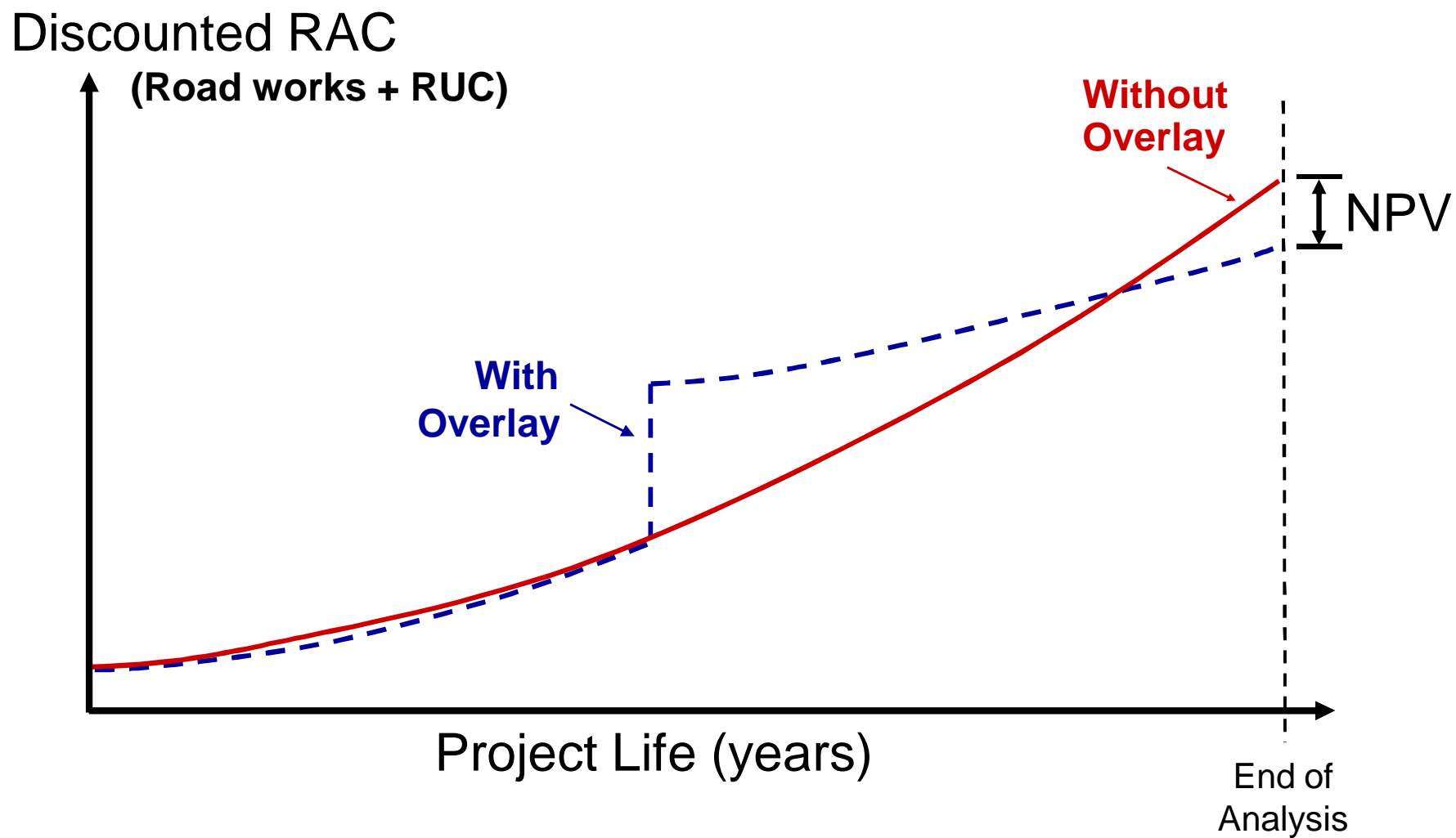
- Management, Operations
- Labor, Equipment, Materials
- Land acquisition
- Maintenance and Rehabilitation

