<u>HDM-4</u>

HIGHWAY DEVELOPMENT & MANAGEMENT

volume two Applications Guide

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THE HIGHWAY DEVELOPMENT AND MANAGEMENT SERIES

About This Manual

This manual is a task-oriented guide describing typical examples of different types of analyses using HDM-4 Version 2.0. It is designed for users that are familiar with HDM-4 who wish to know how to perform HDM-4 analyses or create a study. This manual is one of seven volumes comprising the suite of HDM-4 documentation as illustrated below.

Volu Overview	me 1 of HDM-4
Volume 2	Volume 3
Applications Guide	Software User Guide
Volume 4	Volume 5
Analytical Framework and Model Descriptions	A Guide to Calibration and Adaptation
Volumo 6	Volumo 7
Modelling Road Deterioration	Modelling Road User and
and Works Effects	Environmental Effects

The suite of documents comprises:

Overview of HDM-4 (Volume 1)

A short executive summary describing the HDM-4 system. It is intended to be used by all readers new to HDM-4, particularly high level management within a road organisation

Applications Guide (Volume 2)

A task oriented guide describing typical examples of different types of analyses. It is to be used by users who wish to know how to perform a task or create a study.

Software User Guide (Volume 3)

Describes the HDM-4 software. It is a general purpose document which provides an understanding of the software user interface.

Analytical Framework and Model Descriptions (Volume 4)

Describes the analytical framework and the technical relationships used within the HDM-4 model. It contains comprehensive reference material describing the characteristics of the modelling and strategy incorporated in HDM-4. It is to be used by specialists or experts whose task is to carry out a detailed study for a road management organisation.

- A Guide to Calibration and Adaptation (Volume 5)
 - Suggests methods for calibrating and adapting HDM-4 models to allow for local conditions existing in different countries.
- Modelling Road Deterioration and Works Effects (Volume 6) Describes the development and basis for the relationships in HDM-4 used for modelling road deterioration and works effects.
- Modelling Road User and Environmental Effects (Volume 7)
 - Describes the development and basis for the relationships in HDM-4 used for modelling road user and environmental effects.

Structure of this Manual

The aim of this Applications Guide is to demonstrate the different applications of HDM-4 version 2.0 through selected case studies. The case studies are described in detail and may be reviewed using the data files included on the CD-ROM.

Part A contains a short description of the life-cycle analysis framework used in HDM-4. The concepts of analysis for projects, programmes and strategies are described in Parts B, C and D respectively. Example case studies for Project Analysis are given in Part E, Programme Analysis case studies in Part F and Strategy Analysis case studies in Part G.

ISOHDM Products

The products of the International Study of Highway Development and Management Tools (ISOHDM) consist of the HDM-4 suite of software, associated example case study databases, and the Highway Development and Management Series collection of guides and reference manuals. This Volume is a member of that document collection.

Customer Contact

Should you have any difficulties with the information provided in this suite of documentation please do not hesitate to report details of the problem you are experiencing. You may send an E-mail or an annotated copy of the manual page by fax to the number provided below.

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Change Details

The first edition of Volume 2 detailed case studies for HDM-4 version 1. This second edition details case studies for HDM-4 version 2.0.

Related Documentation

HDM-4 documents

The Highway Development and Management Series Collection is ISBN: 2-84060-058-7, and comprises:

Volume 1 – Overview of HDM-4, ISBN: 2-284060-183-4

Volume 2 – Applications Guide, ISBN: 2-284060-184-2

Volume 3 – Software User Guide, ISBN: 2-284060-185-0

Volume 4 – Analytical Framework and Model Descriptions, ISBN: 2-284060-186-9

Volume 5 – A Guide to Calibration and Adaptation Manual, ISBN: 2-84060-063-3

Volume 6 – Modelling Road Deterioration and Works Effects, ISBN: 2-84060-102-8

Volume 7 – Modelling Road User and Environmental Effects, ISBN: 2-84060-103-6

Terminology handbooks

PIARC Lexicon of Road and Traffic Engineering - First edition. Permanent International Association of Road Congresses (PIARC), Paris 1991. ISBN: 2-84060-000-5

Technical Dictionary of Road Terms - Seventh edition, English - French. PIARC Commission on Terminology, Paris 1997. ISBN: 2-84060-053-6

General reference information

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The initial part of the development of HDM-4 has been sponsored by several agencies, primarily:

- Asian Development Bank (ADB)
- Department for International Development (DFID) in the United Kingdom
- The World Bank
- Swedish National Road Administration (SNRA)

with significant contributions made by:

- Finnish Road Administration (FinnRA)
- Intra-American Federation of Cement Producers (FICEM)

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Finnra

Specification of the strategic and programme analysis applications.

FICEM

Development of deterioration and maintenance relationships for Portland cement concrete roads.

 The Highway Research Group, School of Civil Engineering, The University of Birmingham

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 Road Research Institute (IKRAM) in Malaysia supported by N.D.Lea International (NDLI)

Responsible for providing updated relationships for road deterioration and road user costs.

Transport Research Laboratory (TRL) in the United Kingdom

Responsible for review and update of the road deterioration relationships.

SNRA

Responsible for developing deterioration relationships for cold climates, road safety, environmental effects, and supporting HRG with system design.

Australian Road Research Board (ARRB)

Responsible for review of the specifications on bituminous pavement and unsealed road deterioration models.

Laboratoire Central des Ponts et Chaussées (LCPC) in France

Responsible for overseeing the definition of the specifications for Version 2 and the software development.

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APPLICATIONS GUIDE FOR HDM-4 VERSION 2

PART A CONCEPTS OF HDM-4 ANALYSIS

1 BACKGROUND

The Highway Design and Maintenance Standards Model (HDM-III), developed by the World Bank, was used for over two decades to combine technical and economic appraisals of road investment projects, and to analyse strategies and standards (Watanatada, et al, 1987 and Paterson, 1987). In the 1990's an international study was initiated to extend the scope of the HDM-III model, and to provide a harmonised systems approach to road management, with adaptable and user-friendly software tools. This resulted in the development of the Highway Development and Management Tool (HDM-4).

