THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD

HDM - 4

HIGHWAY DEVELOPMENT & MANAGEMENT

Road Economic Analysis Tools in RSA

Up to 1994...

SOUTH AFRICAN ROADS BOARD

DEPARTMENT OF TRANSPORT

CHIEF DIRECTORATE NATIONAL ROADS

COST-BENEFIT ANALYSIS OF
RURAL ROAD PROJECTS

PROGRAM CB-ROADS

USER'S MANUAL

ISSUED BY:

THE DIRECTOR-GENERAL
DEPARTMENT OF TRANSPORT
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0102

Since 2000

HDM - 4

HIGHWAY DEVELOPMENT & MANAGEMENT

volume **one**

Overview of HDM-4

Henry G. R. Kerali
J. B. Odoki
Eric E. Stannard

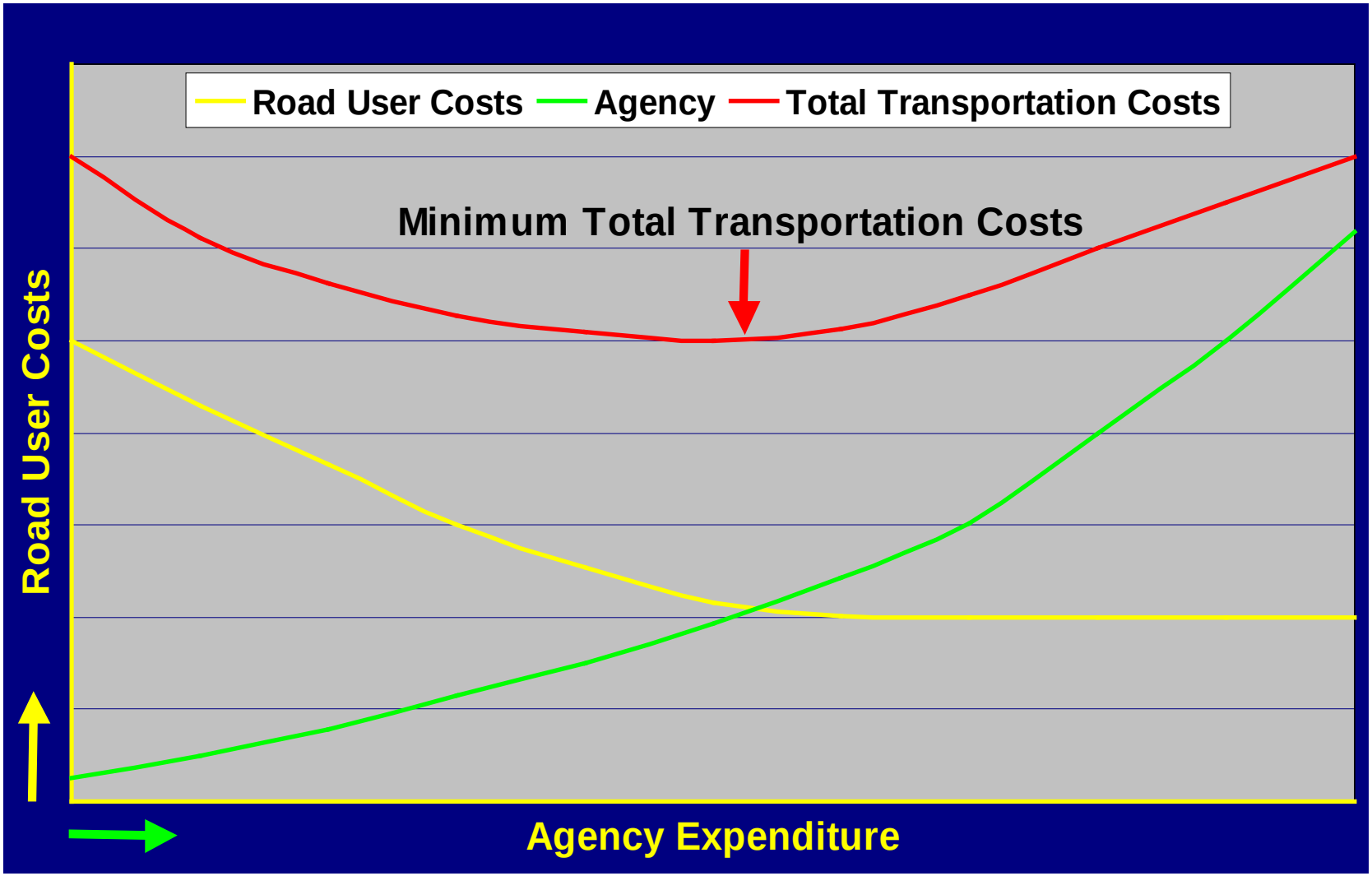
Association mondiale de la Route
AIPCR
PIARC
World Road Association

1

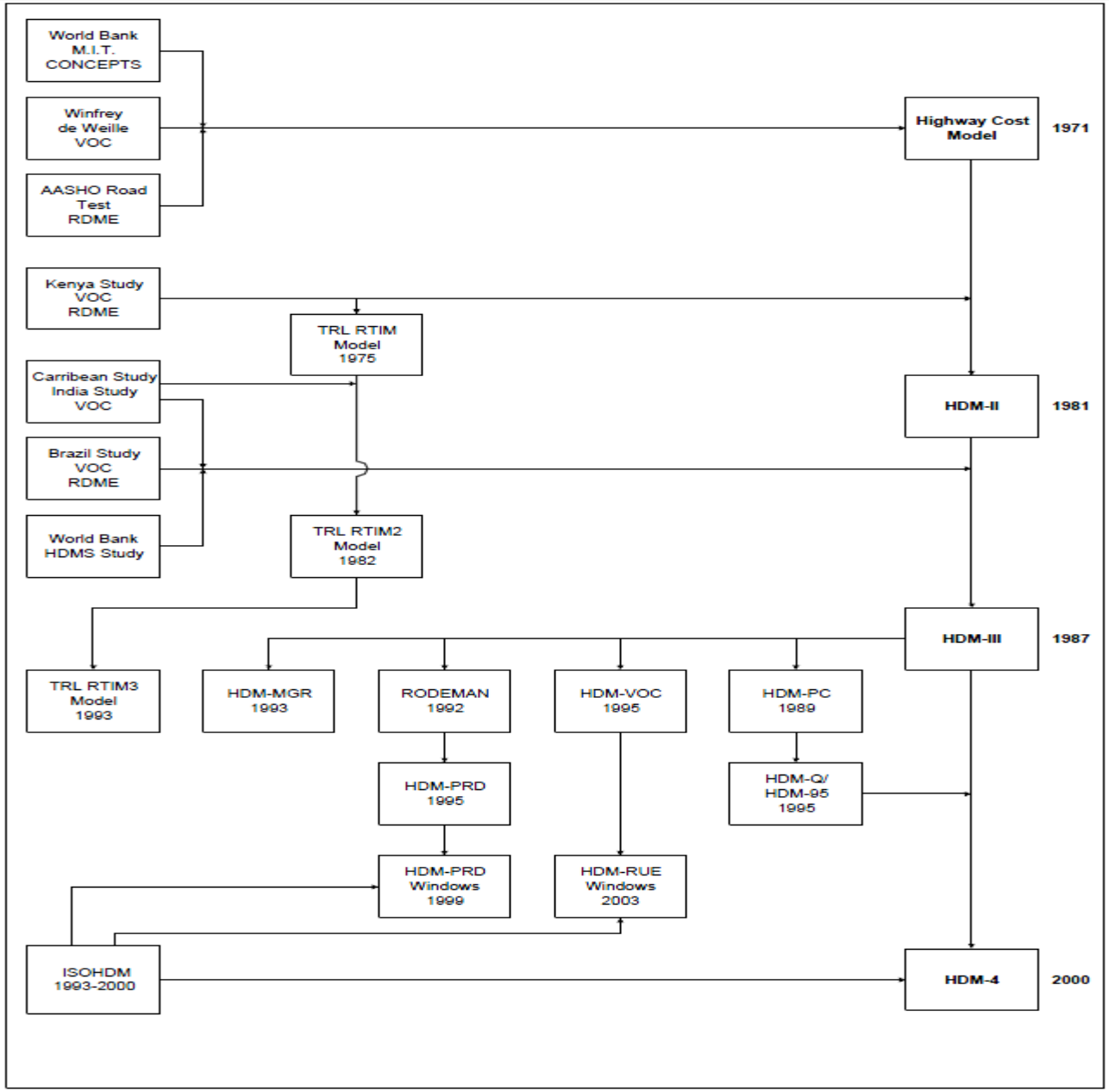
THE HIGHWAY DEVELOPMENT AND MANAGEMENT SERIES

Optimisation Function

Minimization of Total Transportation Costs (High Traffic)



The HDM 4 Predecessors



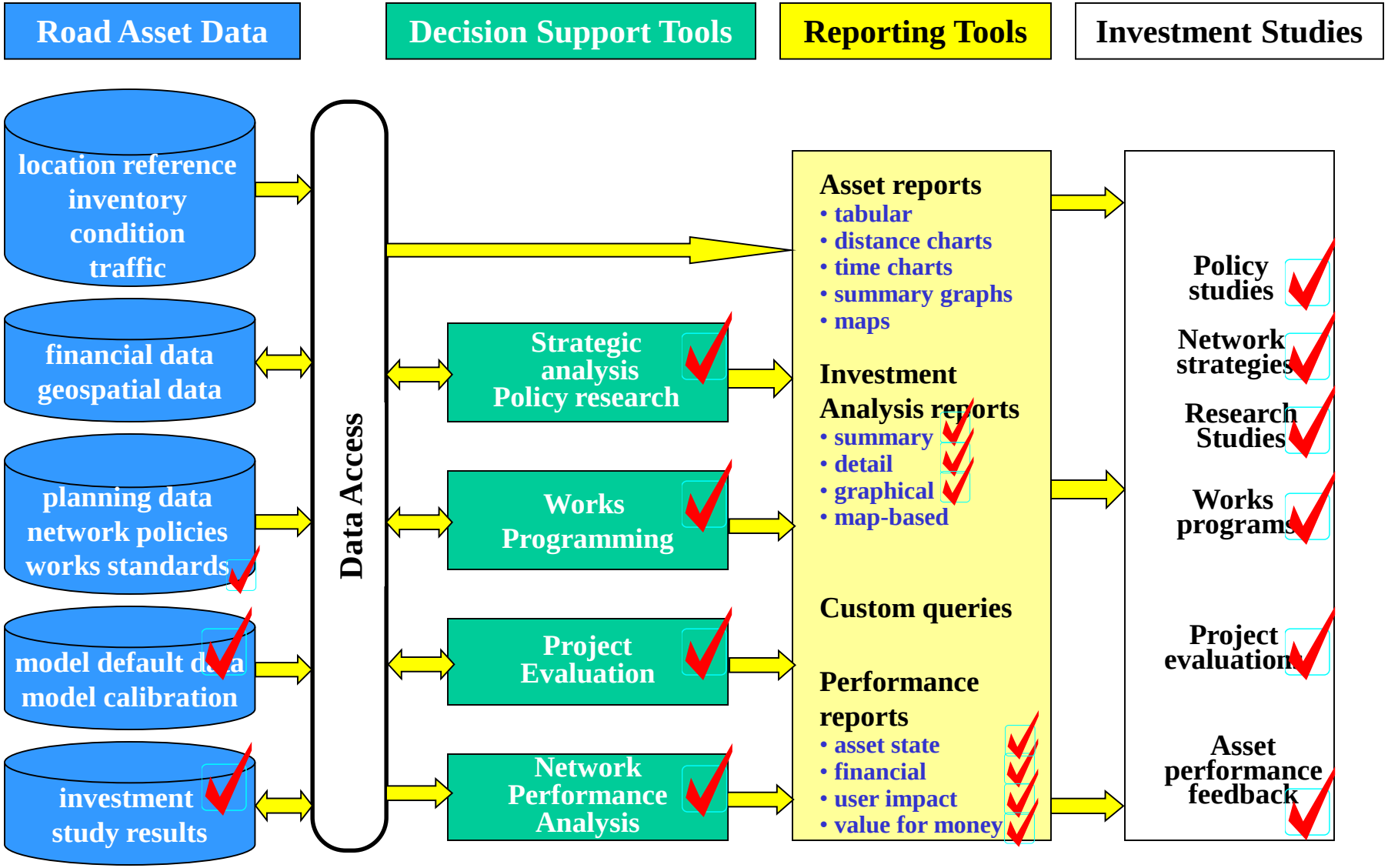
The ISOHDM Study – HDM-4

- Internationally sponsored
- Objectives
  - Update the knowledge and technology
  - user friendly
  - use in funding agencies & road authority PMS
- Was in progress for 7 years (1995 to 2002)
  - technical studies
  - software development and testing
  - software release, support and training
- PIARC leading the implementation phase
  - HDMGLOBAL from Version 2

HDMGLOBAL

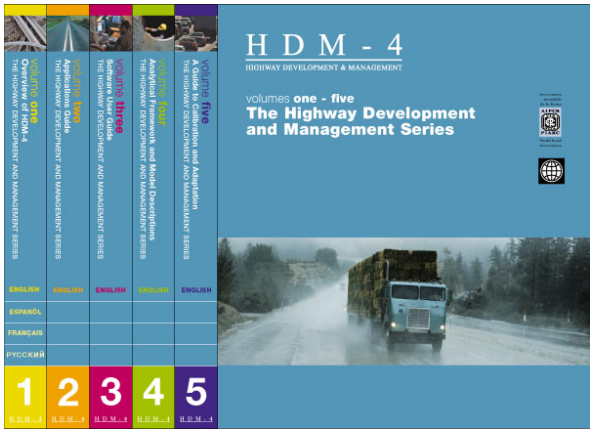
HDM-4 Version 2

HDM-4 in the Decision Framework

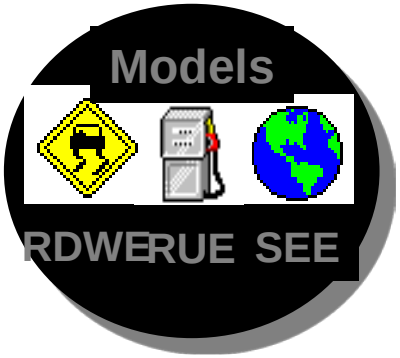


Levels of HDM Technology

Knowledge Base



Models



Software

H D M - 4

HIGHWAY DEVELOPMENT & MANAGEMENT

HDM-4 System Architecture

Data Managers

Road Network | Vehicle Fleet | Road Works | HDM Config.

Analysis Tools

Project | Program | Strategy

Model libraries can be used in other systems

File Converter

transfer data to external systems

Core Data

Vehicle Fleets
Road Networks
Road Works
Projects
Programmes
Strategies

Models

RDWE | RUE | SEE

External Systems

Databases, PMS, etc.