● Road User Costs

- Vehicle operation
- Travel time
- Road accidents



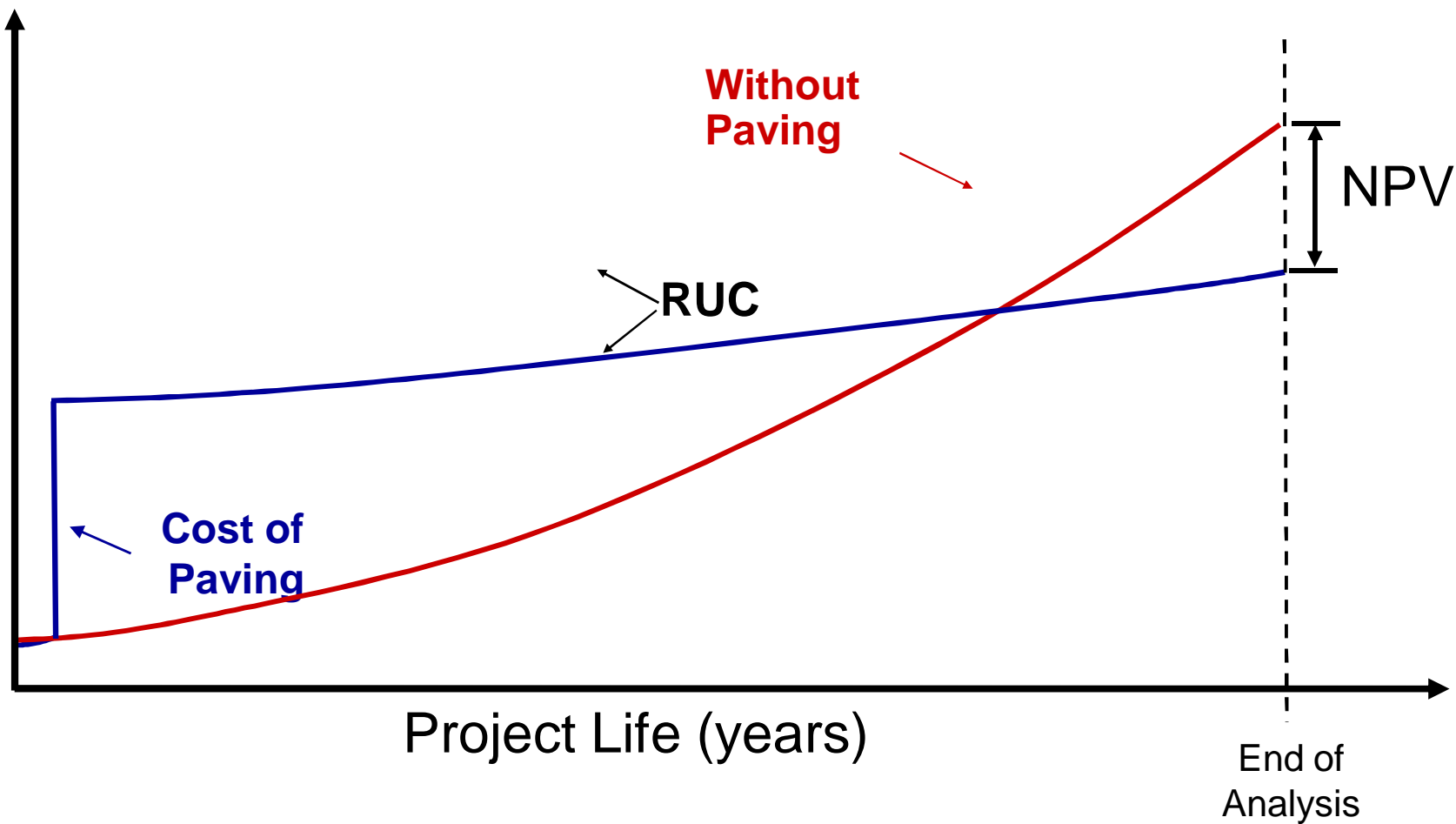
Comparison of Project Alternatives





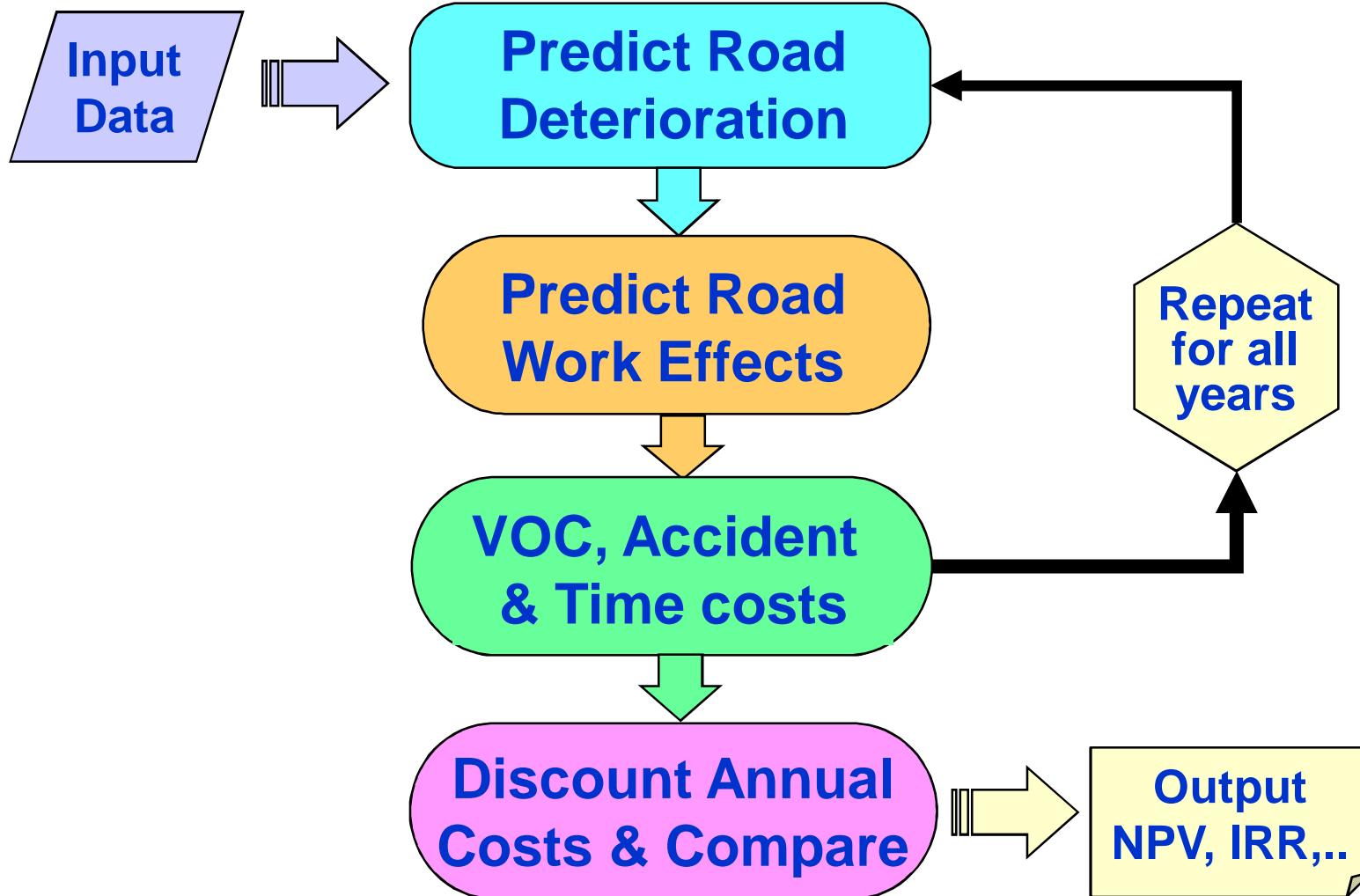
Comparison of Project Alternatives

Discounted RAC





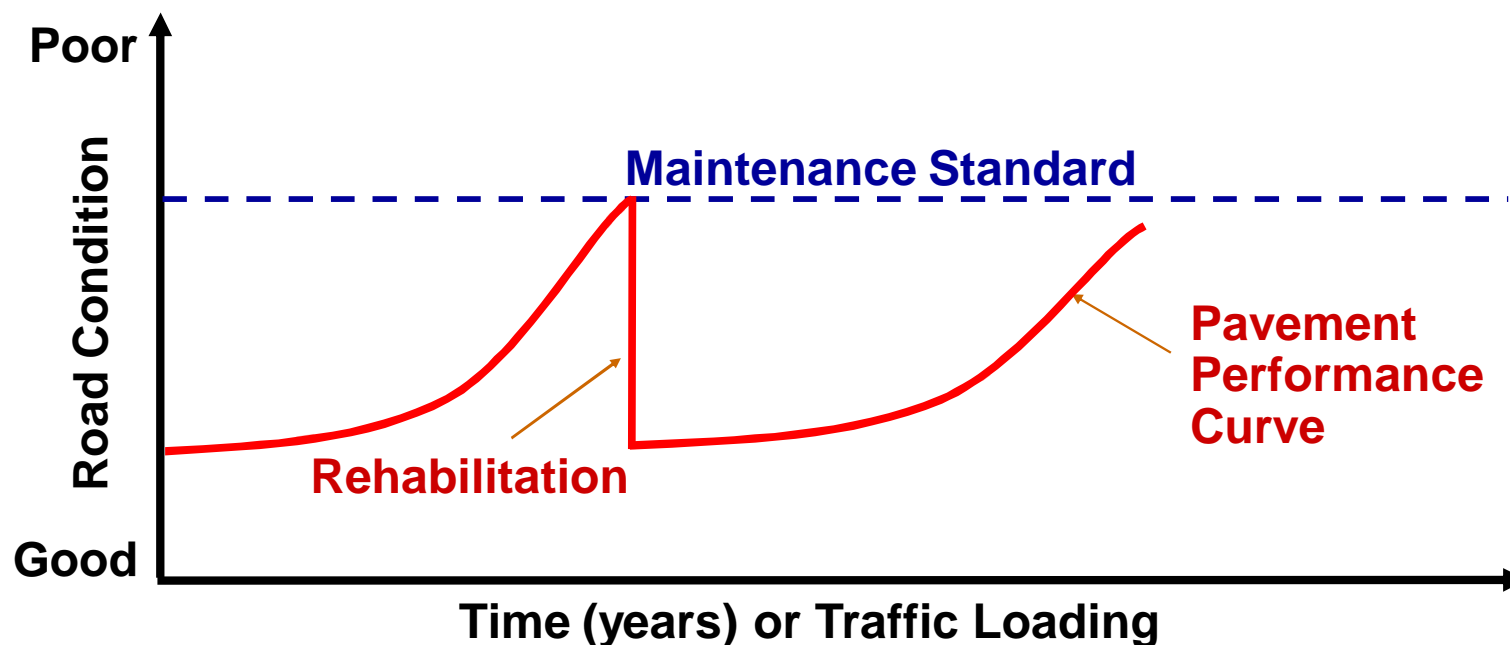
Life Cycle Analysis





Road Deterioration

- ❖ Predict long term pavement performance
- ❖ Predict effects of maintenance standards
- ❖ Calculate annual costs: Road Agency + Road User





Pavement Performance

- Pavement Types modelled:
 - Bituminous (AC, ST, etc.)
 - Unsealed (Gravel, Earth, Sand, etc.)
 - Concrete (JPCP, JRCP, CRCP, etc.)
 - Block (Bricks, etc.)

- Models from pavement performance experiments in:
 - Brazil, Kenya, India, South Africa
 - France, USA, Sweden, Finland, Australia