The scope of HDM-4 has been broadened considerably beyond traditional project appraisals, to provide a powerful system for the analysis of road management and investment alternatives, primarily in four key areas:

Project appraisal

For the economic appraisal of road maintenance, rehabilitation, upgrading and new construction through life-cycle analysis of proposed road investments.

Works programming

For the preparation of multi-year and rolling programmes for road network maintenance and development to facilitate the preparation of medium term budgets for road network maintenance and extension.

Strategic planning

For policy development, long term resource allocation plans and road network planning.

Software environment

A user-friendly system, built around a set of modules with the capacity to cope with a wide range of data requirements and user skill levels.

2 Life-Cycle Analysis

The underlying operation of HDM-4 is similar for a project, programme or strategy analysis. In each case, HDM-4 simulates total life-cycle conditions and costs for an analysis period under a user specified scenario of circumstances. The primary cost set for the life-cycle analysis includes the costs to the road agency of maintaining and improving the road network and costs to road users of vehicle operation, passenger time and road accidents. Environmental effects in the form of vehicle emissions and energy consumption are quantified but not included in the cost streams.

The broad concept of the life-cycle analysis is illustrated in Figure A1. Interacting sets of costs, related to those incurred by the road administration and those incurred by the road user, are added together over time in discounted present values. Costs are determined by first predicting physical quantities of resource consumption and then multiplying these quantities by their unit costs or prices. Economic benefits are then determined by comparing the total cost streams for various maintenance and construction alternatives with a base case (**do nothing** or **do minimum** alternative), usually representing minimal routine maintenance.



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

HDM-4 is designed to make comparative cost estimates and economic analyses of different investment options. It estimates the costs for a large number of alternatives year-by-year for a user-defined analysis period, discounting the future costs. Rates of return, net present values (NPV), and NPV per investment unit can also be determined by HDM-4. In order to make these comparisons, detailed specifications of investment programmes, design standards, and maintenance alternatives are needed, together with unit costs, projected traffic volumes, and environmental conditions.

The model simulates, for each road section, year-by-year, the road condition and resources used under each alternative, as well as the vehicle speeds and physical resources consumed by vehicle operation. Physical quantities involved in construction, maintenance and vehicle operation are estimated, and user-specified prices and unit costs applied to determine financial and economic costs. Relative benefits are then calculated for different alternatives, followed by present value and rate of return computations.

Details of the benefits and costs considered in HDM-4 are included in Part G of Volume 4, the Analytical Framework and Model Descriptions manual.

The three main types of outputs produced by HDM-4 to aid decision making are as follows:

- Economic efficiency indicators from analyses of individual road projects
- Multi-year works programmes produced after prioritisation of several candidate road projects and associated works alternatives
- Strategic road maintenance and development plans produced from long term predictions of road network performance

3 APPLICATIONS

HDM-4 can assist with:

- Project analysis for detailed economic appraisal (see Section 3.1)
- Programme analysis for annual or rolling works programme preparation (see Section 3.2)
- Strategic analysis for long term planning (see Section 3.2)
- Research and policy studies (see Section 0)

3.1 **Project Analysis**

Project Analysis is concerned with:

Évaluation of one or more road projects or investment options. The application analyses a set of road sections with user-selected treatments, with associated costs and benefits, projected annually over the analysis period. Economic indicators are determined for the different investment options.

This is essentially the use for which the earlier generations of HDM systems were developed. Project analysis is used to estimate the economic or engineering viability of road investment projects by considering the following issues:

- Pavement surface and structural performance
- Life-cycle predictions of road deterioration, maintenance effects and costs
- Road user costs and benefits

Economic comparisons of project alternatives

Typical appraisal projects would include the maintenance and rehabilitation of existing roads, widening or geometric improvement schemes, pavement upgrading and new construction. Case studies demonstrating the application of Project Analysis are presented in Section E.

The philosophy of this analysis has not fundamentally changed from the HDM-III version, but improved road deterioration relationships have been extended to cover a wider range of pavements and the performance of materials in temperate and cold climates. Road user cost relationships have been updated and extended to include the impacts of road accidents. Environmental impacts assessment and energy balance analysis are also included.

3.2 **Programme and Strategy Analyses**

It is in the areas of Programme Analysis and Strategy Analysis that HDM-4 offers significant improvements over HDM-III.

Programme Analysis is concerned with:

Preparation of a multi-year rolling programme for a road network in which candidate investment options are identified and selected, subject to resource constraints. Road networks are analysed section by section and estimates are produced of road works and expenditure requirements for each section for each year of the funding period.

Strategy Analysis is concerned with:

Analysis of a chosen network as a whole, for preparing long range planning estimates of expenditure needs for road development and conservation under different budget scenarios. The road network is characterised by lengths of road in different categories defined by parameters such as road class, surface type, and pavement condition or traffic flow. Estimates are produced of expenditure requirements for medium to long term periods of 5 - 40 years.

The main difference between strategy and programme analysis is the way in which sections are physically identified:

Programme Analysis

Deals with sections that are unique physical units identifiable from the road network throughout the analysis.

Strategy Analysis

Considered as grouped representative sections typical of the road network to be analysed. The road system essentially loses its individual section characteristics.

For both types of analysis, the problem can be posed as one of seeking that combination of treatment alternatives across a number of sections in the network that optimises an objective function under budget constraint. If, for example, the objective function is the maximisation of NPV (Net Present Value), the problem can be defined as:

Select that combination of treatment options for all sections, with one treatment strategy selected per section, that maximises NPV for the whole network subject to the sum of the treatment costs being less than the budget available.

An important difference between strategic and programme analysis, and that for project analysis, is in the detail at which data are defined. Use is made of the concept of **Information Quality Levels** (IQL) recommended by the World Bank (Paterson and Scullion,

1990). Project level analysis data are specified in terms of measured defects (IQL-II), whereas the specification of data for strategic and programme analyses can be more generic (IQL-III).