RDWE : *Road Deterioration and Works Effects*

RUE *: Road User Effects*

SEE *: Safety, Energy and Environmental Effects*

PMS *: Pavement Management System*

HDM Knowledge Base - Manuals

Volume 1

Overview of HDM-4

Volume 2

Applications Guide

Volume 3

Software User Guide

Volume 4

Analytical Framework and Model Descriptions

Volume 5

A Guide to Calibration and Adaptation

Volume 6

Modelling Road Deterioration and Works Effects

Volume 7

Modelling Road User and Environmental Effects

HDM – 4

Highway Development & Management

volume SEVEN

MODELLING ROAD USER AND ENVIRONMENTAL EFFECTS IN HDM-4

Christopher R. Bennett

Ian D. Greenwood

7

THE HIGHWAY DEVELOPMENT AND MANAGEMENT SERIES

HDM-4 - [Workspace]

Workspace Window Help

- C:\HDM4\Run Results
  - Vehicle Fleets [1]
    - SA Vehicle Fleet
  - Road Networks [6]
    - Gauteng Toll Network
    - Non Toll Roads
    - Non Toll Roads Old
    - Road User Costs
    - SA National Roads
    - Toll Roads
  - Work Standards
    - Maintenance Standards [12]
      - Base Alternative: N3 Reseal
      - Concrete Maintenance
      - Full Maintenance
      - N2_12 Rehab Option
      - N2_12 Rehab Option Alt 1
      - N2_12 Reseal Option
      - Option 1: N3 Overlay
      - Periodic Maintenance
      - Rehabilitation
      - Routine Maintenance
      - RRM Post Improvement
      - Special Maintenance
    - Improvement Standards [7]
    - New Construction Sections [6]
    - Default Works Currency, Costs & Energy Consumption
  - Projects [7]
    - Gauteng Roads Upgrade
    - Gauteng Toll Highway
    - Lane Rental N1 Section 4
    - N.001_290_2006/1: DNNS2 Musina Bypass
    - Road User Benefits
    - Road User Cost
    - Special Maintenance Projects
  - Programmes [3]
    - Budget 2006/07
    - Non Toll Network
    - Road User Cost
  - Strategies [1]
    - Budget 2006/07
  - Configuration
    - Traffic Flow Patterns [4]
    - Speed Flow Types [8]
    - Accident Classes [16]
    - Climate Zones [5]
    - Currencies
    - Section Aggregate Data
    - Section Aggregate Tables
    - Calibration Parameters
    - RD Calibration Sets [5]

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HDM-4 - [Workspace]

Workspace Window Help

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  - Vehicle Fleets [1]
  - Road Networks [6]
  - Work Standards
  - Projects [7]
  - Programmes [3]
  - Strategies [1]
  - Configuration
    - Traffic Flow Patterns [4]
      - Commuter
      - Free-Flow
      - Inter-urban
      - Seasonal
    - Speed Flow Types [8]
      - SA - 10 Lane Freeway (D5P)
      - SA - 12 Lane Freeway (D6P)
      - SA - 2 Lane Gravel Shoulders (S2U)
      - SA - 2 Lane Paved Shoulders (S2P)
      - SA - 4 Lane Freeway (D2P)
      - SA - 4 Lane Road (N2P)
      - SA - 6 Lane Freeway (D3P)
      - SA - 8 Lane Freeway (D4P)
    - Accident Classes [16]
      - SA - Dual Paved (D2P)
      - SA - Dual Paved G/S (D2P)
      - SA - Dual Unpaved (D2U)
      - SA - Dual Unpaved G/S (D2U)
      - SA - Four Lane Paved (N2P)
      - SA - Four Lane Paved G/S (N2P)
      - SA - Four Lane Unpaved (N2U)
      - SA - Four Lane Unpaved G/S (N2U)
      - SA - Single Paved < 1 (S2P1)
      - SA - Single Paved < 1 G/S (S2P1)
      - SA - Single Paved < 2 (S2P2)
      - SA - Single Paved < 2 G/S (S2P2)
      - SA - Single Paved < 3 (S2P3)
      - SA - Single Paved < 3 G/S (S2P3)
      - SA - Single Unpaved (S2U)
      - SA - Single Unpaved G/S (S2U)
    - Climate Zones [5]
      - SA - Central (Semi Arid)
      - SA - Eastern Plateau (Wet)
      - SA - Highveld (Moderate)
      - SA - Karoo (Dry)
      - SA - Western Cape (Winter)
    - Currencies
    - Section Aggregate Data
    - Section Aggregate Tables
    - Calibration Parameters
    - RD Calibration Sets [5]
      - National Roads Calibration Set
      - Non Toll Calibration Set
      - Non Toll Calibration Set Old
      - Road User Costs
      - Toll Calibration Set

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6.1.2 Passenger car space equivalents

To model the effects of **traffic congestion**, the mixed traffic flows are converted into equivalent standard vehicles. The conversion is based on the concept of Passenger Car Space Equivalents (PCSE) *Hoban et al. (1994)*. This accounts only for the relative space taken up by the vehicle on the road, and reflects the fact that the speed-flow model takes account explicitly of speed differences of the various vehicles in the traffic stream. PCSE factors vary by road type, and narrow roads have higher PCSE values than wide roads. Table B1.1 gives the values of PCSE by vehicle class and road type.

Table B1.1 PCSE Values

Vehicle	Average Length (m)	Space Headway (m)	Total Space (m)	Basic PCSE	Recommended Values		
					2-Lane 4-Lane	Narrow 2-Lane	1-Lane
Car	4.0	32.0	36.0	1.0	1.0	1.0	1.0
Utilities (Pickup)	4.5	36.0	40.5	1.0	1.0	1.0	1.0
Heavy Bus	14.0	44.0	58.0	1.6	1.8	2.0	2.2
Light Truck	5.0	40.0	45.0	1.3	1.3	1.4	1.5
Medium Truck	7.0	44.0	51.0	1.4	1.5	1.6	1.8
Heavy Truck	9.0	48.0	57.0	1.6	1.8	2.0	2.4
Trailer	11.0	50.0	65.0	1.8	2.2	2.6	3.0

Source: *Hoban et al. (1994)*

Notes: The basic PCSE values have been used as defaults for the HDM-4 standard vehicle types (see Part E)

11 Configuring HDM-4

11.1 Traffic Flow Patterns

11.1.1 Key concepts

Traffic Flow Patterns are used to represent the varying traffic intensities that occur on roads throughout the day. Different road Sections exhibit different traffic flow patterns according to their use. Examples of Traffic Flow Patterns are:

- Commuter
- Seasonal
- Inter-city

Traffic Flow Patterns are defined as a set of flow periods. A flow period represents the hours of the day (over the course of a year) with the same traffic flow.

For each flow period p you should specify:

- Total hours per year ($HRYR_p$) that the period occupies, and
- The amount of yearly traffic occurring during the flow period, as either:
  - The proportion of AADT (HV_p) that occurs during each hour of the flow period, or
  - The percentage of AADT ($PCNADT_p$) that occurs during each flow period

11.2 Speed Flow Types

11.2.1 Key concepts

The primary function of HDM-4 Speed Flow Types is to represent the capacity characteristics of different road types. Examples of Speed Flow Types are:

- Single Lane Road
- Intermediate Road
- Two Lane Road
- Four Lane Road

Capacity characteristics are defined in terms of the various parameters (such as ultimate capacity and free flow capacity) that constitute the HDM-4 speed flow curve model.

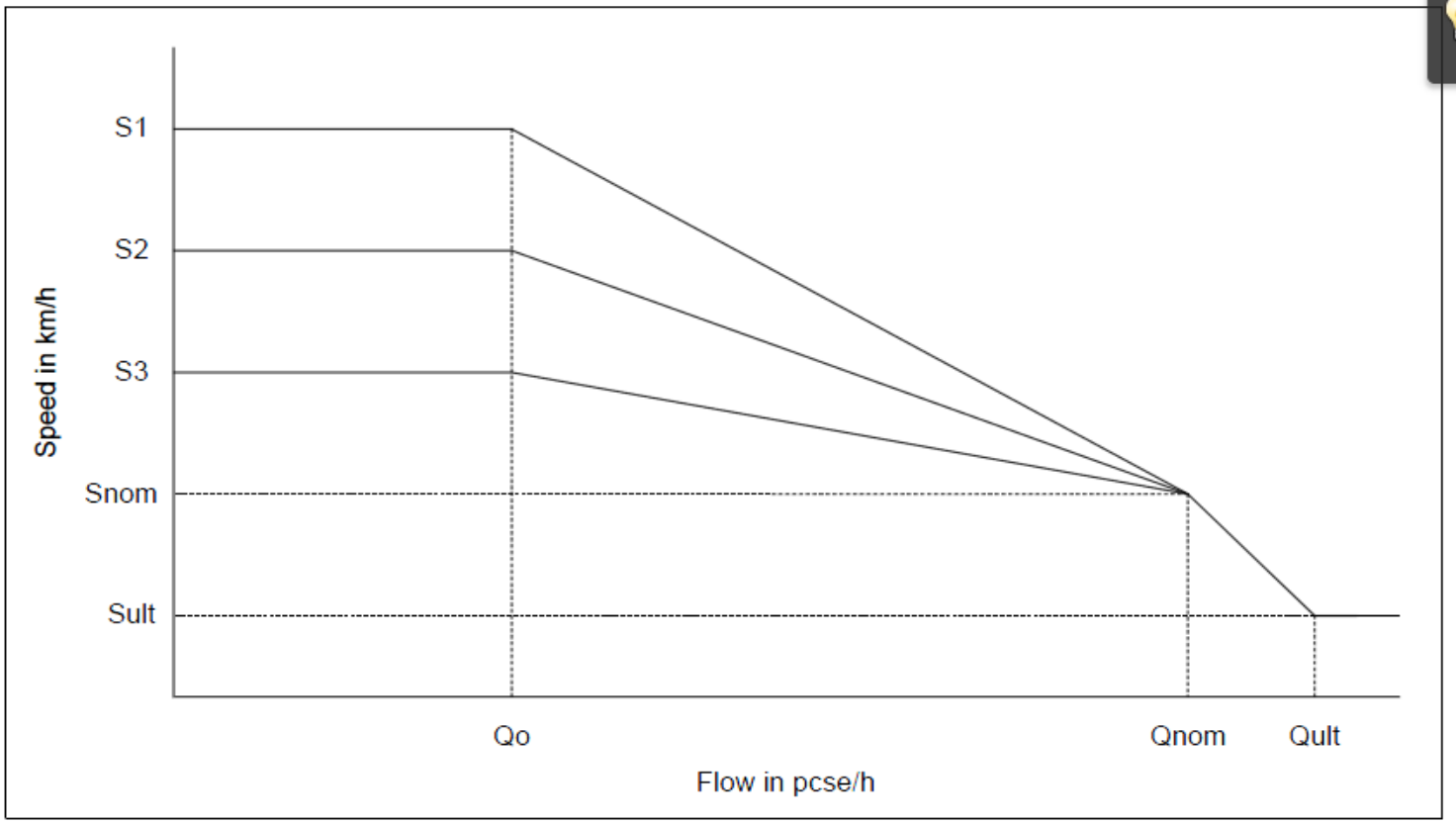


Figure B3.3: HDM Speed-Volume Model

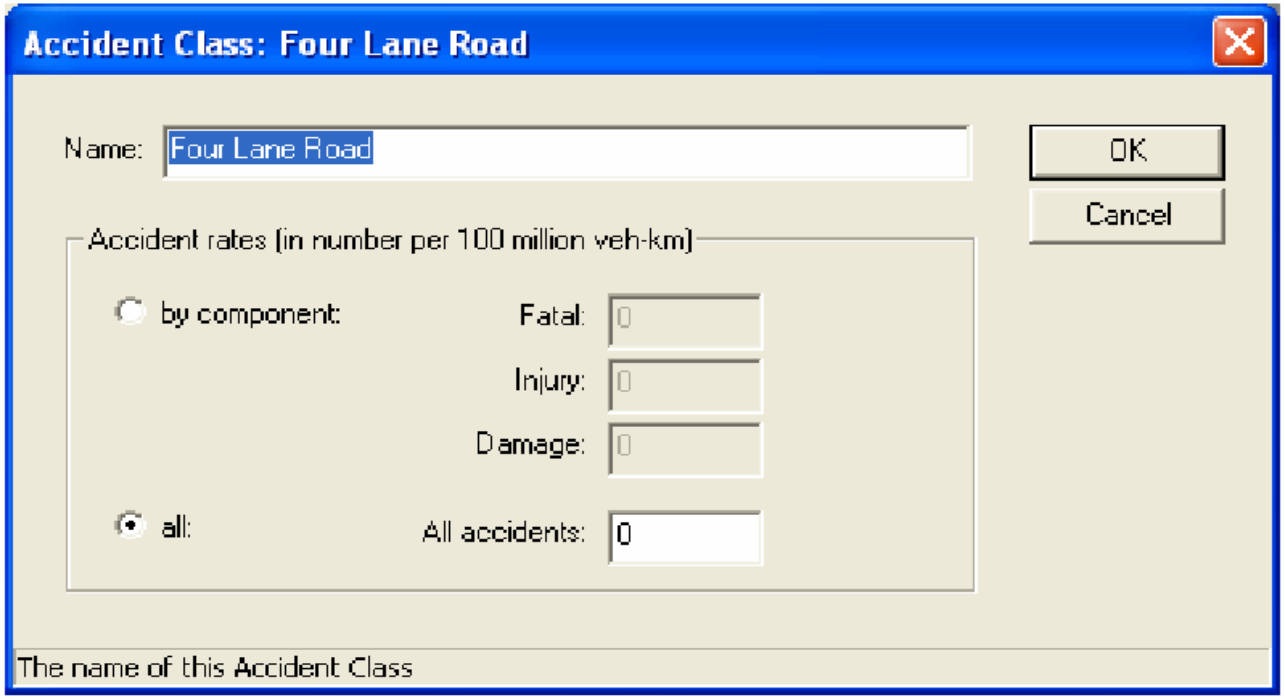
The basic premise of the HDM speed-volume model is that below a certain flow level (Qo) vehicles travel at their free speed. When the flow exceeds Qo there are traffic interactions which cause the mean speed to decrease. On multi-lane highways this may be at a flow as high as 800-1000 pcse/h while on narrow single lane roads it may be a flow of 0. At the nominal capacity (Qnom) all vehicles are travelling at the same speed. If there are additional vehicles the speeds drop rapidly to the minimum speed (Sult) which is at the ultimate capacity (Qult). If the demand exceeds Qult the speed remains at Sult.

11.3 Accident Classes

11.3.1 Key Concepts

The primary function of HDM-4 Accident Class is to represent the accident rate characteristics of different roads.

Accident rate characteristics are defined in terms of the accident rates per 100 million vehicle-km. They can either be specified by accident components, or a single rate for all accident types.



Accident classes are viewed by expanding the **Accident Classes** branch in the **Configuration** branch of a workspace.