Principles Of Deterioration Models

- ✿ Models are structured empirical
- ✿ Individual distresses modelled separately
- ✿ Relationships are incremental and recursive
$$dY = K a_0 f(X_1, X_2, X_3, \text{etc})$$
- ✿ Modelled sequentially through to roughness
- ✿ Maintenance intervention at end of each year



Cracking Initiation Model

$$ICA = K_{cia} \{ CDS^2 * a_0 \exp[a_1 SNP + a_2 (YE4/SN^2)] + CRT \}$$

- ❑ ICA time to cracking initiation, in years
- ❑ CDS construction quality
- ❑ SNP structural number of pavement
- ❑ YE4 traffic loading
- ❑ K_{cia} calibration factor
- ❑ CRT effect of maintenance



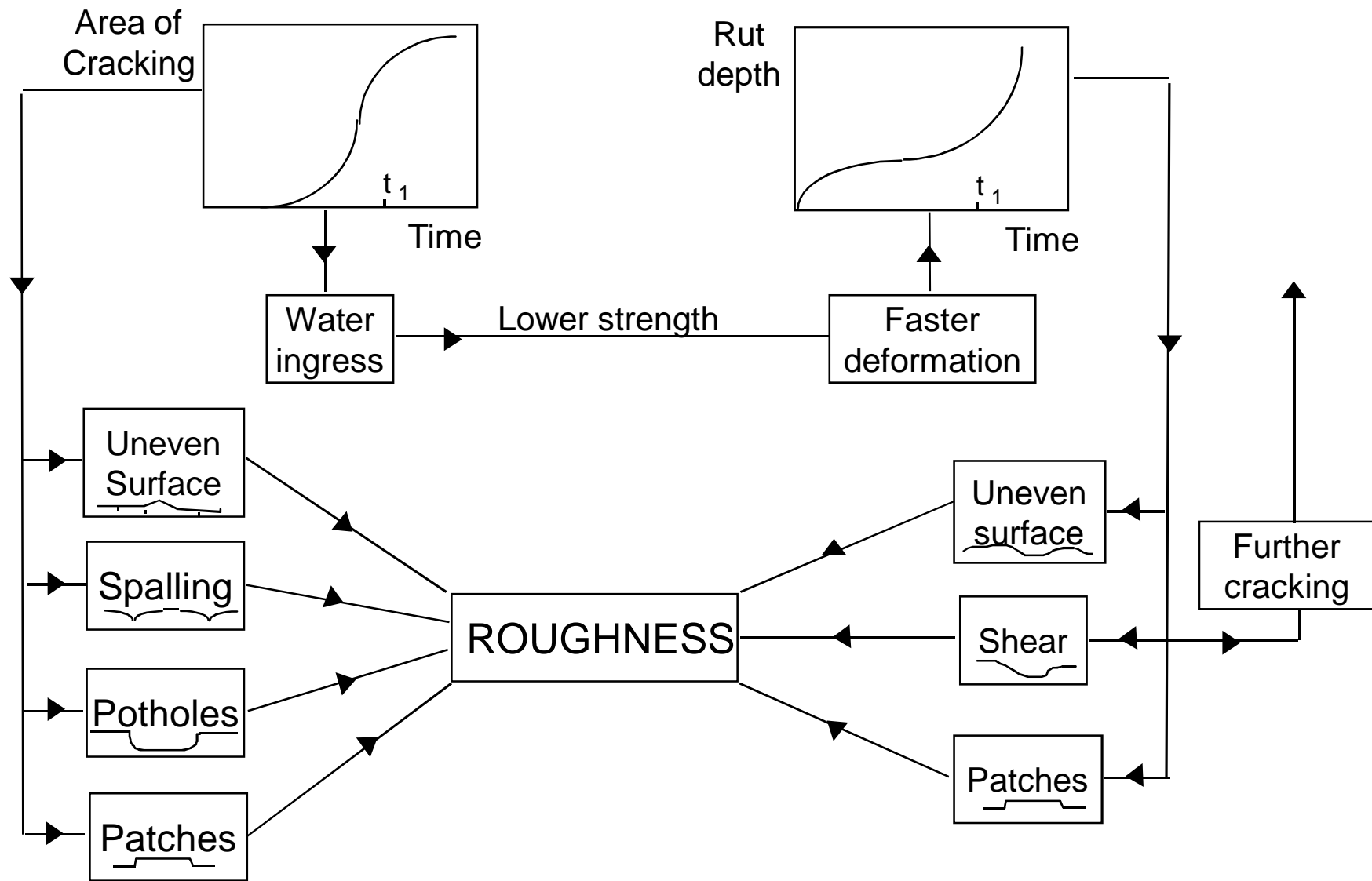
All Cracking Progression

$$dACA = K_{cpa} \left(\frac{CRP}{CDS} \right) z_A [(z_A * a_0 * a_1 * \delta t_A * YE4 * SNP^{a_2} + SCA^{a_1})^{1/a_1} - SCA]$$