For example at project level analysis, roughness would be specified in terms of m/km IRI, whereas at programme and strategy level analyses, roughness may be specified as good, fair or poor.

Case studies demonstrating the application of Programme and Strategy analyses are included in Section F and G respectively.

3.3 Research and Policy Studies

HDM-4 can be used to conduct a number of road sector policy studies including:

- Funding policies for competing needs; for example, feeder roads versus main roads
- Road user charges for setting up road funds
- Impacts of road transport policy changes on energy consumption
- Impact of axle load limits
- Pavement maintenance and rehabilitation standards

4 IMPROVEMENTS IN HDM-4 VERSION 2.0

HDM-4 version 1.0 was first released in January 2000, followed by three updated versions (versions 1.1, 1.2 & 1.3) over the following couple of years Feedback provided by users of these versions of HDM-4 on the usability and functionality of the software led to the further development and improvement of HDM-4. This resulted in the release of version 2.0 of the HDM-4 software in August 2005.

Improvements that are included in version 2.0 of HDM-4 can be categorised as follows:

- Improved Analysis Models Sensitivity Analysis Budget Scenario Analysis Multi-Criteria Analysis (MCA) Estimation of Social Benefits Asset Valuation
- Improved Connectivity
 Run-data in MS Access format
 Import/Export in MS Access
 Import Validation
- Improved Data Handling & Organisation Updated Database Technology Re-design of New Section Facilities Traffic Re-design Report Management

- Improved Technical Models
- Bituminous Road Deterioration
- Bituminous Work Effects
- Unsealed Road Deterioration
- Unsealed Work Effects
- Road User Effects
- •

Improved Usability & Configuration

Intervention Editor & Work Item Triggering Logic Alternatives User-Interface The model DLL architecture Post-Improvement Maintenance Standards Temporary Exclusion of Sections from Study Calibration Sets Improved Configuration - Accident Classes Improved Configuration - Speed Flow Types Improved Configuration - Traffic Flow Patterns

A brief description of these improvements is given in the Getting Started With HDM-4 Version 2.0 manual and detailed descriptions of each category given in the updated version of the Software User Guide (Volume 3). As this document focuses on the analytical applications in HDM-4, only the improvements to the analysis models are described below.

5 IMPROVED ANALYSIS MODELS

5.1 Sensitivity Analysis

Sensitivity Analysis has been introduced to Project Analysis to allow a user to investigate the impact of variations in key parameters on the analysis results. A user can define any number of sensitivity scenarios in which any of the 18 key parameters can be varied. These key parameters cover unit costs, vehicle use, traffic levels and growth, and net benefits. One or more key parameters are varied by defining a multiplication factor and the effects on the outcome of the analysis will be determined. A user determines which variables to vary and this judgment will depend upon the kind of investigation being conducted. Typically the key parameters will be varied to reflect the potential range of forecasts for the parameters.

5.2 Budget Scenario Analysis

HDM-4 version 2.0 allows the user to specify an unlimited number of budget scenarios within the Programme Analysis or Strategy Analysis applications. Each budget scenario defines the road agency financial resources available over the analysis period. The optimised work programme will be produced for each of the selected budget scenarios therefore allowing the user to compare the effects of different funding levels on the network being analysed.

5.3 Multi-Criteria Analysis (MCA)

Multi-Criteria Analysis (MCA) provides a means of comparing projects using criteria that cannot easily be assigned an economic cost. MCA can only be used in the Project Analysis application in HDM-4 and supports 9 criteria to evaluate:

- Economic (Road User Costs RUC, Net Present Value NPV)
- Functional (Comfort, Congestion)
- Energy (Energy Efficiency)
- Political
- Safety (Accident Analysis)
- Environmental (Air Pollution)
- Social (Social Benefits)

5.4 Estimation of Social Benefits

It has often been necessary to include the social benefits of road investments within HDM-4. The simple framework for including social benefits has now been made more transparent by incorporating them within the exogenous costs and benefits user interface.

5.5 Asset Valuation

A road network is a considerable resource that has a significant asset value. It is therefore important to effectively manage this asset and to be able to estimate the financial and economic value of road assets as a function of the level of investment. This optional component of HDM-4 Version 2.0 allows a user to estimate the asset value of a network being analysed during the time period of the analysis.

PART B PROJECT ANALYSIS

1 INTRODUCTION

Project analysis allows users to assess the physical, functional and economic feasibility of specified project alternatives by comparison against a base case, or a without-project alternative. The key processes of the analysis are:

Prediction of road deterioration

Estimation of road user costs (vehicle operating costs, travel time and accidents)

Modelling of road works effects and the costs of these to the road administration

Calculation of economic benefits from comparisons of the project alternatives

The aim is to determine which project alternative is most cost-effective. Four case studies to demonstrate this application are described in Section E.

Project analysis is associated with the following types of road projects:

Maintenance of existing roads

These works cover a wide range of maintenance techniques for different pavement types. This type of works also includes those that arise when a road pavement has received insufficient maintenance over its life, or because the pavement was not built to the standards of quality required by the original design.

Improvement of existing roads

These projects aim to provide additional capacity when a road is nearing the end of its life or because there has been an unforeseen change in use of the road. Works include measures to improve the quality of service, such as relieving traffic congestion, road safety, road passibility, the need to accommodate increased vehicle axle loads, etc. Typical examples of road improvement projects are:

- Pavement reconstruction
- Pavement upgrading
- The paving of gravel roads, the provision of concrete pavements in places where the subgrade soils may be very poor, etc.
- Road widening and geometric improvements
- Includes widening of existing carriageways, the provision of additional lanes, dualcarriageways, overtaking lanes, climbing lanes, and the betterment of shoulders.
- Realignment and pavement upgrading of the existing roadway
- Combines the activities described in pavement upgrading and road widening.