11.4 Climate Zones

11.4.1 Key concepts

Climate Zones are used to represent the climatic conditions found in different parts of a Road Network. The data items that represent these climatic

conditions affect pavement deterioration. Climate Zone data are divided into two categories:

- Moisture
- Temperature

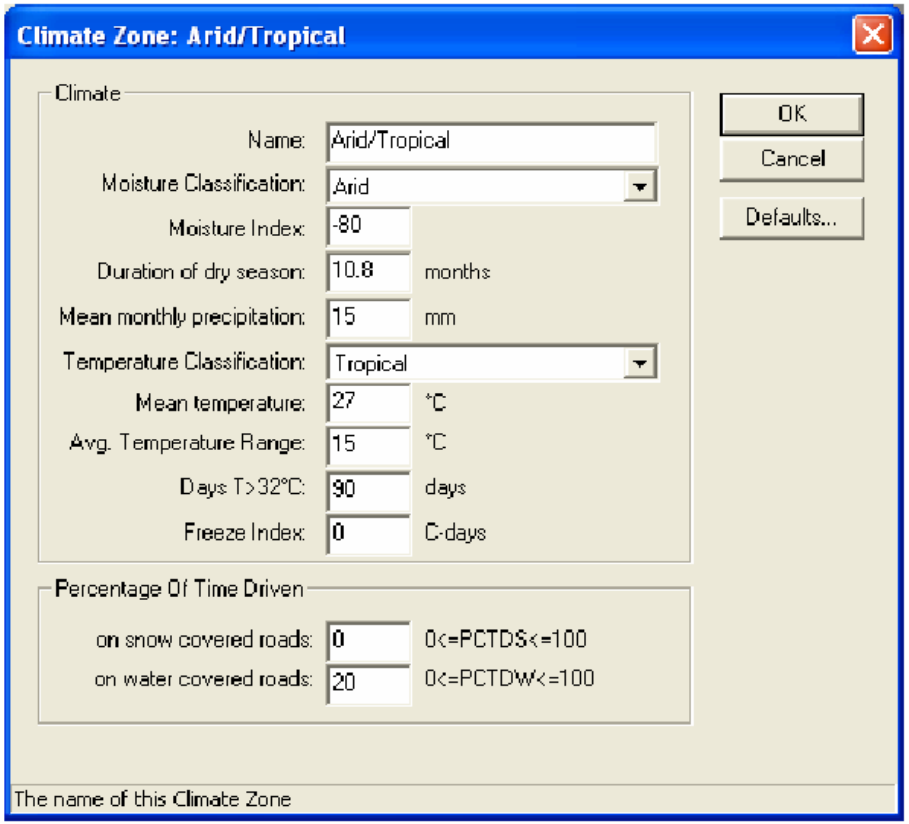
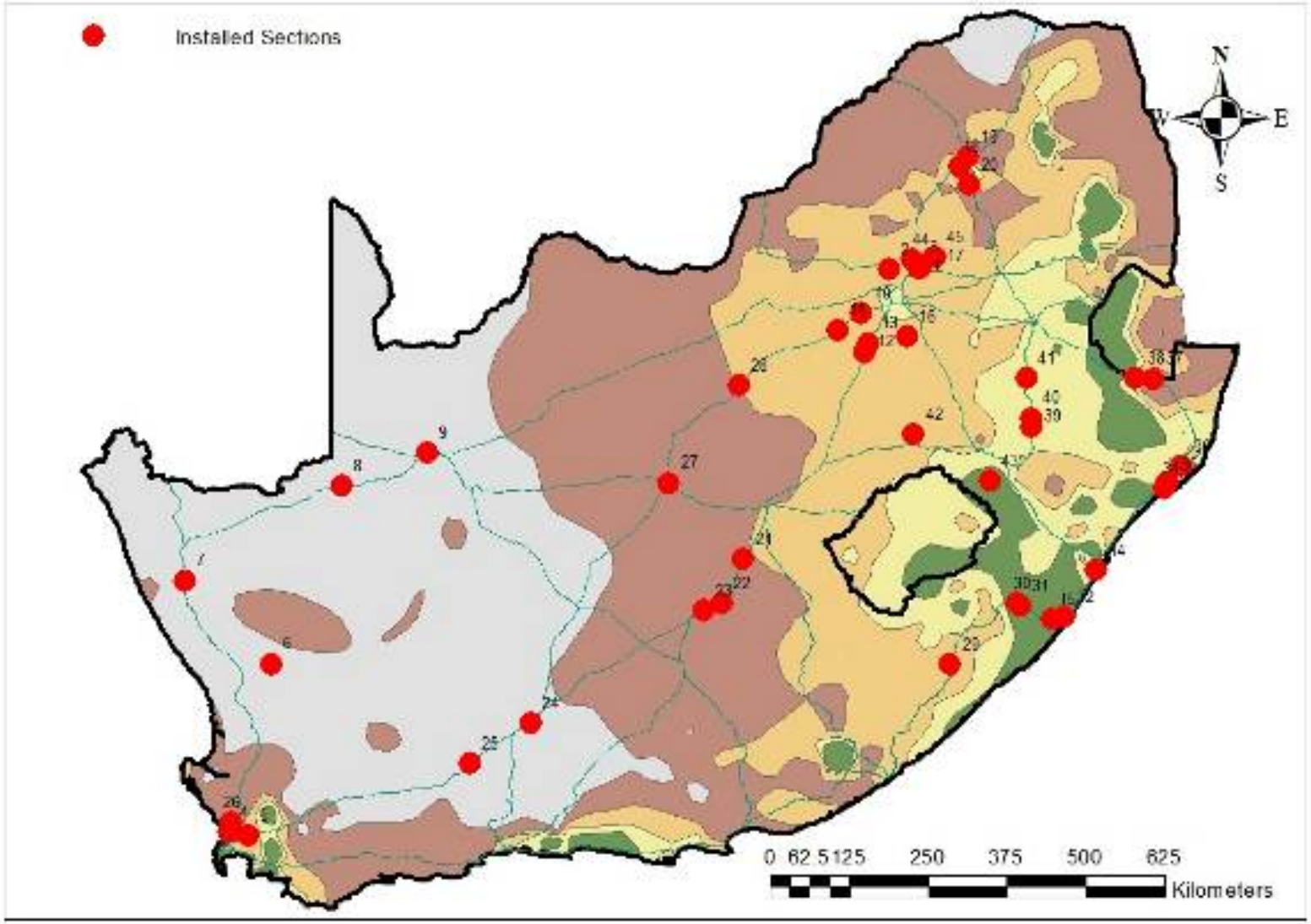


Table C1.3 Moisture classification

Moisture classification	Description	Thornthwaite moisture index	Annual precipitation (mm)
Arid	Very low rainfall, high evaporation	-100 to -61	< 300
Semi-arid	Low rainfall	-60 to -21	300 to 800
Sub-humid	Moderate rainfall, or strongly seasonal rainfall	-20 to +19	800 to 1600
Humid	Moderate warm seasonal rainfall	+20 to +100	1500 to 3000
Per-humid	High rainfall, or very many wet-surface days	> 100	> 2400

Table C1.4 Temperature classification

Temperature classification	Description	Temperature range (°C)
Tropical	Warm temperatures in small range	20 to 35
Sub-tropical - hot	High day cool night temperatures, hot-cold seasons	-5 to 45
Sub-tropical - cool	Moderate day temperatures, cool winters	-10 to 30
Temperate - cool	Warm summer, shallow winter freeze	-20 to 25
Temperate - freeze	Cool summer, deep winter freeze	-40 to 20


Installed Sections
N
W
E
S
0 62.5 125 250 375 500 625
Kilometers

4.1.4 Freezing index

The **freezing index (FI)** is defined as the difference between the mean ambient temperature and 0°C (degrees per day). The freezing index is **negative** when the ambient temperature is below 0°C and **positive** otherwise.

The freezing index is calculated as:

$$FI = \sum_{i=1}^{ndays} ABS[MIN(TEMP,0)] \qquad ...(4.2)$$

where:

FI	freezing index
TEMP	temperature (°C)
Ndays	number of days in one freezing season

Local Calibration of HDM-4

- To ensure international application HDM a high degree of transferability across technological and climate conditions needed to be build into the models.
- Not all factors could however be incorporated:
  - Was not measured during model development studies
  - Would have made models to complex
  - Effects could not be quantified in data ranges observed
- For these reasons calibration to local conditions is both sensible and desirable.
  - Data Inputs – Correct interpretation of data inputs
  - Calibration of Outputs – Adjusting model parameters to enhance correlation between forecasts and observations

Calibration Hierarchy of Effort

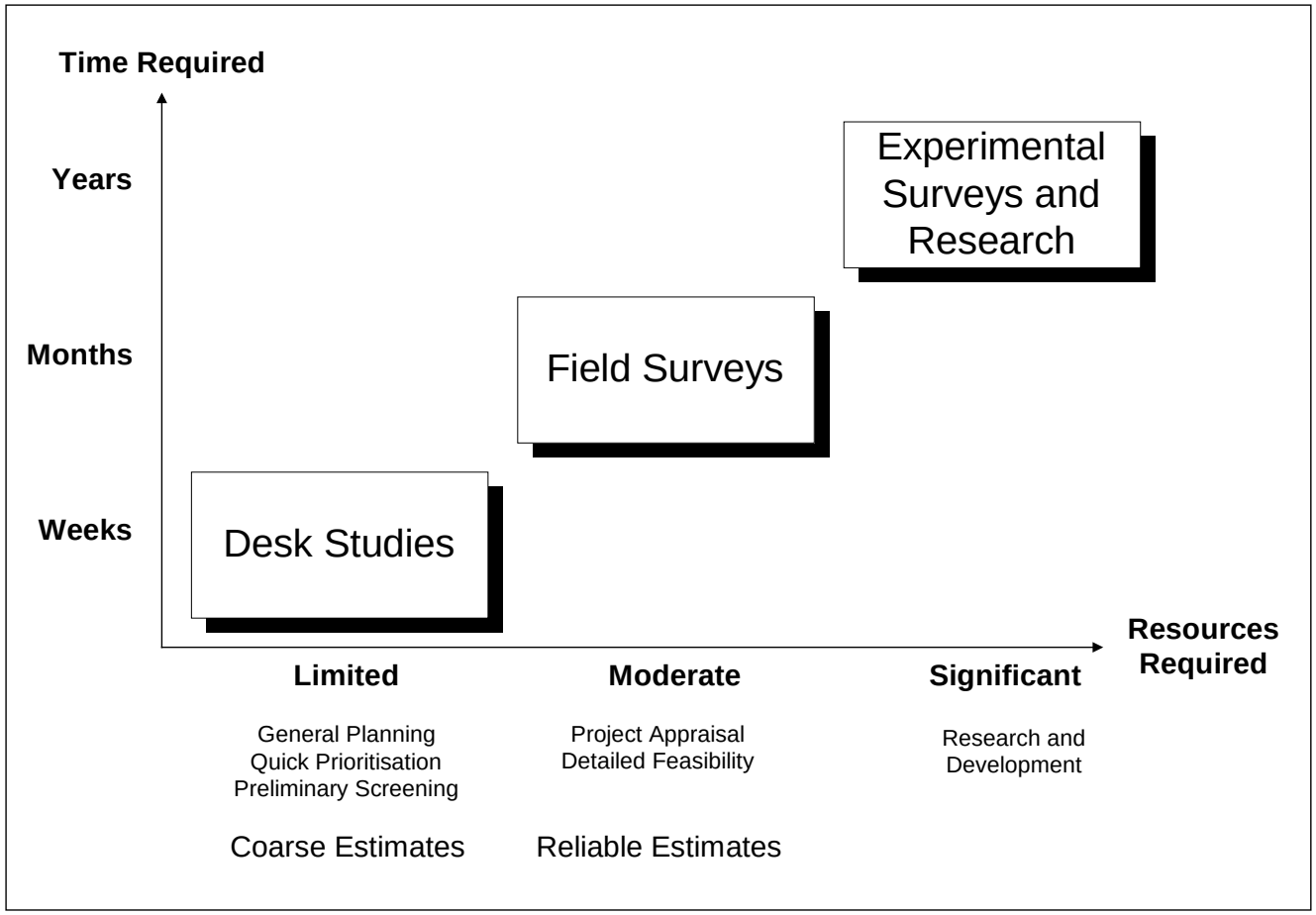


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Table 4.2
Sensitivity classes for HDM-4 RUE model[1]

Sensitivity class[2]	Impact elasticity	Variables or data important for total VOC[3]	Variables or data important for VOC savings[4]
S-I	> 0.50	Replacement vehicle price Parts model exponent kp	Replacement vehicle price Parts model exponent kp
S-II	0.20 - 0.50	Roughness in IRI Parts model a1	Roughness in IRI Parts model a1
S-III	0.05 - 0.20	Aerodynamic drag coefficient Aerodynamic drag multiplier Cdmult Annual utilisation Base fuel-power factor ξb Cost of fuel Cost of maintenance labour Cost of passenger work time Desired speed Driveline efficiency Driving power Engine accessories power factor Fuel ξ Interest rate Labour hours calibration factor Mass density of air Maximum average rectified velocity NMT friction factor XNMT Number of passengers Number of wheels Parts model a0 Posted speed limit Projected frontal area Rolling resistance CR1 Rolling resistance CR2 a0 Rolling resistance factor CR2 Roughness-speed a0 Side friction factor XFRI Speed bias correction factor Speed limit enforcement factor Vehicle mass Vehicle service life Wheel diameter	Aerodynamic drag coefficient Aerodynamic drag multiplier Cdmult Annual utilisation Base fuel-power factor ξb Cost of fuel Cost of maintenance labour Cost of passenger work time Cost of tyre Driveline efficiency Driving power Engine accessories power factor Engine idle speed Fuel ξ Interest rate Labour hours calibration factor Mass density of air Maximum average rectified velocity Number of passengers Number of wheels Parts model a0 Posted speed limit Projected frontal area Rolling resistance CR1 Rolling resistance CR2 a0 Rolling resistance factor CR2 Roughness-speed a0 Speed β Speed limit enforcement factor Vehicle mass Vehicle service life Volume of wearable rubber Wheel diameter
S-IV	<0.05	All others	All others

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Table 4.4
Sensitivity classes for RDWE variables

Sensitivity class	Impact elasticity	Parameter	Outcomes most impacted		
			Pavement performance	Resurfacing and surface distress	Economic return on maintenance
S-I	> 0.50	Structural number [1/]	•	•	•
		Modified structural number[1/]	•	•	•
		Traffic volume			•
		Deflection[3/]	•	•	•
		Roughness	•		•
S-II	0.20-0.50	Annual loading	•	•	•
		Age		•	•
		All cracking area		•	•
		Wide cracking area		•	•
		Roughness-environment factor	•		•
		Cracking initiation factor	•	•	•
		Cracking progression factor		•	
S-III	0.05-0.20	Subgrade CBR (with SN)	•		
		Surface thickness (with SN)		•	•
		Heavy axles volume		•	•
		Potholing area	•	•	
		Rut depth mean	•		
		Rut depth standard deviation	•		
		Rut depth progression factor	•		
		Roughness general factor	•		•
S-IV	< 0.05	Deflection (with SNC)		•	
		Subgrade compaction	•		•
		Rainfall (with Kge)	•		
		Ravelling area		•	
		Ravelling factor		•	

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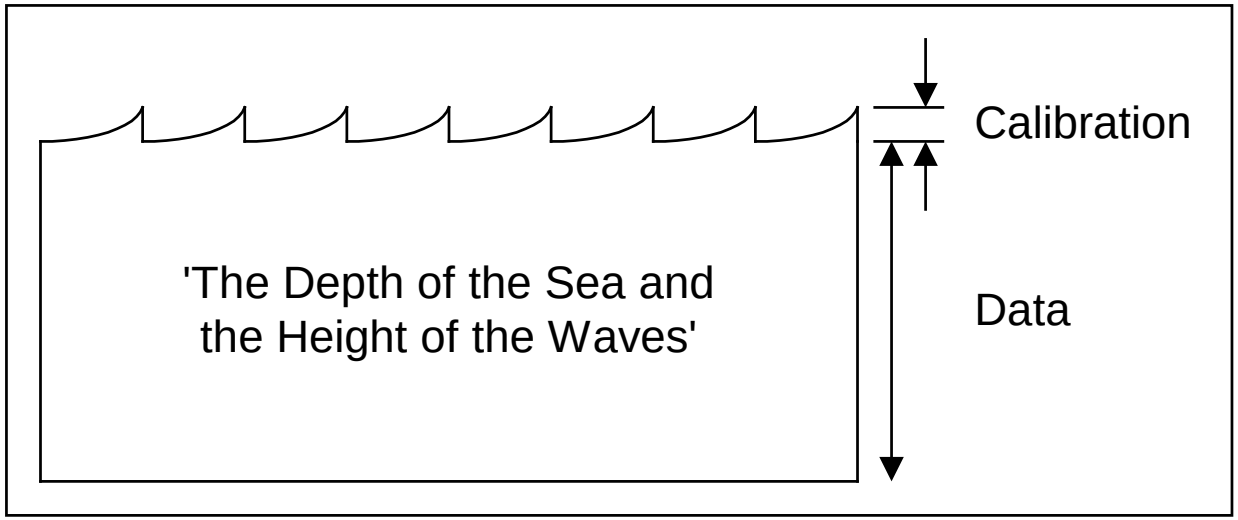
Data vs Calibration

- Need to appreciate importance of data over calibration
- If input data are wrong why worry about calibration?