- CRP = retardation of cracking progression due to preventive treatment
- Progression of All cracking commences when $\delta t_A > 0$ or $ACA_a > 0$

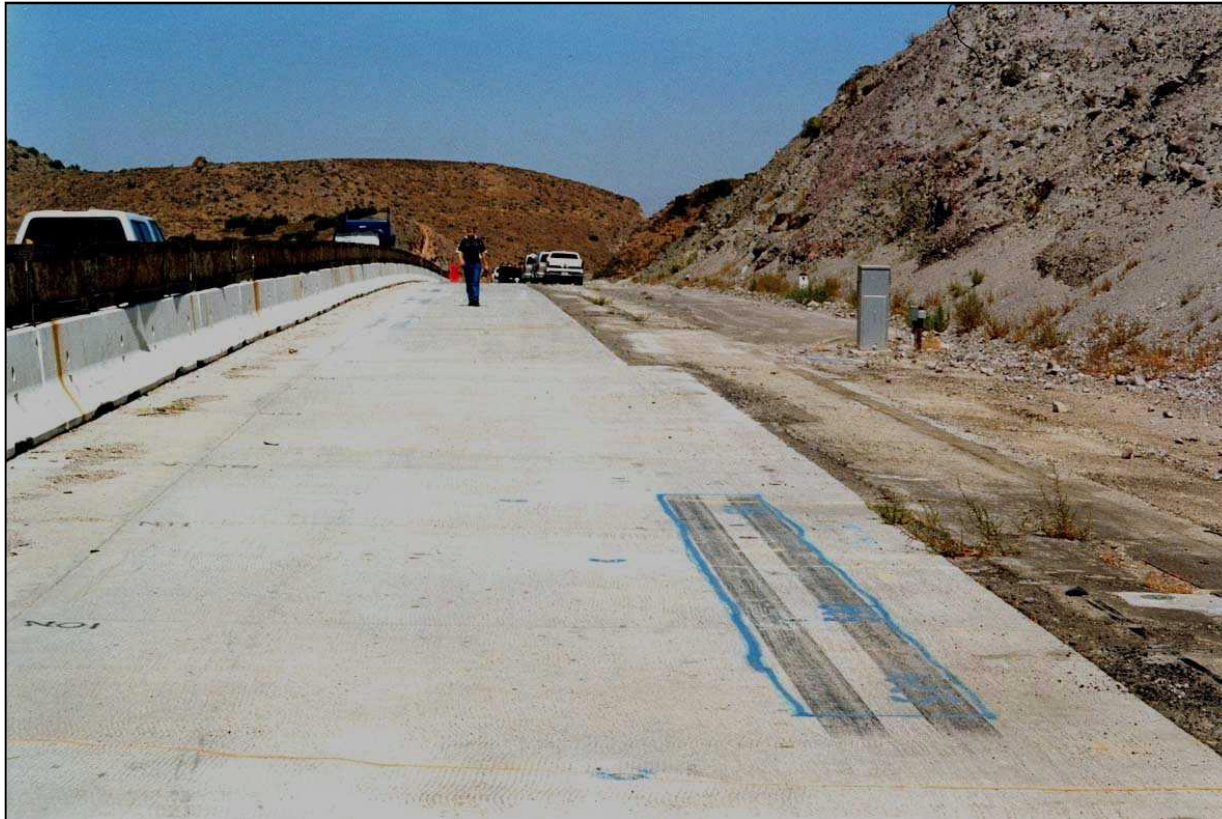


Pavement Deterioration Concept





Concrete Roads



- ⊕ Joint Spalling
- ⊕ Punch outs
- ⊕ Cracking
- ⊕ Faulting
- ⊕ Slab failures
- ⊕ Riding Quality

Models From

⊕ USA

⊕ Chile



Bituminous Pavements

Predicted defects:

- ❑ Cracking
- ❑ Ravelling
- ❑ Edge Break
- ❑ Potholes
- ❑ Riding Quality
- ❑ Skidding





Bituminous Road Deterioration .





Bituminous Road Deterioration ..





Unsealed Roads





Unsealed Road Deterioration ..





Unsealed Road Deterioration ...