New construction

Involves the construction of a new pavement in an entirely new location, although in many cases they follow existing alignments. New alignments are required, for example, for bypasses, or in difficult terrain, or to connect other new infrastructure developments.

Stage construction

Consists of planned improvements to the pavement standards of a road at fixed stages throughout the project life. Often, the road alignment needed at the final stages of the project is provided from the outset. A typical strategy might be initially to construct a gravel road that will be paved when traffic flows have reached a given level.

Evaluation of past projects

Assesses the performance of a completed project to see if objectives set out during appraisal have been met. Project evaluation requires project data that have been collected and recorded in a systematic way throughout all stages of the project cycle. The evaluation should result in specific recommendations about improving aspects of the project design that can be used to improve ongoing and future planning.

2 ANALYSIS METHODS

Two methods of analysing investment options are provided in HDM-4 Project Analysis:

- Analysis by Section
- Analysis by Project

2.1 Analysis by Section

In Analysis by Section, each of the road sections selected for the project are analysed separately. Several alternatives (i.e. maintenance and/or improvement standards) can be defined for each section as shown in Table B2.1 (e.g. three alternatives for section A, four alternatives for section B, etc.), with one alternative designated by the user as the **base alternative** against which all the other alternatives will be compared. Economic indicators (e.g. NPV, IRR and NPV/C) are calculated for each section alternative.

Poad	Section Alternative					
Section	1 Base Alternative	2	3	4	5	
Section A	Routine Maintenance	Resealing	Overlay			
Section B	Routine Maintenance	Overlay	Reconstruction	Widening		
Section C	Routine Maintenance	Resealing	Rehabilitation	Lane addition	Realignment	
Section D	Grading 1 / year	Regravelling	Paving			

Table B2.1Analysis by Section

2.2 Analysis by Project

In Analysis by Project, a project is defined as the set of road works to be carried out on one or more road sections that can be grouped together conveniently to be undertaken as one contract or work instruction. Several project alternatives can be analysed to determine, for example, which is the most cost-effective to implement. A project alternative can consist of different works options applied to various sections making up the project as shown in Table B2.2.

Using this method, road sections are analysed together as a package by considering project alternatives as the basic unit for performing economic analysis. First, the annual costs and benefits are summed over all the section alternatives within each project alternative to give yearly totals. Economic indicators are then calculated for each project alternative by comparison against the **base alternative**.

Pood	Project Alternative				
Section	1 2 Base Alternative		3	4	
Section A	Routine Maintenance	Resealing	Reconstruction	Realignment	
Section B	Routine Maintenance	Overlay	Mill and replace	Widening	
Section C	Routine Maintenance	Inlay	Reconstruction	Lane addition	
Section D	Grading 1 / year	Regravelling	Widening	Upgrading	
ΣProject NPV	0	ΣΝΡΥ	ΣΝΡΥ	ΣΝΡΥ	

Table B2.2 Analysis by Project

Analyses involving new sections and diverted traffic can only be performed using this method. Table B2.3 shows the definition of a project involving the construction of a new section (e.g. a by-pass), and the maintenance of four existing road sections which are affected by the introduction of the new link, mainly in terms of traffic diversion effects.

Pood	Project Alternatives				
Section	1 Base Alternative	2	3	4	
Section A	Routine	Routine	Routine	Routine	
	Maintenance	Maintenance	Maintenance	Maintenance	
Section B	Routine	Routine	Routine	Routine	
	Maintenance	Maintenance	Maintenance	Maintenance	
Section C	Routine	Routine	Routine	Routine	
	Maintenance	Maintenance	Maintenance	Maintenance	
Section D	Routine	Routine	Routine	Routine	
	Maintenance	Maintenance	Maintenance	Maintenance	
New Section		AMSB 2-lane	AMSB 4-lane	STGB 4-lane	
ΣProject NPV	0	ΣΝΡΥ	ΣΝΡΥ	ΣΝΡΥ	

Table B2.3 Analysis Involving New Sections

3 PROCEDURE FOR PROJECT ANALYSIS

The procedure for project analysis is summarised below and described in the following sections.

- 1. Create the road project to be analysed by giving it a title and specifying the road network to be analysed.
- 2. Define the project by specifying the following:
 - a) general information about the project
 - b) method of analysis
 - c) road sections to be analysed

- 3. Specify maintenance and improvement standards to be analysed for each selected road section.Set-up and run the analysis. Optionally carry out sensitivity analysis.
- 4. Generate the reports and if necessary, print the required outputs.

3.1 Creating a Project

To create a project, give the project a title and select a previously created road network as shown in the screen below. In version 2.0 of HDM-4 the vehicle fleet that uses the road network needs to be specified at the time that the road network is created. Thus by specifying the road network to be used in the analysis, the vehicle fleet is automatically selected.

New Project		×
<u>N</u> ame:		ОК
<u>R</u> oad Network:	<undefined></undefined>	Cancel
Vehicle <u>F</u> leet:	<undefined></undefined>	
The title of the proj	ject	

Having created a new Project Analysis, the following screen is displayed:

📫 HDM-4 - [Projec	t: Demo]	_ <u>8</u>
Workspace Viev	<u>Report/Chart Window H</u> elp	_ _ 8
Define Project	General Study Sections	
Specify Alternatives	Description:	
Analyse Projects		
Multi Criteria Analysis	Analyse by: Start year: Analysis period: Anal	
Generate Regorts	Road Network: National Road Network Matrix	
	Vehicle Eleet: National Vehicle Characteristics	
	Currencies	
	Worke: US Dollar x 1 = output currency	
	Wolgs. US boliai × 11 - output currency	
	Network: US Dollar × 1 = output currency	
	Qutput: US Dollar	
Save		
Close		
Dealershield and she was		

The information required to define and run a Project Analysis is described below.

3.2 Define Project Details

Project details that need to be defined are as follows:

3.2.1 General

Description

A brief description of the works involved in the project.