HDM-4 - [Vehicle Fleet: SA Vehicle Fleet - Definition Data]

Workspace Fleet View Window Help

Name	Class	Data Last Modified	Base Type	Category
Toll Class 1	Passenger Cars	2007/02/15	Car Medium	Motorised
Toll Class 2	Trucks	2007/02/15	Truck Medium	Motorised
Toll Class 3	Trucks	2007/02/15	Truck Articulated	Motorised
Toll Class 4	Trucks	2007/02/15	Truck Articulated	Motorised

Vehicle Attributes: Toll Class 1

Definition | Basic Characteristics | Economic Unit Costs

Physical

Passenger Car Space Equiv: 1
No. of Wheels: 4
No. of Axles: 2

Tyres

Tyre type: Radial-ply
Base no. of recaps: 1.3
Retread cost: 39 %

Utilisation

Annual km: 25000 km
Working hours: 450 hrs
Average life: 5 years
Calculate...
Private use: 44 %
Passengers: 1 persons
Work related passenger-trips: 56 %

Loading

ESALF: 0.02
Calculate...
Operating weight: 1.2 tonnes

Calibration...
Reset Defaults
OK
Cancel

View vehicle calibration parameters

Vehicle Calibration: Toll Class 1

Emissions - Engine Output Model | Emissions - Catalytic Converter | Energy
Forces | Speed | Fuel | Acceleration Effects | Tyres | Maintenance | Optimal Life

Aerodynamic

Frontal Area: 1.9 m²
CD: 0.42
CD Multiplier: 1.1

Rolling Resistance

parameter a0: 37
parameter a1: 0.064
parameter a2: 0.012

Power

Driving Power: 33 kW
Braking Power: 20 kW
Rated Engine Power: 70 kW

Unsealed Road Impassibility

FPLIM: 1

OK
Cancel

Projected frontal area

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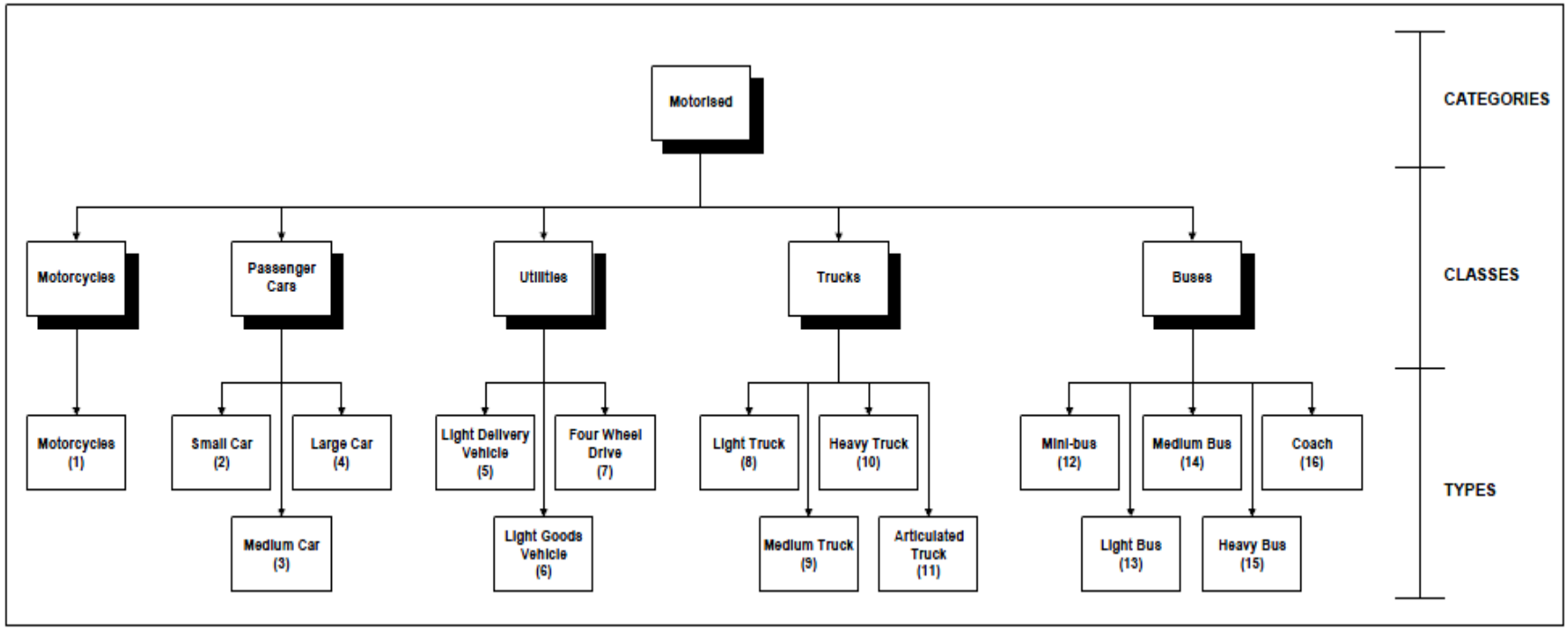


Figure A3.1: Motorised Vehicle Representation in HDM-4

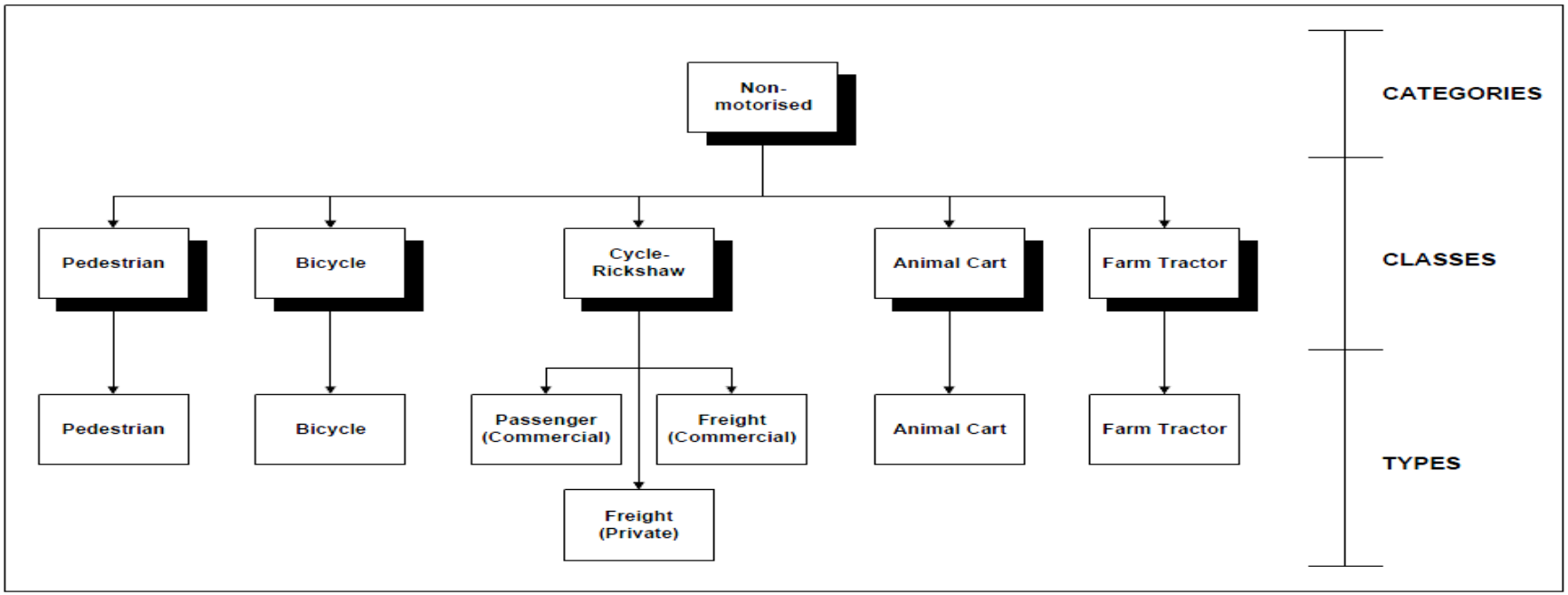
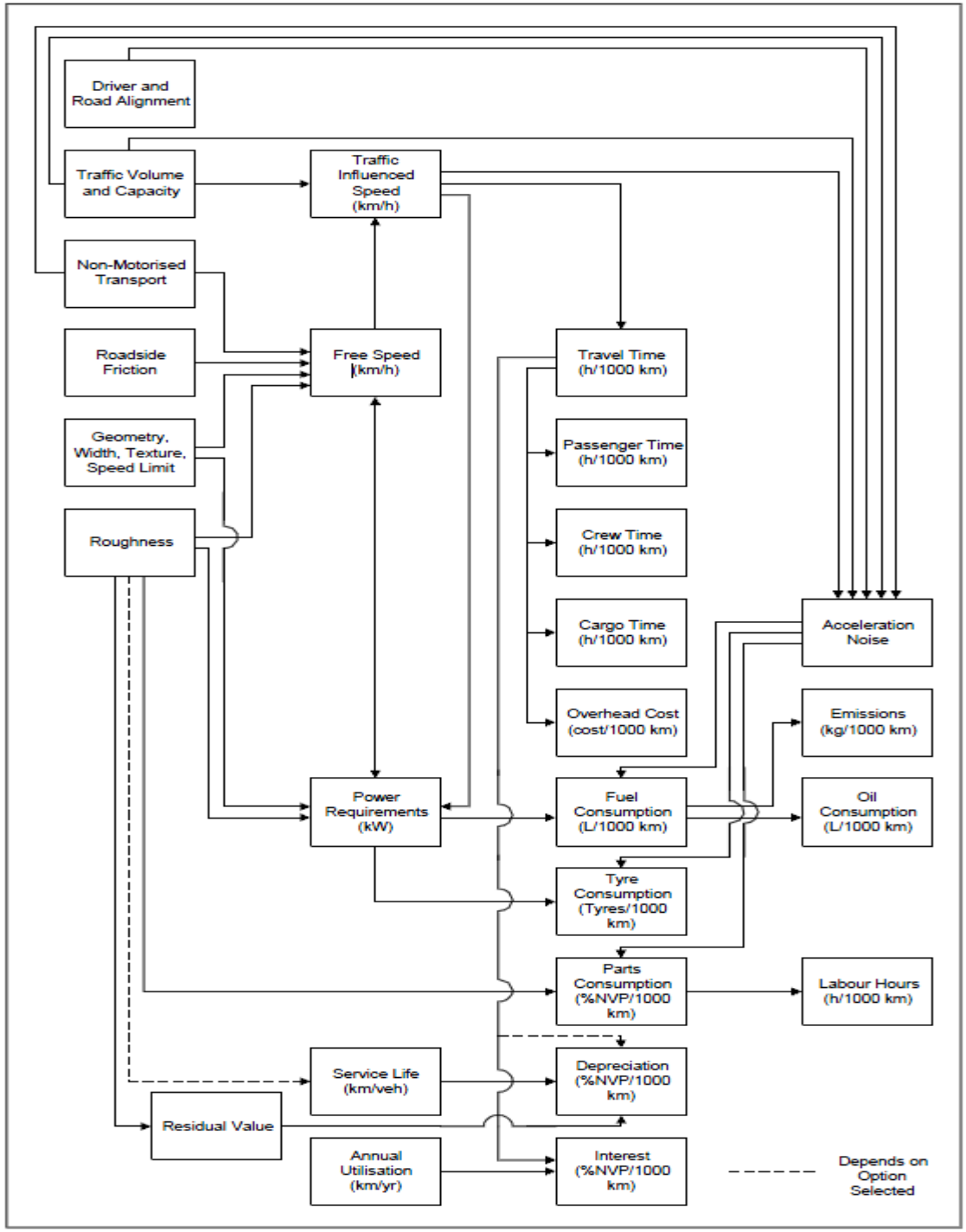