Road Work Classification

Preservation

■ Routine

- Patching, Edge repair
- Drainage, Crack sealing

■ Periodic

- Preventive treatments
- Rehabilitation
- Pavement reconstruction

■ Special

- Emergencies
- Winter maintenance

Development

■ Improvements

- Widening
- Realignment
- Off-carriageway works

■ Construction

- Upgrading
- New sections



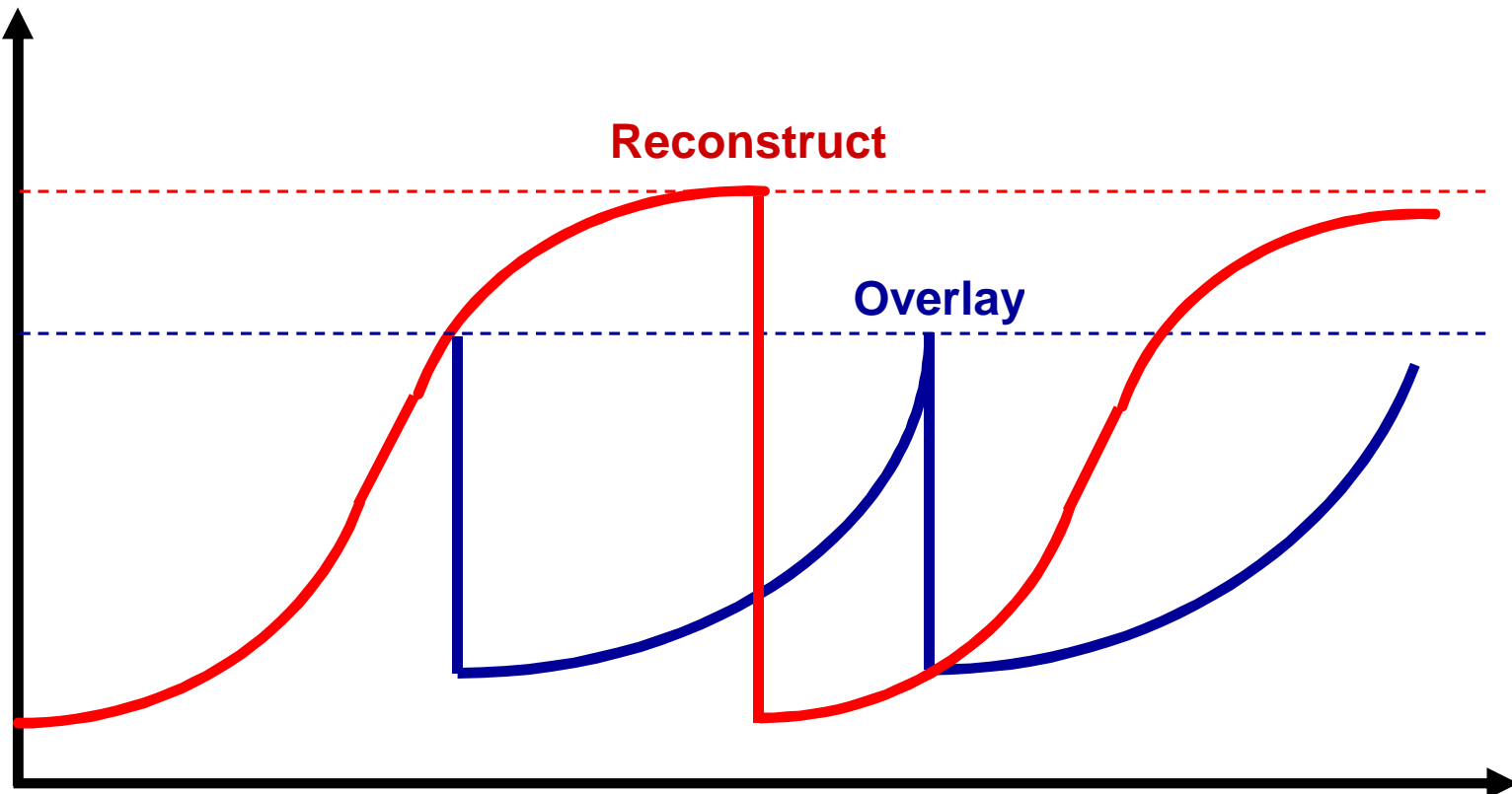
Road Works





Road Work Effects

Condition



Reconstruct

Overlay

Traffic / Time



Road User Effects





RUE Components

- MT Vehicle operating costs (VOC)
- MT Travel time costs (TTC)
- NMT Time and operating costs (NMTOC)
- Accident costs (AC)

$$\mathbf{RUE = RUC + Emissions + Energy + Noise}$$

$$\mathbf{RUC = VOC + TTC + NMTOC + AC}$$



Road User Effects

- Vehicle operating costs
 - fuel, oil, tyres, parts consumption
 - vehicle utilisation & depreciation
- Travel time
 - passengers
 - cargo
- Road accidents
- Non-Motorized Transport
- Energy consumption
- Vehicle emissions & noise



RUE Features in HDM-4

- ✚ Effects of traffic congestion on speed, fuel, tyres and maintenance costs
- ✚ Non-motorised transport modelling
- ✚ Effects of road works on users
- ✚ Traffic safety impact
- ✚ Vehicle emissions impact
- ✚ Vehicle noise impact

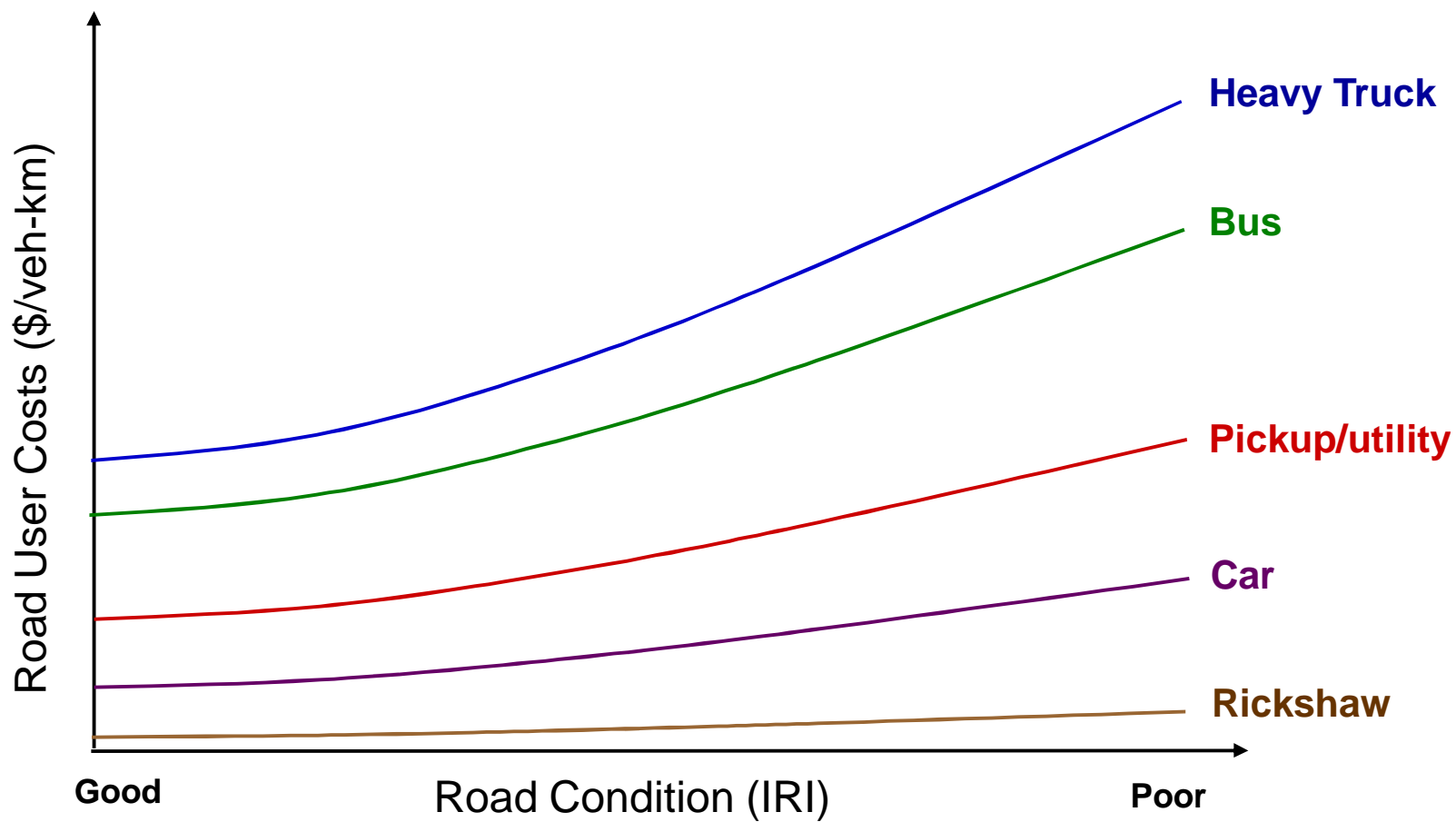


Motorised Vehicles





Impact of Road Condition on VOC





Non-Motorised Transport





Role of HDM-4

Management Function	HDM-4 Application
Planning	Strategy Analysis
Programming	Programme Analysis
Preparation	Project Analysis



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
 - 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

Analysis of entire road networks to determine funding needs and predict performance under budget constraints