Analysis method

Select the method of analysis as either:

- Analysis by Section or
- Analysis by Project

Start year of the analysis period

Duration of the analysis period

Output currency

The units of currency in which the project outputs are to be presented.

Conversion rate

The conversion factors between the output and vehicle fleet currency units, and that between output and road works currency units used in the analysis.

3.2.2 Study Sections

All the sections in the selected road network are available for analysis. The sections to be included in an analysis can be selected using the following methods:

Selecting sections individually

Individual sections are selected by clicking on the box in the Study column at the left of the section. Sections can be unselected by clicking on the boxes of the sections that have been selected

Selecting sections by criteria

An alternative approach to selecting sections is to define criteria to be used to select sections. The following criteria are available:

Pavement

Surface class – options are All, Bituminous, Concrete or Unsealed Structural Adequacy – options are All, or one of the pre-defined categories

Speed Flow Type

Options are All, or one of the pre-defined categories

Traffic Volume

Options are All, or one of the pre-defined categories

Geometry

Minimum and/or maximum values of Rise and Fall (m/km), Horizontal Curvature (deg/km) and Carriageway Width (m)

The selection criteria can be used to add new sections to those already selected, or to replace those selected.

Traffic Growth

A pre-defined traffic growth set has to be assigned to each selected section. A copy facility is available to copy a growth set that has been assigned to one section to other sections.

3.3 Specify Alternatives

Certain road works may generate additional traffic on a road section, or cause traffic to divert from other roads to a road section. The generated and/or diverted traffic characteristics need to be specified for such works. The method of specifying alternatives is dependent of whether Analysis by Section or Analysis by Project has been selected in the Project Details dialog screen.

Analysis by Section

The assignment of one or more Maintenance and/or Improvement Standards to a road section results in the formation of a Section Alternative. A section alternative is one of a set of mutually exclusive works alternatives specified as options to be analysed for an applicable road section within a project. The basic unit of analysis in HDM-4 is the section alternative.

In Analysis by Section, an alternative entitled Base Alternative is automatically created for each selected section, to which Maintenance and/or Improvement Standards can be assigned. The user can add as many alternatives to a section as required for the analysis of that section. An example is shown in Table B2.1.

A section alternative is defined by firstly giving the alternative a name. Maintenance and/or Improvement Standards are then assigned, specifying the date from which the standard is effective. For Improvement Standards, the user has the option of including generated traffic and exogenous benefits and costs.

Analysis by Project

In Analysis by Project, the user needs to define an alternative. A project alternative is defined by firstly giving the alternative a name. All selected sections are assigned to the alternative. Maintenance and/or Improvement Standards are then assigned to each section, specifying the date from which the standard is effective. For example, each of the columns numbered 1 to 4 in Table B2.2 constitutes a project alternative.

For Improvement Standards, the user has the option of including generated traffic and exogenous benefits and costs. If the project includes the construction of a new section, the user has the option of including diverted traffic.

3.4 Analyse Projects

3.4.1 Setup Run

In Setup Run, the user specifies the scope of the analysis to be undertaken.

Conduct Economic Analysis

If economic analysis is to be performed, the base alternative needs to be selected if Analysis by Project is being undertaken. If Analysis by Section is being undertaken, the base alternative is automatically selected. For both types of analysis, the **discount rate** needs to be specified.

Accident Costs

If accident analysis is to be included, then unit costs for accidents should be specified for fatal, injury, damage only or all accidents.

Other Models

Other models that can be included in the analysis are energy balance, vehicle emissions and acceleration effects.

Asset Valuation

This optional component estimates the asset value of a network that is being analysed during the analysis period. This option is new in version 2 of HDM-4.

3.4.2 Sensitivity

The impact of variations in key parameters on the analysis results can be investigated using this option. Any number of sensitivity scenarios can be investigated by varying any of the 18 parameters that are displayed. Multiplication factors are defined for the parameters and the effects on the outcome of the analysis will be determined.

3.4.3 Run Analysis

Selecting the **Start** button runs the project analysis. During the run, the status is displayed in terms of the stage of analysis reached and the percentage completion. The analysis can be stopped at any time by clicking the **Abort** button.

3.5 Multi Criteria Analysis

MCA Setup

The user can choose from 9 criteria, and set the relative importance of each criterion. The base criterion also needs to be selected from one of the 9 criteria. The relative importance of the base criterion is automatically set to 'equally preferred'. Having selected the base criterion and at least one other criterion, then clicking the Start button commences the MCA.

Results

The results of the MCA are displayed on this screen.

3.6 Generate Reports

The reports that are generated by HDM-4 can be categorised as input data or analyses results. These reports, presented in tabular format and in some cases a graphical format, are stored in the following folders:

- Traffic
- Deterioration / Works Effects
- Road User Effects
- Environmental Effects
- Cost Streams and Economic Evaluation
- Input Data Multi Criteria Analysis
- Asset Valuation

PART C PROGRAMME ANALYSIS

1 INTRODUCTION

Programme Analysis deals primarily with the prioritisation of a defined list of candidate road projects into a one-year or multi-year works programme under defined budget constraints. The candidate road projects are discrete segments of a road network. The selection criteria will normally depend on the maintenance, improvement or development standards that a road administration may have defined.

When all candidate projects have been identified, the HDM-4 programme analysis application can be used to compare the life-cycle costs predicted under an existing pavement management scenario (i.e. the base alternative) against the life-cycle costs predicted for the periodic maintenance, road improvement or development alternative (i.e. the other user-specified alternatives). This provides the basis for estimating the economic benefits that would be derived by including each candidate project within the budget timeframe.

The programme analysis application may be used to prepare a multi-year rolling works programme, subject to resource constraints. The prioritisation method employs the incremental NPV/cost ratio as the ranking index, which provides an efficient and robust index for prioritisation purposes. Indices such as the NPV, economic rate of return (ERR), or predicted pavement condition attributes (e.g. road roughness) are not recommended as ranking criteria. The incremental NPV/cost ratio satisfies the objective of maximising economic benefits for each additional unit of expenditure.