Figure A3.2: Non-Motorised Vehicle Representation in HDM-4

HDM Road User Effects



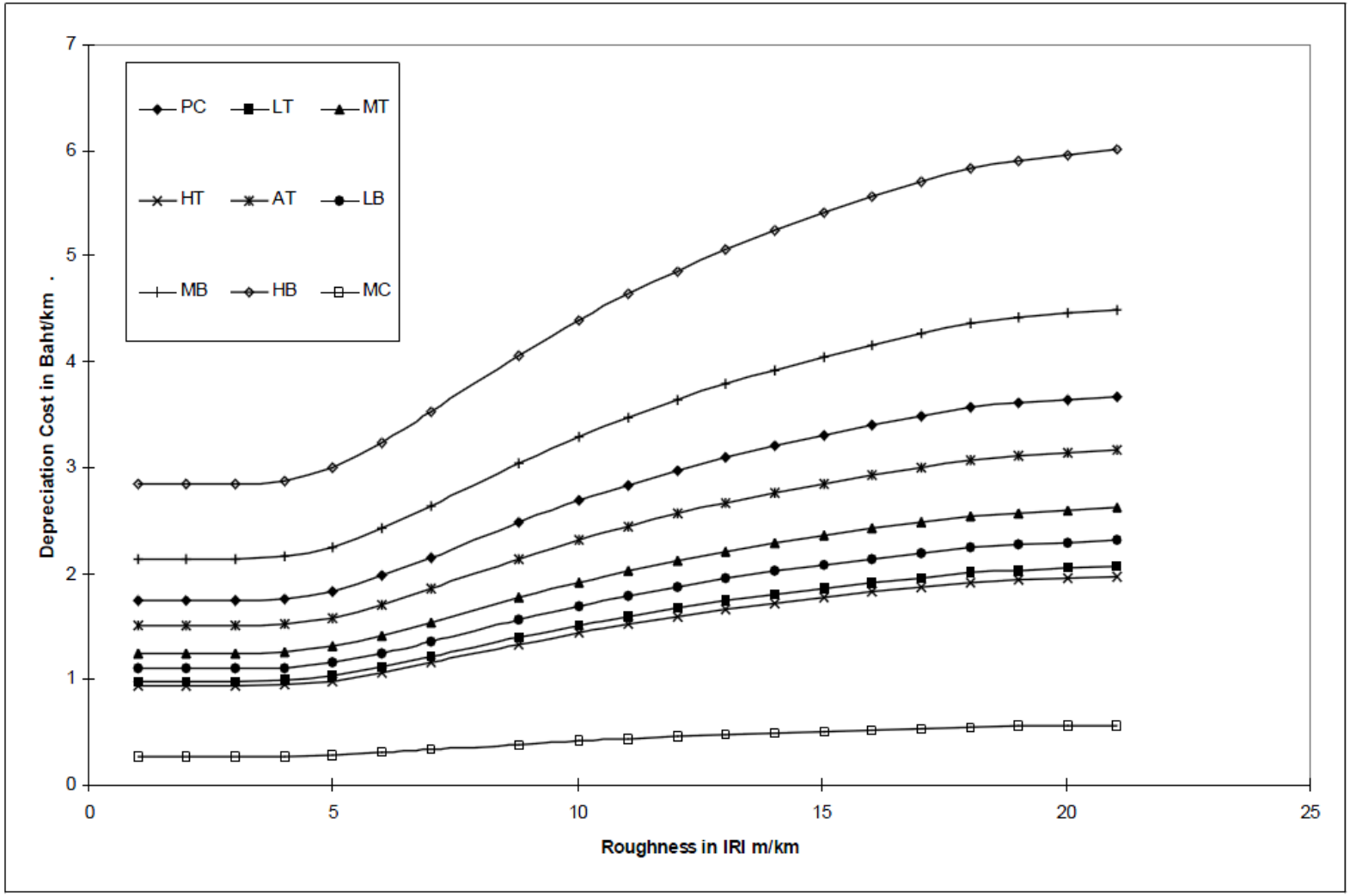


Figure B8.4: Example of the Effect of Roughness on Depreciation Costs

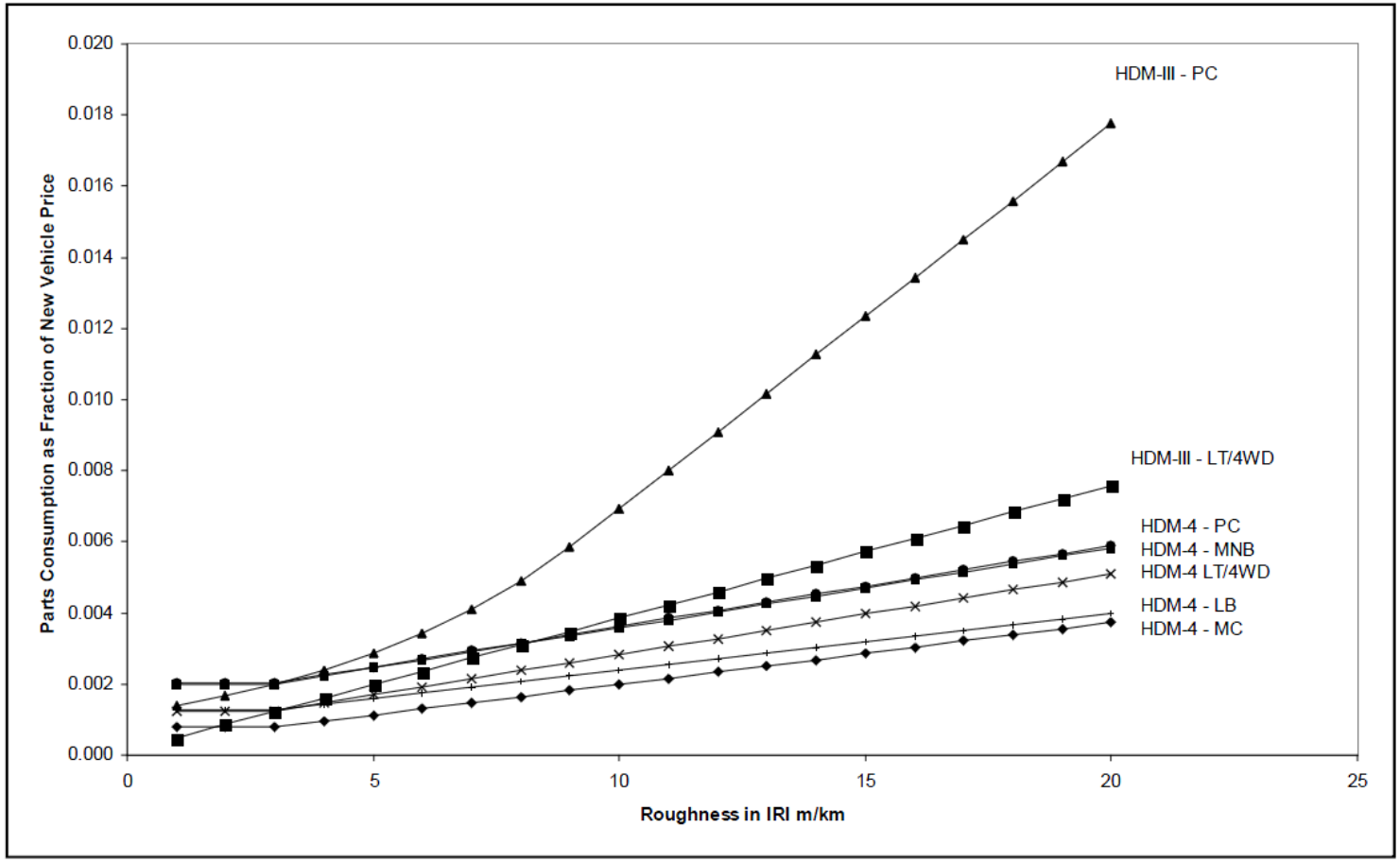


Figure B6.9: Comparison of HDM-4 and HDM-III Parts Consumption: Light Vehicles

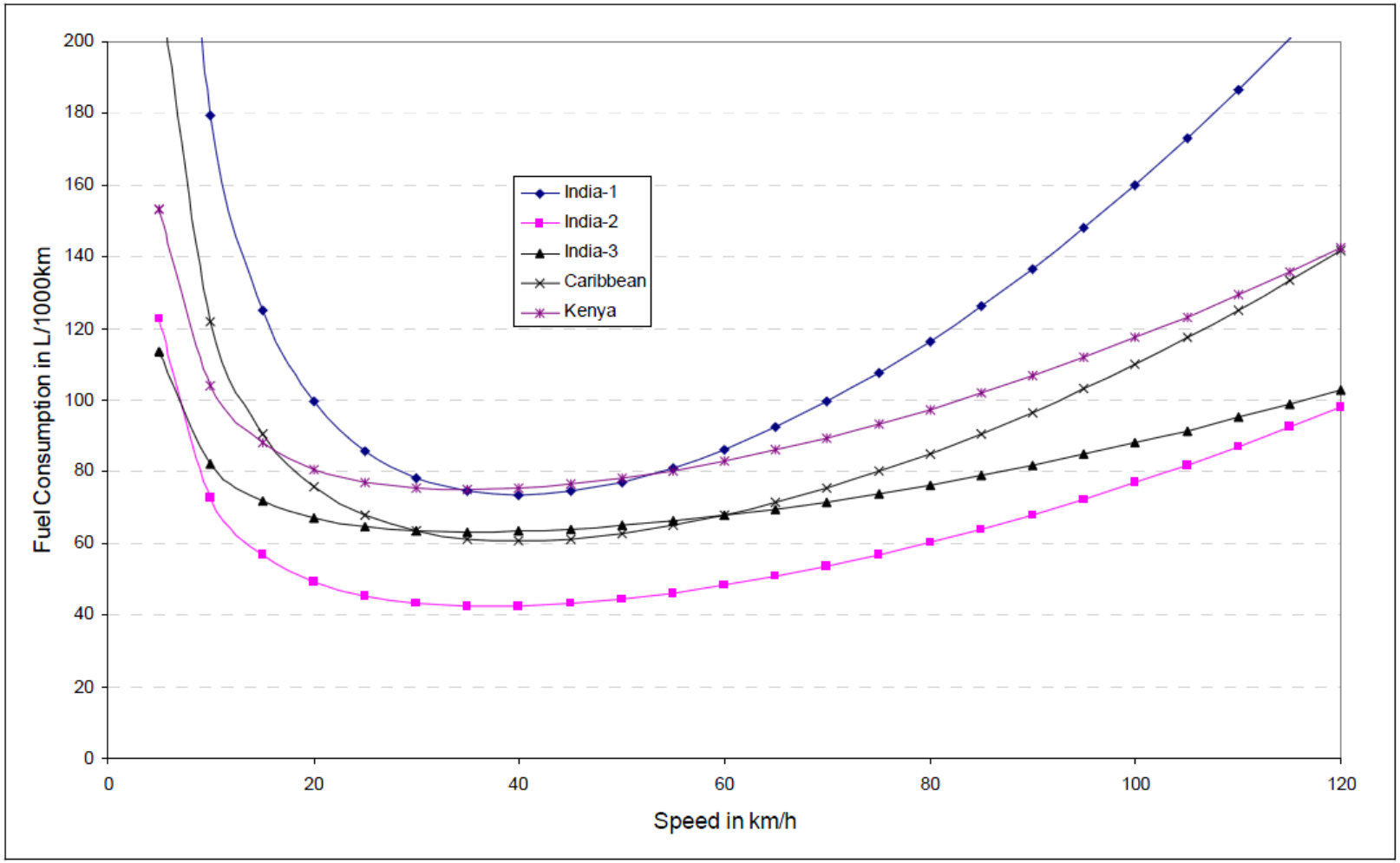


Figure B4.5: Effect of Speed on Passenger Car Fuel Consumption

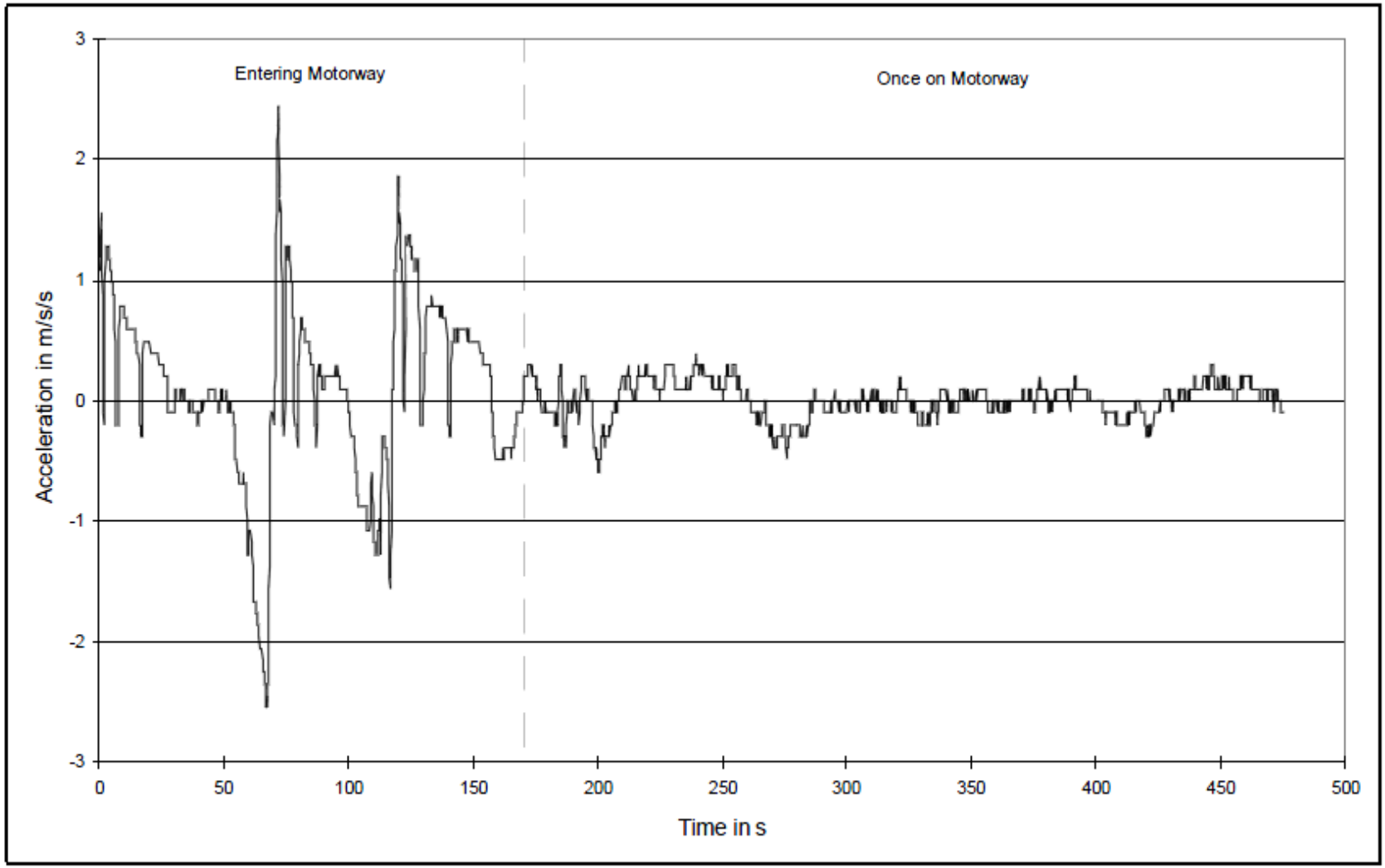


Figure 6.12 Example of acceleration data on motorway

HDM-4 - Non Toll Roads

Workspace RoadNet View Window Help

Road Network: Non Toll Roads - All Sections/Definition Data

ID	Description	Data Last Modified	Surface Class	Pavement Type	RD Calibration Item	Length (km)	Carriageway Width (m)	Traffic Flow	Shoulder Width (m)	Speed Flow Type	Traffic Flow Pattern	Acci Cla
N00224S	N00224S 6.5 - 12	2006/07/26	Bituminous	Surface Treatment on Asphalt Ba	N00224S0065	5.5	10.40	Two-way	2.00	SA - 4 Lane I	Commuter	SA - Dua
N00224S	N00224S 12 - 19	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00224S0120	7.0	10.40	Two-way	2.00	SA - 4 Lane I	Commuter	SA - Dua
N00224S	N00224S 19 - 21.3	2006/07/26	Bituminous	Asphalt Mix on Stabilised Base	N00224S0190	2.3	10.40	Two-way	2.00	SA - 4 Lane I	Commuter	SA - Dua
N00224S	N00224S 21.3 - 24.1	2006/07/26	Bituminous	Asphalt Mix on Stabilised Base	N00224S0213	2.8	10.40	Two-way	2.00	SA - 4 Lane I	Commuter	SA - Dua
N00224S	N00224S 24.1 - 28.228	2006/07/26	Bituminous	Asphalt Mix on Stabilised Base	N00224S0241	4.1	10.40	Two-way	2.00	SA - 4 Lane I	Commuter	SA - Dua
N00225N	N00225N 0 - 3.4	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0000	3.4	14.10	Two-way	2.00	SA - 6 Lane I	Commuter	SA - Dua
N00225N	N00225N 3.4 - 6.1	2008/10/21	Bituminous	Asphalt Mix on Asphalt Base	N00225N0034	2.7	17.80	Two-way	2.00	SA - 8 Lane I	Commuter	SA - Dua
N00225N	N00225N 6.1 - 12.8	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0061	6.7	14.10	Two-way	2.00	SA - 6 Lane I	Commuter	SA - Dua
N00225N	N00225N 12.8 - 17.2	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0128	4.4	14.10	Two-way	2.00	SA - 6 Lane I	Commuter	SA - Dua
N00225N	N00225N 17.2 - 22.4	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0172	5.2	17.80	Two-way	2.00	SA - 8 Lane I	Commuter	SA - Dua
N00225N	N00225N 22.4 - 27.5	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0224	5.1	14.10	Two-way	2.00	SA - 6 Lane I	Commuter	SA - Dua
N00225N	N00225N 27.5 - 28.6	2006/07/26	Bituminous	Asphalt Mix on Asphalt Base	N00225N0275	1.1	14.10	Two-way	2.00	SA - 6 Lane I	Commuter	SA - Dua