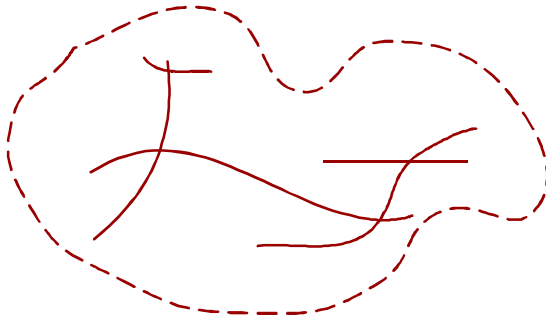
🌐 Objectives:

- ❑ Determine budget allocations for road maintenance and improvement
- ❑ Prepare work programs
- ❑ Determine long term network performance
- ❑ Assess impact on road users



Strategic Analysis Approach

Road Network



Matrix

	G	F	P
H			
M			
L			

Revenues, Sector budgets



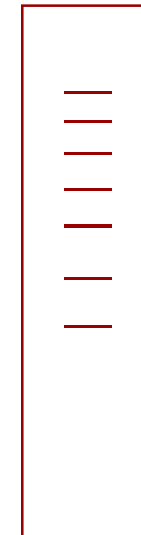
Resource Constraints



Development Candidates



Preservation Evaluation



Optimal Strategy under Budgetary Constraints



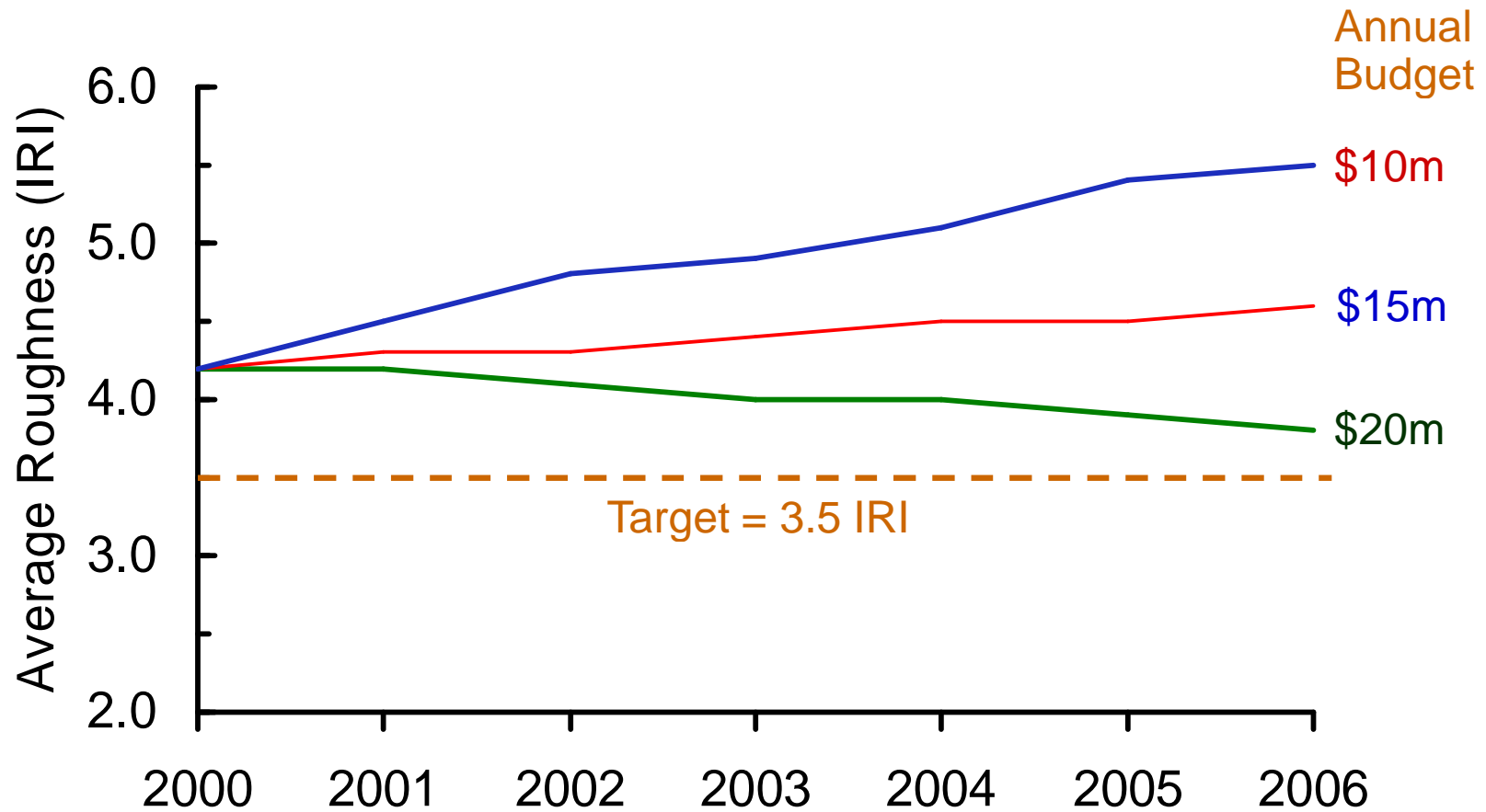
Optimization Module