2 ANALYSIS METHODS

The purpose of programme analysis is to evaluate maintenance or improvement options, and to try and select the set of investments to be made on a number of road sections in a road network, which will optimise an objective function. Programme analysis is concerned with short to medium term planning and preparation where budget levels are known with reasonable certainty. Thus the problem can be posed as one of searching for the combination of investment alternatives that optimises the objective function, under a budget constraint.

Two methods of analysis are provided in programme analysis:

Life-cycle analysis

Multi-year forward programme

In both cases, optimisation is done using the incremental NPV/Cost ratio where the problem can be defined as the selection of that combination of investment options on sections that maximises total NPV for the selected sections in the road network subject to the sum of the investment costs being less than the budget available.

Note that the set of investment options to be optimised is user-defined and is not the set of all possible options for the particular network; hence the problem is not true optimisation since all possible solutions are not normally considered. Note also that the investment options on any one section are mutually exclusive.

2.1 Life-Cycle Analysis

The life-cycle analysis for the development of an unconstrained works programme is identical to that for project analysis as described in Section A0 and illustrated in Figure A1.1.

To produce a constrained works programme under budget optimisation, the user must specify a set of section alternatives which offer different timing alternatives for the assigned maintenance and/or improvement standards, or different standards, which provide a means by which costs can be delayed or reduced.

A typical need is to specify sufficient timing alternatives so that any investment backlog can be substantially removed or deferred to a period where unconstrained funding may exist. The problem is normally a short-medium term constraint, where typically single 'constrained' budget periods may be specified for a number of years, and an unconstrained budget is provided beyond.

An example is shown below:

Section alternatives	<u>Assignments</u>	Year
Base Alternative	Minimum maintenance	from Year 1
Year 1 – Periodic maintenance	Periodic Maintenance	from Year 1
Year 2 – Periodic maintenance	Minimum maintenance	from Year 1
	Periodic maintenance	from Year 2
Year 3 – Periodic maintenance	Minimum maintenance	from Year 1
	Periodic maintenance	from Year 3
etc	etc	etc

The need to specify timing alternatives is to provide sufficient section-alternatives so that where the 'ideal' section-alternative cannot be selected in the year where it appears on the unconstrained works programme due to budget constraints, then a possibility of it being selected in another year will exist. This can only occur if a reasonable number of choices are given. The method is illustrated in Programme Case Study No.1 in Section F.

2.2 Multi-Year Forward Programme

For many road agencies, the short term planning cycle is normally based on a one year budget period. However, other road agencies adopt a multi-year tactical planning period. A common example of a multi-year forward programme is a three-year works programme, which could be considered as three calendar year budget periods.

The multi-year forward programme option is a simplification of the life-cycle analysis method based on comparison of the following alternatives:

- Apply the assigned road works within the budget period or
- Postpone road works until the first year after the budget period

This simplification is normal practice in works programming – if there is insufficient budget, then works are postponed - and it can be used to keep the analysis simple and reduce run times when there is a large number of road sections to be analysed.

Economic calculations are done by comparing investments made within the budget period against deferring the action to the first year after the budget period as illustrated in Figure C2.1. For example, an overlay applied in the first year of the budget period year would be compared against the road works required in the year after the budget period. The deferred road works are not necessarily the same because the road could be in worse condition after postponement of the overlay, and a higher level of investment may be needed.



Figure C2.1 Calculation of benefits for a multi-year works programme

A simplifying assumption is made that the deferred action will be less effective in improving pavement condition as shown in Figure C2.1. It is also assumed that the pavement performance after the next year will be similar for both alternatives. Therefore, there is no need to calculate pavement deterioration and road user costs beyond the first year after the budget period. This approach is a modification of that used in the United States Highway Economics Requirements System (HERS) and in the UK Highway Agencies PMS (HAPMS).

The following two examples in Table C2.1 and Table C2.2 illustrate the above process.

Section	Works required in Year 1	Works required in Year 2
S1	Overlay	Overlay
S2	Overlay	Reconstruct
S3	Overlay	Overlay

Table C2.1Example of one-year forward programme

In Table C2.1, a one-year works programme for three sections is analysed. An overlay is triggered for all sections in year 1, but the budget is insufficient for all these works. If the work is deferred to year 2, section S2 requires reconstruction. Both alternatives are generated for each road section in order to calculate the economic indicators used in the optimisation.

The first alternative is user specified in terms of maintenance or improvement standards with their associated intervention levels. The base alternative is automatically generated by HDM, applying the same maintenance or improvement standards, with the works that been deferred until the first year after the budget period,

The second example in Table C2.2 illustrates a 3-year works programme for four sections.

Section	Programme Period Alternative 1		Deferred Works Alternative 2	
	Year 1	Year 2	Year 3	Year 4
S1	Reseal			Overlay
S2	Overlay			Reconstruct
S3		Reseal		Overlay
S4			Reseal	Reseal

Table C2.2Example of three-year forward programme

When defining a multi-year forward programme analysis, only one maintenance standard and/or one improvement standard is specified for each section. Normally this would be effective from the first year of the programme period. The interventions for the standards should be condition related. In the example shown in Table C2.2, the intervention criteria may have been of the form:

Reseal	when	3 < Roughness < 4 IRI
Overlay	when	4 < Roughness < 6 IRI
Reconstruct	when	Roughness > 6 IRI

Thus, in the case of section S1, the roughness was between 3 and 4 IRI at the end of the first year (reseal) but had increased to value between 4 & 6 IRI at the end of the year 4, requiring an overlay. The base alternative in this example is Alternative 2 (works in the first year after the budget period), and the economic benefits are calculated by comparing Alternative 1 for each section against Alternative 2.