Add New Section... | Delete | Edit.. | Info... | Save | Close

Label for section

Section: N00225N 3.4 - 6.1

Definition | Geometry | Pavement | Condition | Other | Motorised Traffic | Asset Valuation

Name: N00225N 3.4 - 6.1

ID: N00225N0034

Link Name: Louis Botha I/C - Chatsworth I/C

Link ID: N00225

Length: 2.7 km

Cway Width: 17.8 m

Shoulder Width: 2 m

Flow Direction: Two-way

Surface Class: Bituminous

Speed Flow Type: SA - 8 Lane Freeway (D4P)

Traffic Flow Pattern: Commuter

Accident Class: SA - Dual Paved G/S (D2P)

Climate Zone: SA - Eastern Plateau (Wet)

Road Class: Primary or trunk

Calibration Set: Non Toll Calibration Set

Calibration Item: N00225N0034

Selected Calibration Item Summary

Pavement type: Asphalt Mix on Asphalt Base

Surface material: Asphaltic Concrete

OK | Cancel

Name of section

start | MetaFrame Presenta... | <Recently Edited Do... | SAP Logon 710 - \\R... | Microsoft PowerPoin... | HDM-4 - Non Toll Roads | HDM4 | EN | 08:00 AM

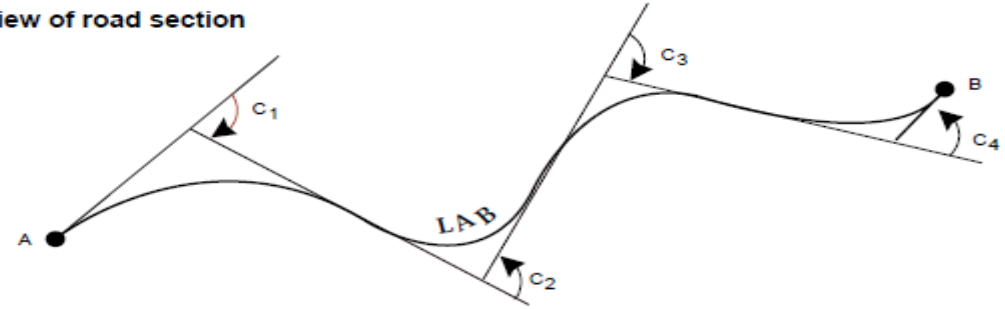
Table C1.1 Pavement classification system in HDM-4

Surface category	Surface class	Pavement type	Surface type	Surface material	Base type	Base material
Paved	Bituminous	AMGB	AM	AC, HRA,	GB	NG, CRS, WBM, etc.
		AMAB		RAC, PA,	AB	AB, EB, etc.
		AMSB		CM, etc.	SB	CS, LS, etc.
		AMAP			AP	TNA, FDA, etc.
		AMRB			RB	JUC, RBC, CUC, etc.
		STGB	ST	SBSD, PM,	GB	NG, CRS, WBM, etc.
		STAB		DBSD, SL,	AB	AB, EB, etc.
		STSB		CAPE, etc.	SB	CS, LS, etc.
		STAP			AP	TNA, FDA, etc.
		STRB			RB	JUC, RBC, CUC, etc.
	Concrete	JPGB	JP	VC, RC,	GB	NG, CRS, WBM, etc.
		JPAB		FC, PC,	AB	AB, EB, etc.
		JPSB		etc.	SB	CS, LS, etc.
		JPAP			AP	TNA, FDA, etc.
		JPRB			RB	JUC, RBC, CUC, etc.
		JRGB	JR	VC,	GB	NG, CRS, WBM, etc.
		JRAB		FC, etc.	AB	AB, EB, etc.
		JRSB			SB	CS, LS, etc.
		JRAP			AP	TNA, FDA, etc.
		JRRB			RB	JUC, RBC, CUC, etc.
		CRGB	CR	VC,	GB	NG, CRS, WBM, etc.
		CRAB		FC, etc.	AB	AB, EB, etc.
		CRSB			SB	CS, LS, etc.
		CRAP			AP	TNA, FDA, etc.
		CRRB			RB	JUC, RBC, CUC, etc.
	Block	CBSG	CB	CB	SG	SA, NG, etc.
		BRLC	BR	BR	LC	LC
		SSGB	SS	SS	CG	LC, NG, etc.
Unpaved	Unsealed	GRUP	GR	LT, QZ, etc.		
		EAUP	EA	EA	UP	
		SAUP	SA	SA		

Table C2.2 Descriptions of surface and base materials

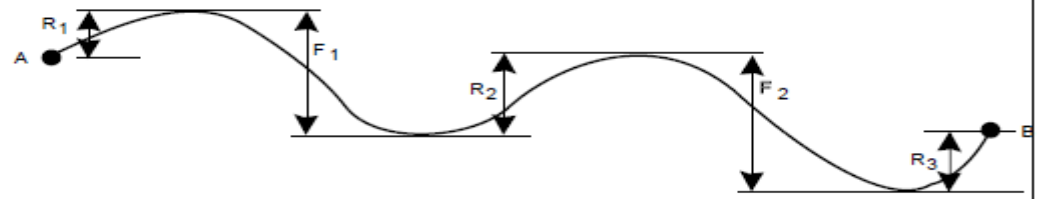
Surface type		Surface materials	
Abbreviation	**Description**	**Abbreviation**	**Description**
AM	Asphalt Mix	AC	Asphaltic Concrete
		CM	Soft Bitumen Mix (Cold Mix)
		HRA	Hot Rolled Asphalt
		PA	Porous Asphalt
		PMA	Polymer Modified Asphalt
		RAC	Rubberised Asphalt Concrete
		SMA	Stone Mastic
ST	Surface Treatment	CAPE	Cape Seal
		DBSD	Double Bituminous Surface Dressing
		PM	Penetration Macadam
		SBSD	Single Bituminous Surface Dressing
		SL	Slurry Seal
Base types		**Base materials**	
Abbreviation	**Description**	**Abbreviation**	**Description**
AB	Asphalt Base	CRS	Crushed Stone
AP	Asphalt Pavement	NG	Natural Gravel
GB	Granular Base	CS	Cement Stabilisation
SB	Stabilised Base	LS	Lime Stabilisation
		TNA	Thin Asphalt Surfacing
		FDA	Full Depth Asphalt

Plan View of road section



- Average horizontal curvature (deg/km) = $\dfrac{C_1 + C_2 + C_3 + C_4}{L_{AB}}$ $\dfrac{\text{(deg)}}{\text{(km)}}$
- L_{AB} = length of road section AB (km)

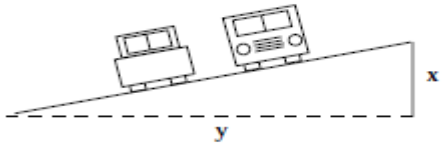
Plan View of road section



- Average rise plus fall (m/km) = $\dfrac{R_1 + F_1 + R_2 + F_2 + R_3}{L_{AB}}$ (km)
- Average number of rises and falls per km = $\dfrac{5}{L_{AB}}$ $\dfrac{\text{(m)}}{\text{(km)}}$

Road cross-section at bends (exaggerated vertical scale)

- Super-elevation, $e\ (\%) = \dfrac{100\,x}{y}$



Road Side Friction

XFRI = 0.70

XFRI = 0.60

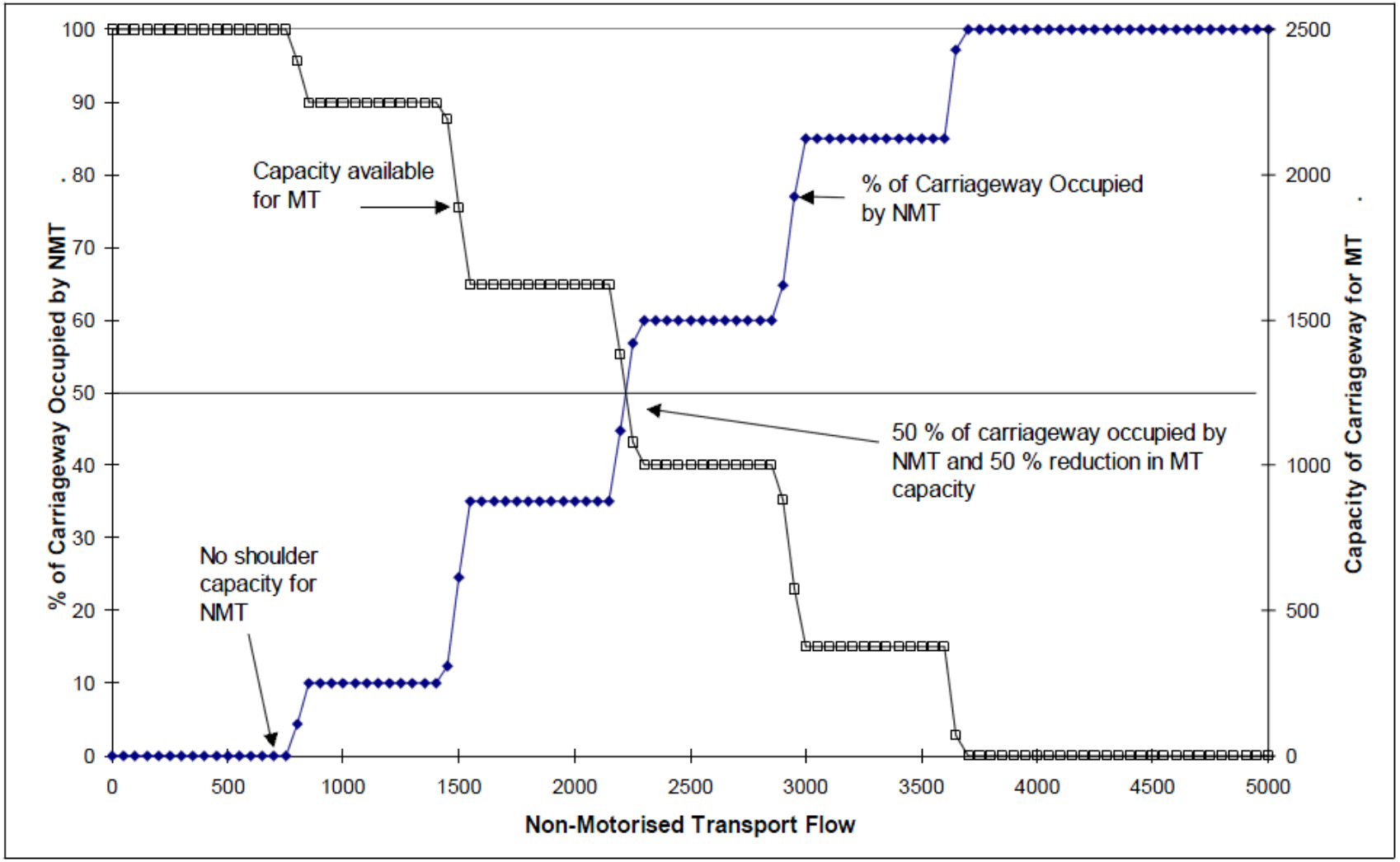


Figure B12.1: Effect of NMT on Capacity

Table C1.2 Pavement defects modelled in HDM-4

Bituminous	Concrete	Block*	Unsealed
Cracking	Cracking	Rutting	Gravel loss
Ravelling	Joint spalling	Surface texture	Roughness
Potholing	Faulting	Roughness	
Edge break	Failures		
Rutting	Serviceability loss		
Surface texture	Roughness		
Skid resistance			
Roughness			

* Not implemented in this HDM-4 release

Table C2.5 Definitions of distress measures

Measure	Definition
Area (of distress)	Sum of rectangular areas circumscribing manifest distress (line cracks are assigned a width of 0.5 m), expressed as a percentage of the carriageway area
All cracking	Narrow and wide structural cracking inclusive
Narrow cracking	Interconnected or line cracks of 1-3 mm crack width (equivalent to AASHTO Class 2)
Wide cracking	Interconnected or line cracks of 3 mm crack width or greater, with spalling (equivalent to AASHTO Class 4)
Indexed cracking	Normalised sum of AASHTO Classes 2 to 4 cracking weighted by class, see Section 5.3
Transverse thermal cracking	Unconnected crack running across the pavement
Ravelling	Loss of material from wearing surface
Pothole	Open cavity in the road surface with at least 150 mm diameter and at least 25 mm depth
Edge-break	Loss of bituminous surface material (and possibly base materials) from the edge of the pavement
Rutting	Permanent or unrecoverable traffic-associated deformation within pavement layers which, if channelled into wheelpaths, accumulates over time and becomes manifested as a rut
Rut depth	Maximum depth under 2 m straightedge placed transversely across a wheelpath
Roughness	Deviations of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage (ASTM E-867-82A) – typically in the ranges of 0.1 to 100 m wavelength and 1 to 100 mm amplitude
IRI	International Roughness Index, the reference measure expressing roughness as a dimensionless average rectified slope statistic of the longitudinal profile and defined in *Sayers et al. (1986)*
Mean Texture depth	The average depth of the surface of a road surfacing expressed as the quotient of a given volume of standardised material [sand (sand patch test), glass spheres] and the area of that material spread in a circular patch on the surface being tested, (*PIARC, 1997*)
Skid resistance	Resistance to skidding expressed by the sideways force coefficient (SFC) measured using the Sideways Force Coefficient Routine Investigation Machine (SCRIM)