Effect of budget levels

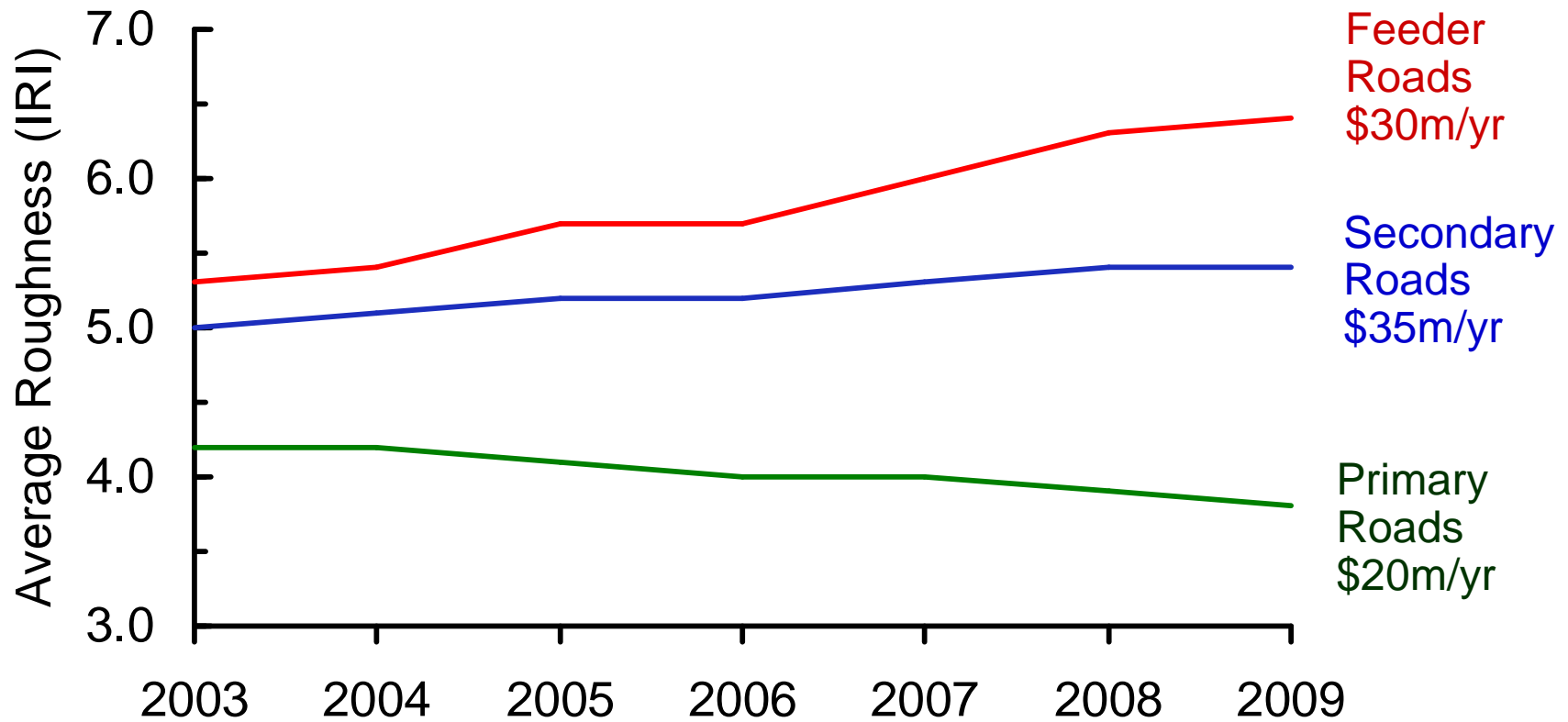
Primary Roads





Road Network Performance

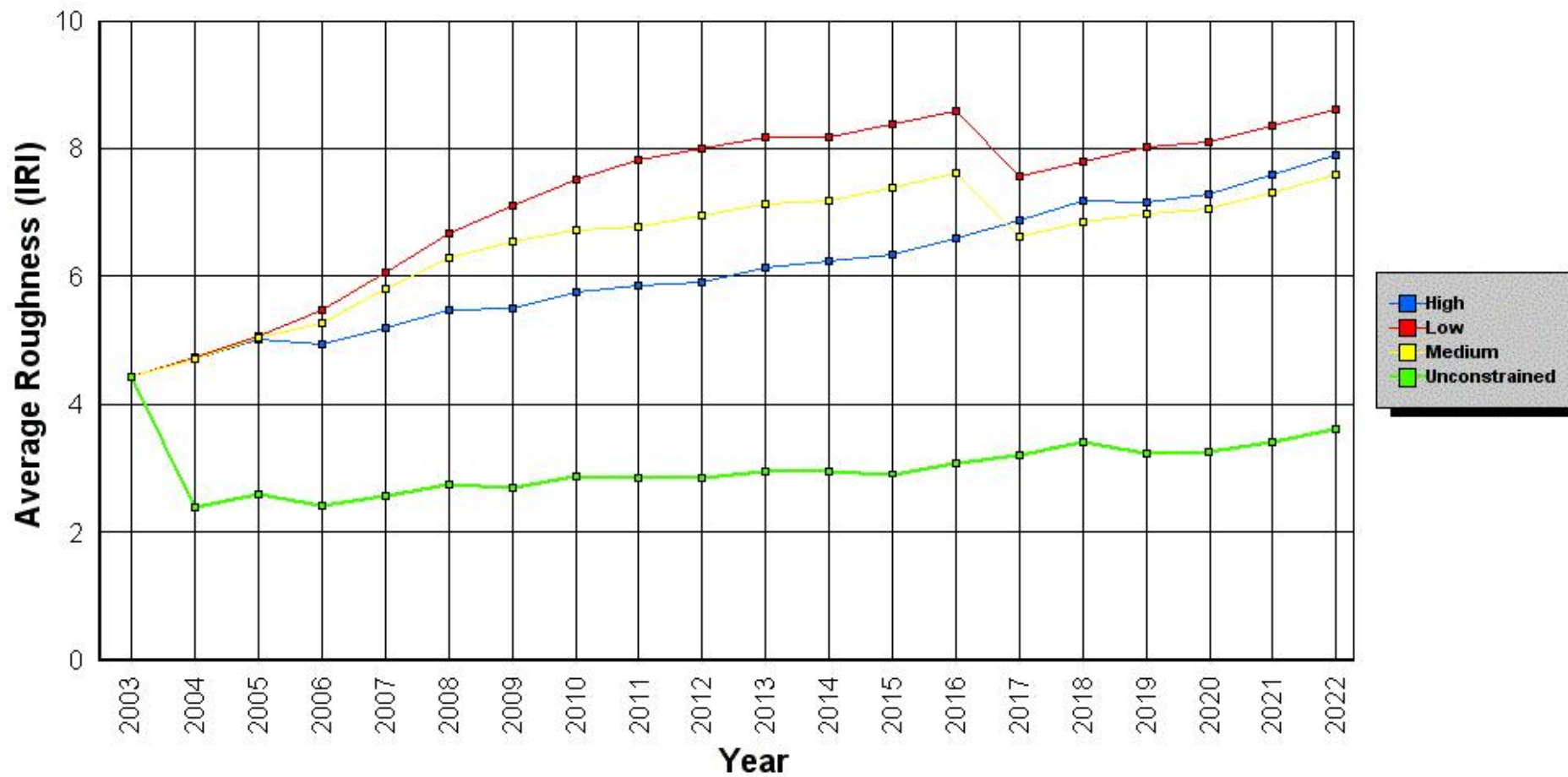
Budget Allocations





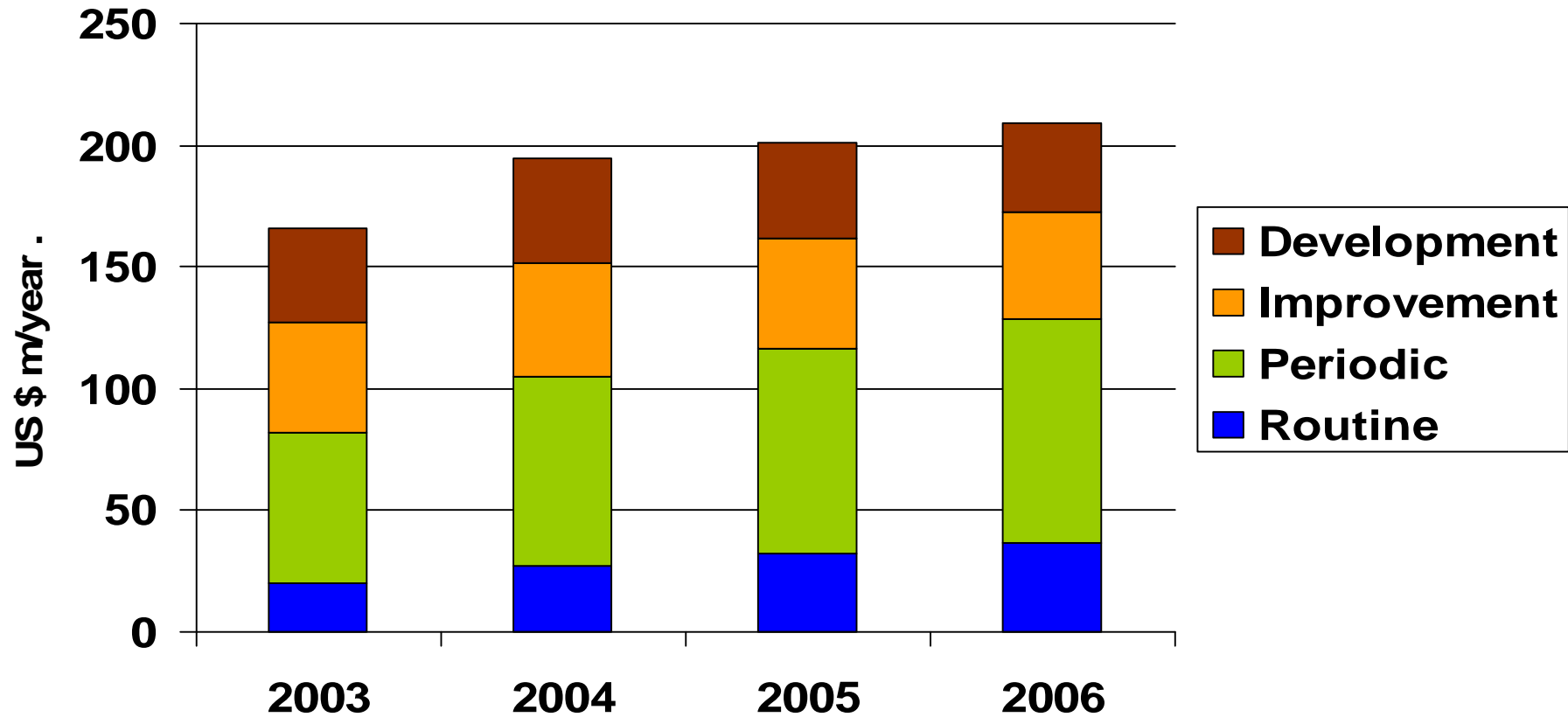
Budget Scenario Analysis

Annual Average Roughness for the network grouped by Budget Scenario (weighted by length)





Optimal budget requirements





Programme Analysis

Preparation of single or multi-year expenditure programs 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



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)