Care must be taken that the maintenance and improvement standards used are compatible. For example, if the works programme requires maintenance and the deferred work is a major improvement (due to a threshold being reached in the intervention criteria for the improvement standard) a distorted result will occur. This is because no benefits are estimated for the effects of the improvement as it is applied in the final year of the analysis. So an abnormally high NPV will be calculated due to the large difference in cost between the maintenance and improvement works.

When specifying an improvement standard, there is a field for the residual value of the new work in the asset valuation window. This is the value of the work remaining at the end of the analysis period and is deducted from the agency costs in the last analysis year.

3 PROCEDURE FOR PROGRAMME ANALYSIS

The procedure for programme analysis is summarised below and described in the following sections.

- 1. Create the programme analysis by giving it a title and specifying the road network to be analysed.
- 2. Define the programme by specifying:
 - a) general information about the programme
 - b) method of analysis
 - c) road sections to be analysed
- 3. Specify maintenance and/or improvement standards to be analysed for each selected road section
- 4. Generate an unconstrained works programme analysis
- 5. Define budget constraints
- 6. Generate an optimised works programme within the constrained budget
- 7. Generate the required outputs

3.1 Creating a Programme

To create a programme, give the programme a title and select a previously created road network. In version 2.0 of HDM-4 the vehicle fleet that uses the road network needs to be specified at the time that the road network is created. Thus by specifying the road network to be used in the analysis, the vehicle fleet is automatically selected.

Having created a new Programme Analysis, the following screen is displayed.



The information required to define and run a Programme Analysis is described below.

3.2 Define Programme Details

Programme details that need to be defined are as follows:

3.2.1 General

Description

A brief description of the works involved in the programme.

Analysis method

Select the method of analysis as either:

- Life-Cycle or
- Multi-Year Forward Programme

Start year of the analysis period

Duration of the analysis period

Output currency

The units of currency in which the programme analysis outputs are to be presented.

Conversion rate

The conversion factors between the output and vehicle fleet currency units, and that between output and road works currency units used in the analysis.

3.2.2 Study Sections

All the sections in the selected road network are available for analysis. The sections to be included in an analysis can be selected using the same two methods as described for Project Analysis (see Section B3.2.2).

A pre-defined traffic growth set has to be assigned to each selected section. A copy facility is available to copy a growth set that has been assigned to one section to other sections.

3.3 Specify Alternatives

The method of specifying alternatives is dependent on whether Life-Cycle or Multi-Year Forward Programme has been selected as the analysis method.

Life-Cycle

If Life-Cycle has been selected then an alternative entitled Base Alternative is automatically created for each selected section, to which Maintenance and/or Improvement Standards can be assigned. The user can add as many alternatives to a section as required for the analysis of that section.

A section alternative is defined by firstly giving the alternative a name. Maintenance and/or Improvement Standards are then assigned, specifying the date from which the standard is effective. For Improvement Standards, the user has the option of including generated traffic and exogenous benefits and costs.

This process is similar to the specification of alternatives for Project Analysis. However, timing alternatives should be considered where a budget constraint is applicable (i.e. same maintenance / improvement alternatives assigned to different years (see Section C.2.1).

Multi-Year Forward Programme

For Multi-Year Forward Programme, only one maintenance standard is allowed per road section except where an improvement standard has been specified, in which case it must be followed by a maintenance standard. The analysis will be carried out by applying only one maintenance or improvement standard for each section, and selecting one works item (highest in the hierarchy) from the given standard for each year of the analysis period.

3.4 Generate Programme

3.4.1 Perform Run

The options available in Perform Run depend on whether Life-Cycle or Multi-Year Forward Programme analysis has been selected.

Life-Cycle

The Base Alternative is automatically selected using the Maintenance and/or Improvement Standards that have been previously assigned to this alternative.

Multi-Year Forward Programme

The user has the options of running an analysis with or without economic analysis.

The other options are common for both types of analysis.

Accident Costs

If accident analysis is to be included, then unit costs for accidents should be specified for fatal, injury, damage only or all accidents.

Other Models

Other models that can be included in the analysis are **energy balance**, **vehicle emissions** and **acceleration effects**.

Asset Valuation

This optional component estimates the asset value of a network that is being analysed during the analysis period. This option is new in version 2 of HDM-4.

Selecting the **Start** button initiates the analysis. During the run, the status is displayed in terms of the stage of analysis reached and the percentage completion. The analysis can be stopped at any time by clicking the **Abort** button.

3.4.2 Unconstrained Programme

After either multi-year forward programme **or** life-cycle analysis, the options with the highest NPV (net present value) are assigned for each section. The result of this process is a tentative, unconstrained works programme, determined from the maintenance or improvement standards defined by the user.

One of the key aspects of road management is the ability to intervene and select projects that should be carried out for reasons other than economic priority alone. Practitioners have stressed the need for user intervention to select discrete projects to be assigned high priorities for maintenance. Such projects should meet the minimum criterion of a positive economic return in order to qualify for the user selected list.

Users may select projects to be committed (i.e. given high priority for funding) from the unconstrained programme. The pre-defined works will then be submitted to the optimisation routines to schedule projects that can be undertaken within the budget constraints taking into account the pre-defined projects.

The costs of works classified by the user as recurrent are not initially displayed in the unconstrained works programme. The user has the option to display the costs of the recurrent works.

3.5 Perform Budget Optimisation

The user can specify any number of budget scenarios to investigate. For each scenario the user specifies the budget available for different budget periods of the analysis period. Separate analyses are conducted for each budget scenario.

If the needed budget for each budget period is below the given budget constraints, no further economic analysis is necessarily needed. However, if the budget needs are higher than the available budgets, the user has two choices:

- 1. Review maintenance and improvement standards and then run the analysis again
- 2. Execute an economic analysis and optimisation

Two methods for budget optimisation are used in programme analysis.

- Total enumeration
- Incremental NPV/cost ranking

Both methods are described in detail in Volume 4 of the HDM-4 series – Analytical Framework and Model Descriptions.