3.1 Adjusted structural number

Pavement strength is characterised by the adjusted structural number, SNP, (*Parkman and Rolt, 1997*). This has been derived from the modified structural number, which was adopted as the pavement strength descriptor for HDM-III. The adjusted structural number applies a weighting factor, which reduces with increasing depth, to the sub-base and subgrade contributions so that the pavement strength for deep pavements is not over-predicted (a concern with the use of the modified structural number). It is calculated as:

$$SNP_s = SNBASU_s + SNSUBA_s + SNSUBG_s \qquad ...(3.1)$$

$$SNBASU_s = 0.0394 \sum_{i=1}^{n} a_{is}\ h_i \qquad ...(3.2)$$

$$SNSUBA_s = 0.0394 \sum_{j=1}^{m} a_{js} \left\{ \left(\frac{b_0 \exp(-b_3 z_j)}{-b_3} + \frac{b_1 \exp(-(b_2+b_3) z_j)}{(b_2+b_3)} \right) - \left(\frac{b_0 \exp(-b_3 z_{j-1})}{-b_3} + \frac{b_1 \exp(-(b_2+b_3) z_{j-1})}{(b_2+b_3)} \right) \right\} \qquad ...(3.3)$$

$$SNSUBG_s = [b_0 - b_1 \exp(-b_2 z_m)]\,[\exp(-b_3 z_m)]\,\left[3.51 \log_{10} CBR_s - 0.85\,(\log_{10} CBR_s)^2 - 1.43\right] \qquad ...(3.4)$$

where:

SNP_s	adjusted structural number of the pavement for season s
$SNBASU_s$	contribution of surfacing and base layers for season s
$SNSUBA_s$	contribution of the sub-base or selected fill layers for season s
$SNSUBG_s$	contribution of the subgrade for season s
n	number of base and surfacing layers ($i = 1, 2, \ldots, n$)
a_{is}	layer coefficient for base or surfacing layer i for season s
h_i	thickness of base or surfacing layer i (mm)
m	number of sub-base and selected fill layers ($j = 1, 2, \ldots, m$)
z	depth parameter measured from the top of the sub-base (underside of base) (mm)

HDM-4 - HDM-4 Workspace

Workspace Window Help

Workspace

- Maintenance Standards [12]
  - Base Alternative: N3 Reseal
  - Concrete Maintenance
  - Full Maintenance
  - N2_12 Rehab Option
  - N2_12 Rehab Option Alt 1
  - N2_12 Reseal Option
  - Option 1: N3 Overlay
  - Periodic Maintenance
  - Rehabilitation
  - Routine Maintenance
  - RRM Post Improvement
  - Special Maintenance
- Improvement Standards [7]

New | Open | Delete | Copy | Rename | Export | Import

For Help, press F1

Maintenance Standard: Full Maintenance

General

Name: Full Maintenance

Short code: NRAFM

Surface class: Bituminous

OK | Cancel

Work Items

DSRGS: Rehabilitation with seal	DSRGS
MPRAC: 40mm Asphalt Overlay	MPRAC
MPRS2: Double Seal 13/6.7	MPRS2
MPRS1: Single Seal 13 mm	MPRS1
MPRS9: Diluted Emulsion	MPRS9
MRPPR: Pothole Repair	MRPPR
MPRS4: Cape Seal 19 mm	MPRS4

Add New Work Item... | Copy Work Item | Delete Work Item | Edit...

List of maintenance work items associated with this standard

Maintenance Works Item: MPRS2: Double Seal 13/6.7

General | Design | Intervention | Costs | Effects | Asset Valuation

Intervention Trigger Expression

Two-way AADT >= 2000, <= 10000 veh/day	AND
Total carriageway cracked >= 5, <= 50 %	AND
Interval >= 7 Year(s)	
OR	
Two-way AADT >= 2000, <= 10000 veh/day	AND
Skid resistance <= 0.25 SFC	AND
Interval >= 7 Year(s)	
OR	
Two-way AADT >= 2000, <= 10000 veh/day	AND
Texture depth <= 0.4 mm	AND
Interval >= 7 Year(s)	
OR	
Two-way AADT >= 2000, <= 10000 veh/day	AND
Interval >= 7 Year(s)	

Add New Criterion... | Edit Criterion... | Copy Criterion... | Paste Criterion... | Delete Criterion | Add OR expression | Copy OR expression | Paste OR expression | Delete OR expression

OK | Cancel | Apply

Add an intervention criterion

start | MetaFrame Presenta... | <Recently Edited Do... | SAP Logon 710 - \\R... | Microsoft PowerPoin... | HDM-4 - HDM-4 Wor... | HDM4 | EN | 08:01 AM

B13.1 Modelling Logic

B13.1.1 Ranking of Works

A works activity (or operation) is triggered when any one or a combination of user-specified criteria has been met. When more than one works activity meets the criteria for being applied in a given analysis year, the highest ranking operation for the particular road feature is selected.

Table B13-1 shows the ranking of works activities that are applicable to the carriageway.

Table B13-1
Ranking of carriageway road works

Works type	Works activity / operation	Ranking	Unit cost
New section	Dualisation of an existing section	1	per km
Upgrading	Upgrading to a new surface class	2	per km
Realignment	Geometric realignment	3	per km
Widening	Lane addition	4	per m^2 or per km
	Partial widening	5	per m^2 or per km
Reconstruction	Pavement reconstruction	6	per m^2 or per km
Rehabilitation	Mill and replace	7	per m^2
	Overlay rubberised asphalt	8	per m^2
	Overlay dense-graded asphalt	9	per m^2
	Overlay open-graded asphalt	10	per m^2
	Inlay	11	per m^2
	Thin overlay	12	per m^2
Resurfacing (Resealing)	Cape seal with shape correction	13	per m^2
	Cape seal	14	per m^2
	Double surface dressing with shape correction	15	per m^2
	Double surface dressing	16	per m^2
	Single surface dressing with shape correction	17	per m^2
	Single surface dressing	18	per m^2
	Slurry seal	19	per m^2
Preventive Treatment	Fog sealing	20	per m^2
	Rejuvenation	21	per m^2
Routine Pavement	Edge-repair[1]	22	per m^2
	Patching[1]	22	per m^2
	Crack sealing[1]	22	per m^2

Note 1: Routine pavement works (i.e. crack sealing, patching, edge-repair) have the same ranking, and all of them can be performed in the same analysis year

INPUTS	MODEL	OUTPUTS
Vehicle type, volume, growth, loading, physical parameters, terrain, precipitation, road geometry, pavement characteristics, unit costs	Start of analysis loop	
Pavement type, strength, age, condition, and ESAL	Road Deterioration	Cracking, ravelling, potholes, rut depth, faulting (paved); gravel thickness (unpaved); roughness
Road geometry and roughness; vehicle speed, type; congestion parameters; unit costs	Road User Effects	Fuel, lubricant, tyres, maintenance, capital costs, speed, travel time, road user costs, road accidents
Road works standards and strategies	Works Effects	Reset road condition and geometry. Works quantities and costs
Road geometry and surface texture, vehicle characteristics	Social and Environmental Effects	Levels of emissions and energy used
Agency costs, road user costs, exogenous costs and benefits	Economic Analysis	Total costs by component; net present values and rates of return by section
	Return to start of analysis loop	

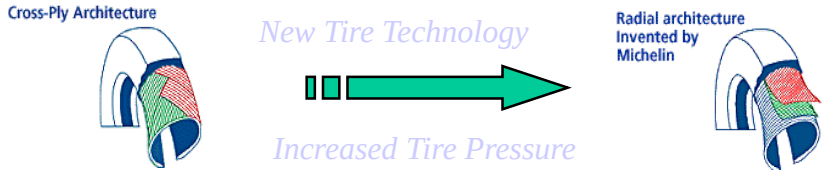
Figure A1.1
Life-cycle analysis using HDM-4

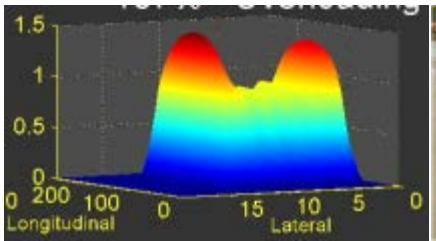
Workflow button	Tab-page	Procedure	
Define Project Details	General	1	Specify the Road Network that contains the Sections to be analysed.
		2	Specify general Project information such as the start year, duration, and output Currency.
		3	Specify the analysis mode. There are two modes of analysis: ■ By Project Determines the best alternative for the group of Sections analysed. ■ By Section Determines the best alternative for each Section.
	Study Sections	4	Select specific Sections for analysis and assign a traffic growth to them.
Specify Alternatives	Alternatives	5	Define the alternatives to be analysed. Some alternatives may include diverted and/or generated traffic, exogenous benefits and costs, and new Sections.
Analyse Projects	Setup run	6	Customise the run setup. This includes: ■ Specifying if an economic analysis should be performed. ■ If performing an economic analysis, specifying a base alternative with which the other alternatives should be compared, and a discount rate. ■ Specifying various sub-models and calculation options. ■ Specifying various run control and save options.
	Sensitivity	7	Select to perform sensitivity analysis and define the required attributes.
	Run Analysis	8	Run the analysis. If vital information is missing, you are informed, and must supply the necessary information so that HDM-4 can complete the run. The time required to perform the analysis depends on the complexity of the Project.
Multi-Criteria Analysis	MCA Setup	9	Setup the parameters required to perform a Multi-criteria analysis, if required.
	Results	10	View the results of the Multi-criteria analysis.
Generate Reports	Select Reports	11	Generate reports and examine the results of the run.

South African Pavement Design Method (SAPDM)

Why is Revision of SAMDM Required ?

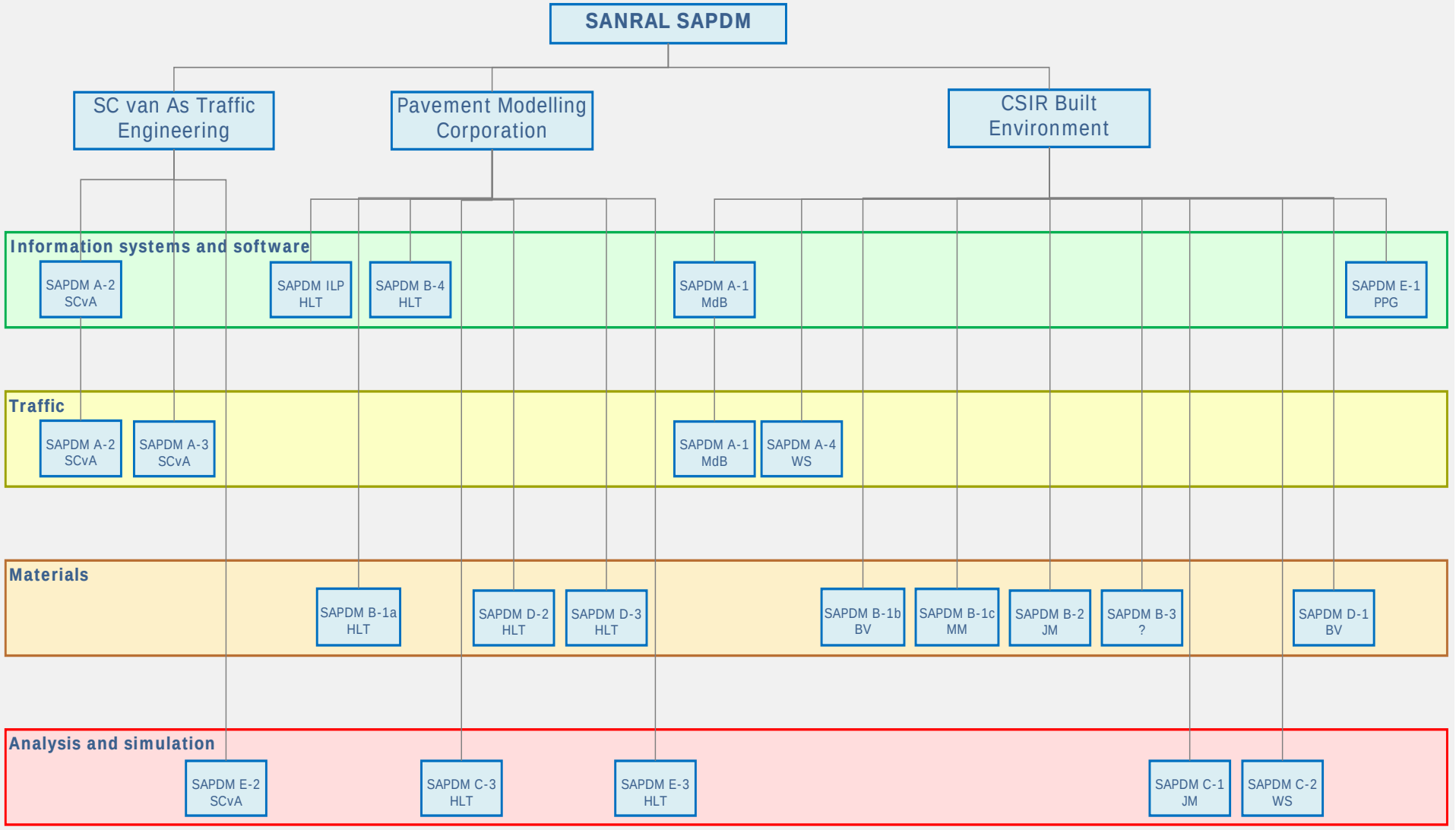
- Summary
  - Road Deterioration
    - Classical ME design method - single estimate of bearing capacity - **no lifecycle model**
    - Critical layer approach – distress mechanisms disconnected
    - Separated resilient response and damage models
  - Material resilient response
    - Recommended M_r and Poisson's Ratio values
      - Conflict between slow (Deflectograph) and dynamic (FWD) test results
  - Road User Life Cycle Costs
    - **Not Included**
- Users are disillusioned with the method
  - Counter-intuitive and inadmissible results
  - Extreme sensitivity of the method to input data
  - Inconsistent input
    - Resilient response (FWD, MDD, Laboratory)
    - Strength parameters
- Statements made that ME-design is not possible due to:
  - Too many unexplained effects (chaos)
  - Getting the right answers for the wrong reasons (i.e. correctly predicted expected life, but wrong layer failing !)
- New Technology