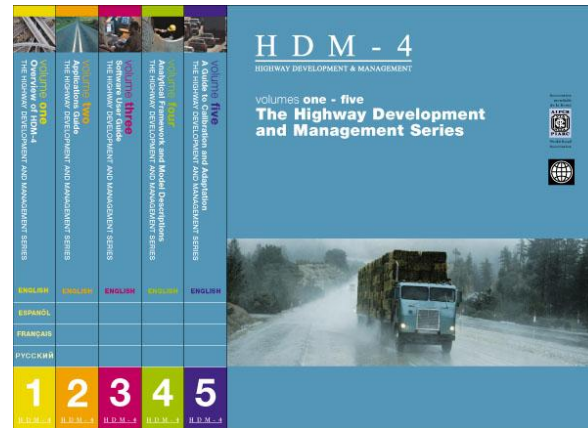
Project Level Outputs

- ✦ Sensitivity analysis results
 - ▣ Scenario analysis
 - ▣ Road condition indicators
 - ▣ Road user cost details
 - ▣ Energy & emissions



HDM Technology Set

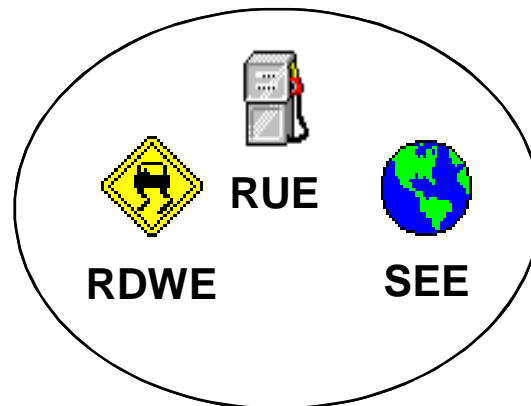
Knowledge Base



Software



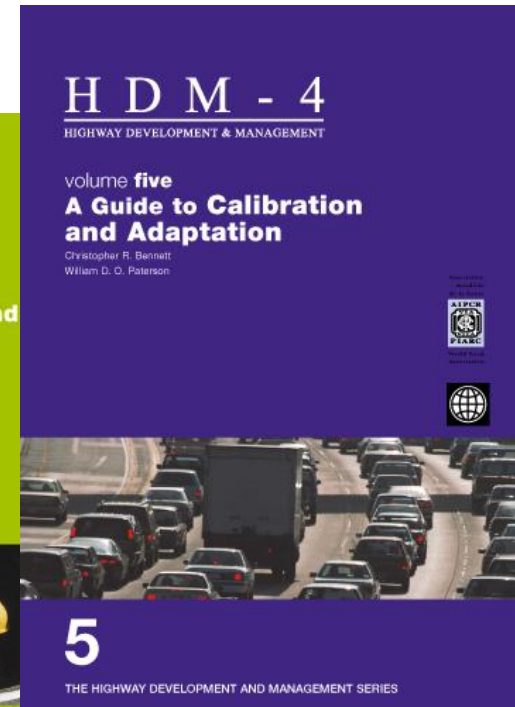
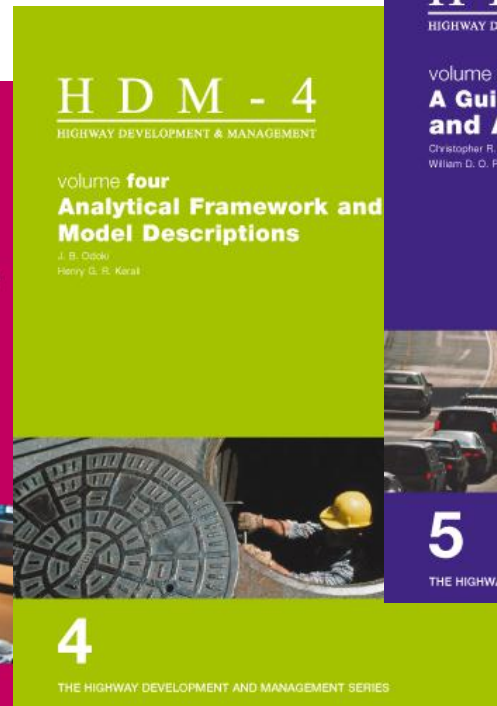
Models



HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT



HDM Series





Conclusions – Why HDM-4?

- Transparency of analysis
- Life cycle 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>