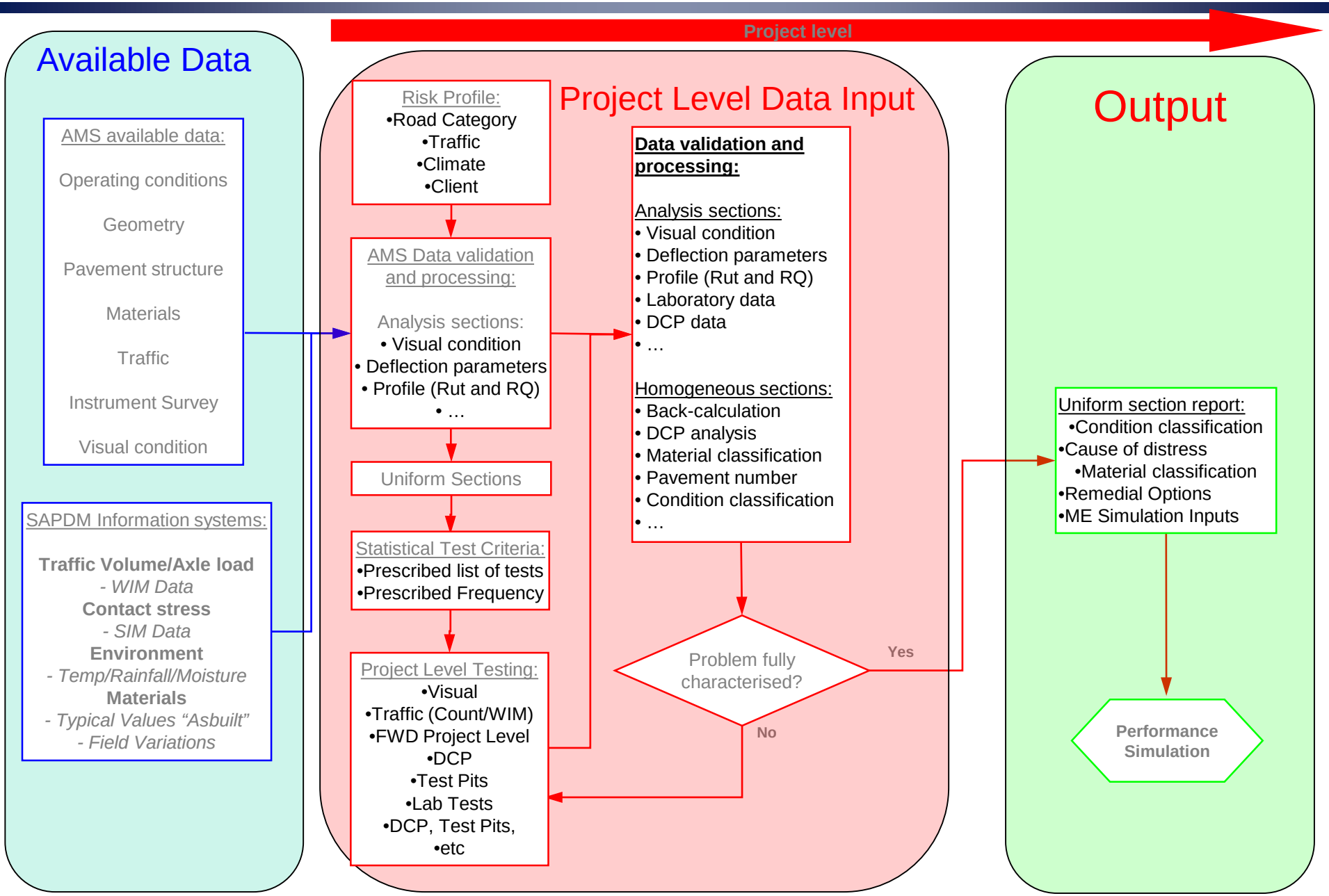


SAPDM Revision – Current Status

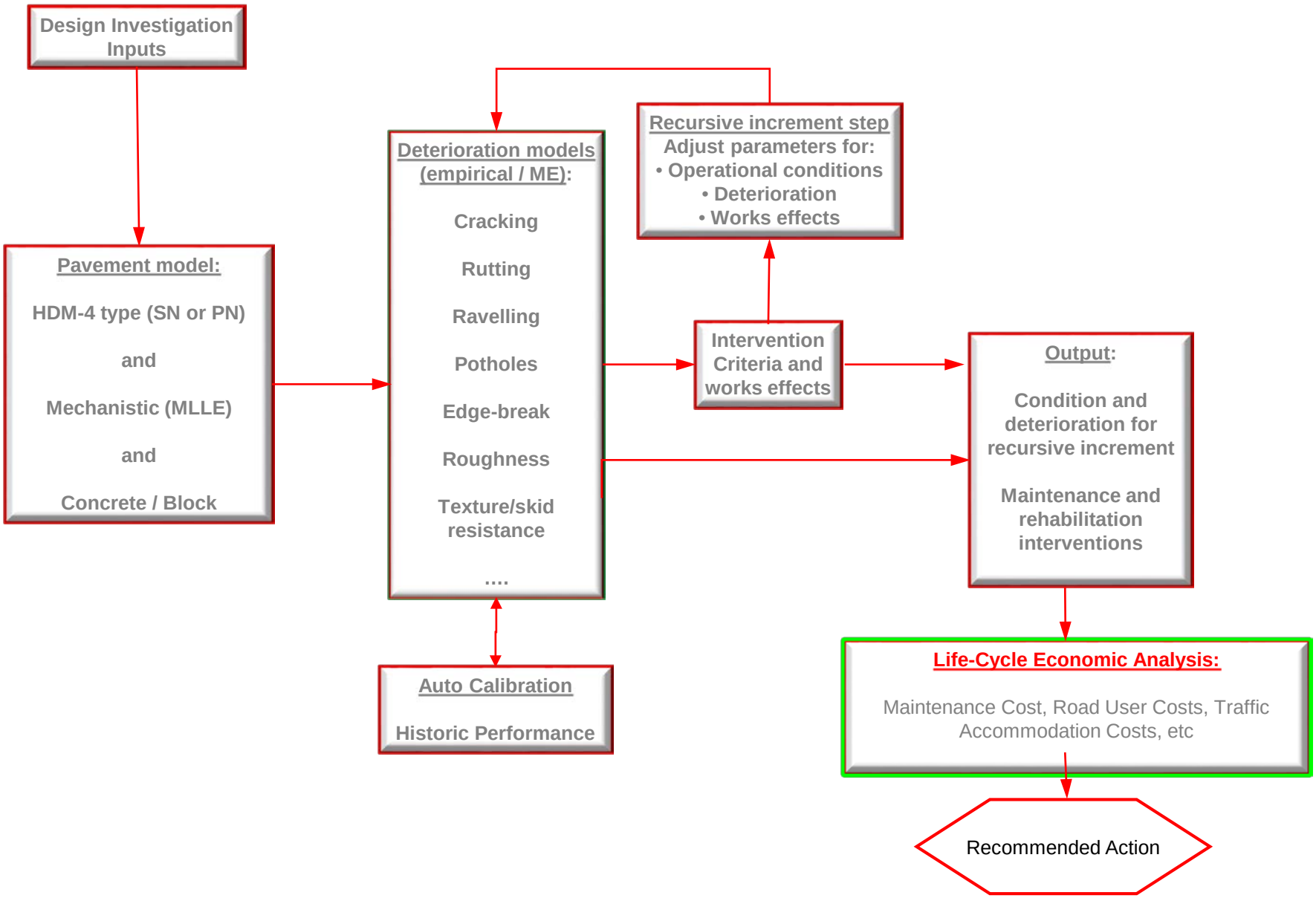
- Appointment of Main Service Providers – September 2008



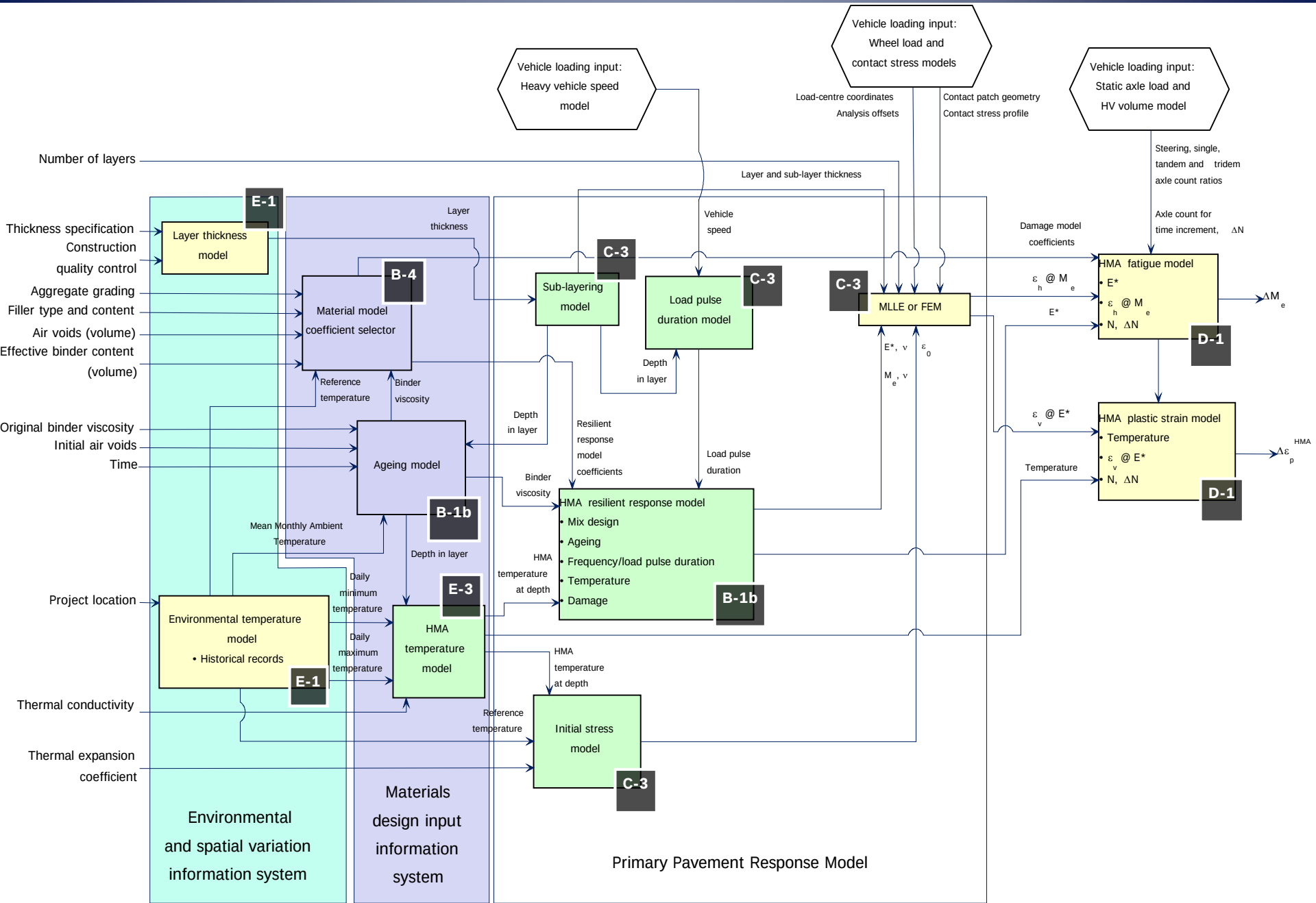
SAPDM – Investigation Process Flow



SAPDM – Performance Simulation Process Flow

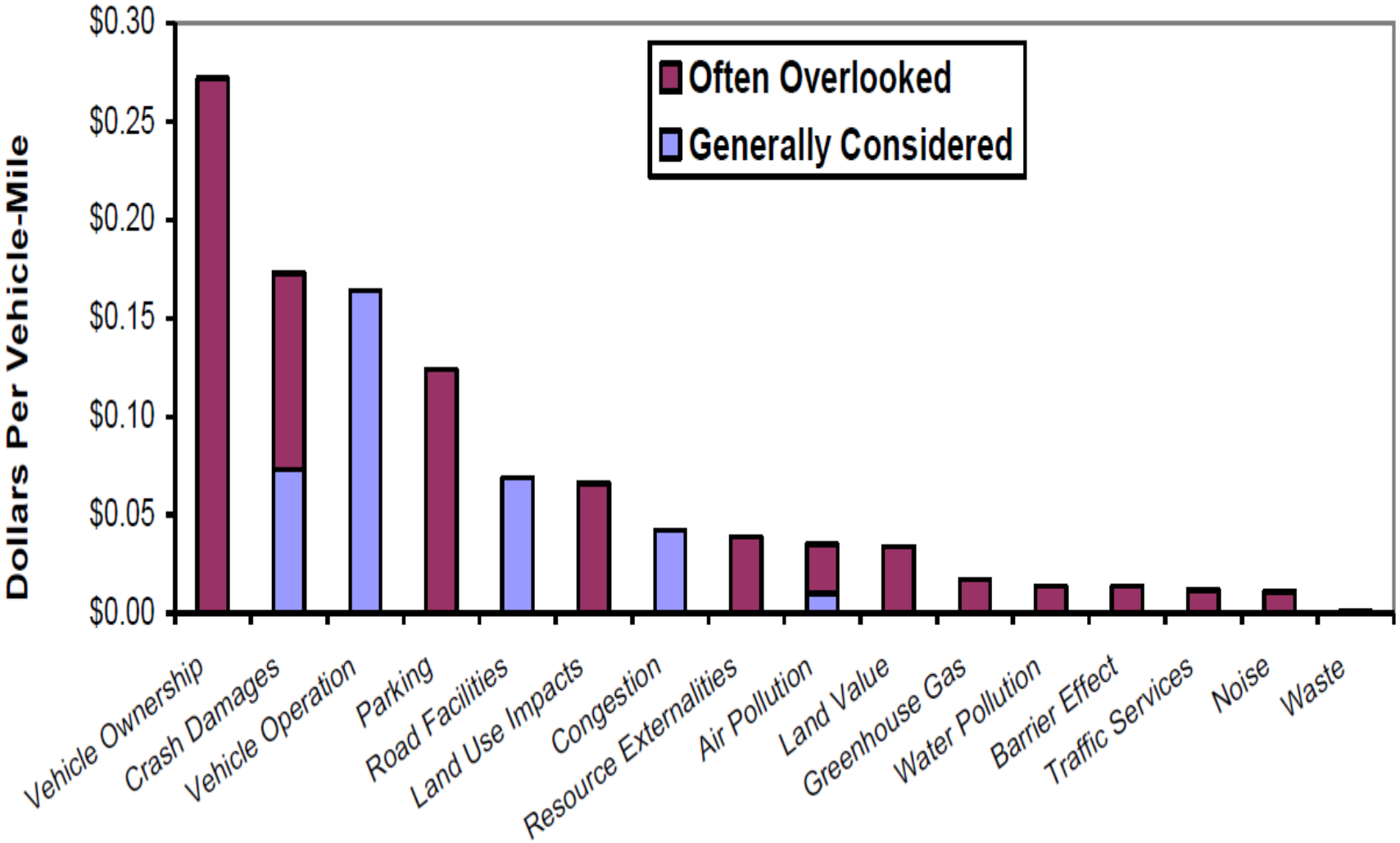


SAPDM – Performance Simulation – Asphalt



SAPDM Considered Costs ?

Figure 1 **Automobile Costs** (Litman 2009)



Thank You