Once the budget optimisation has been performed, an optimised programme is generated for each budget scenario. The user needs to select from the pull-down menu the appropriate budget scenario to view the optimised programme for that budget scenario.

3.6 Generate Reports

The input data and the results of the analysis are presented in appropriately named reports that are stored in folders as listed in Section B3.6

PART D STRATEGY ANALYSIS

1 INTRODUCTION

Strategic planning of medium to long term road network expenditures considers the requirements of an entire road network asset which may be a network or sub-network managed by one road organisation or situated within an administrative area (a state or county for example). Examples of sub-networks might be; all motorways or expressways, all main roads, all paved roads etc.

Strategy analysis is primarily a tool for resource allocation by, or for, managers within a road agency. Typical applications of strategy analysis would include:

Medium to long term forecasts of funding requirements for specified target road maintenance standards.

Forecasts of long term road network performance under varying levels of funding.

Optimal allocation of funds according to defined budget heads; for example routine maintenance, periodic maintenance and development (capital) budgets.

Optimal allocations of funds to sub-networks; for example, by functional road class (main, feeder and urban roads, etc.) or by administrative region.

Policy studies such as impact of changes to the axle load limit, pavement maintenance standards, energy balance analysis, provision of NMT facilities, sustainable road network size, evaluation of pavement design standards, etc.

In order to predict the medium to long term requirements of a road network or sub-network, strategy analysis normally applies the concept of a matrix of representative road sections, comprising categories of the road network defined according to the key attributes that most influence road agency and road user costs. Although it is possible to model individual road sections in a strategy analysis, road administrations will often be responsible for several thousand kilometres of roads, thereby making it cumbersome to set up and run an analysis for each road segment.

The road network matrix is defined by the most important factors affecting transport costs on the network. For example, a road network matrix could be modelled using; three traffic categories (high, medium, low), four pavement condition levels (good, fair, poor, bad) and three levels of structural adequacy (good, fair, poor). The resulting road network matrix would therefore comprise 36 ($3 \times 4 \times 3$) representative sections. In this example, it is assumed that other parameters throughout the network are similar (road geometry, environment, etc). Such a network matrix might be used to examine maintenance and/or improvement funding requirements for each cell (representative section) of the matrix.

The road length assigned to each representative section is the total length of all the road segments in the network that fall within the parameters defining the matrix cell. In the example above, the length of the first representative section would be the total length of all road sections in the network with high traffic, in good condition and having good structural adequacy.

There is no limit to the number of representative pavement sections that can be used in a strategy analysis. The trade-off is usually between a simple representative road network matrix that would give rather coarse results compared against a detailed road network matrix with more representative sections that could potentially provide more accurate results.

If the analysis uses optimisation under constrained budgets, it must be ensured that the cost of works on a single representative section does not exceed the defined constraint in a budget period. If it does it will never be selected as HDM-4 does not have the facility to "split" a section and spread the work over two or more budget periods.

Also, sufficient timing alternatives and/or standards should be specified, as for programme analysis, to ensure viable section-alternatives exist to be selected in years which differ from that identified in the unconstrained analysis.

2 ANALYSIS METHODS

The primary purpose of conducting a road network strategy analysis is to determine networkwide resource requirements and the impacts of various development and preservation options on the road network performance. The objective of the analysis can be defined as either:

- 1. Determining funding levels required to meet a given set of network performance standards
- 2. Determining network performance for given funding levels

In strategy analysis, three optimisation methods are available, each with an objective function and a constraint.

Objective Function	Constraint
Maximise benefits (NPV)	Financial agency costs
Maximise improvement in network condition (roughness)	Financial agency costs
Minimise agency costs	Target network condition (roughness)

To minimise road agency costs in order to achieve specified target road network condition, HDM-4 selects from amongst the specified road work standards, the combination which will minimise road agency costs in achieving the target road network condition.

It should be noted that the network development or preservation standards to be used in the analysis are user-defined and are not therefore the set of all possible standards for the network being analysed.

3 PROCEDURE FOR STRATEGY ANALYSIS

The procedure for strategy analysis is summarised below and described in the following sections.

- 1. Create the strategy analysis by giving it a title and specifying the road network to be analysed.
- 2. Define the strategy by specifying:
 - a) general information about the strategy
 - b) method of analysis
 - c) road sections to be analysed
- 3. Specify maintenance and/or improvement standards to be analysed for each selected road section
- 4. Generate an unconstrained works programme analysis

- 5. Define budget constraints
- 6. Generate an optimised works programme within the constrained budget
- 7. Generate the required outputs

3.1 Creating a Strategy

To create a new strategy analysis, the user has a choice of creating a new network matrix or using an existing network as shown in the screen below.

New Strategy Analysis	×
Name:	OK
Representative Network	Cancel
C Create new network matrix	
Vehicle Fleet: <undefined></undefined>	
Calibration Set: <undefined></undefined>	
Currency: <undefined></undefined>	
Use existing network:	
Boad Network: <undefined></undefined>	
Vehicle Fleet: <vehicle fleet=""></vehicle>	
Title of the Strategy Analysis study	

Create new network matrix

The user needs to select previously defined vehicle fleet, calibration set and currency. The network can then be created by adding new sections based on the aggregate data as shown in the screen below. (In this example, high traffic, good condition and good structural adequacy have been selected).

New Section from	n Aggregate Data		×
<u>N</u> ame:	T1C1S1	Speed <u>f</u> low type:	SF7 👤
<u>I</u> D:	T1C1S1	Traf flow <u>p</u> attern:	MP
Link Na <u>m</u> e:	All	<u>A</u> ccident class:	AC7
Lin <u>k</u> ID:	All	<u>C</u> limate zone:	MP
Length:	1 km	<u>R</u> oad class:	Secondary or main 💌
Cway <u>w</u> idth:	7 m	<u>⊺</u> raffic:	High 💌
S <u>h</u> oulder width:	1 m	<u>G</u> eometry:	Mostly straight and gently undula
Flow <u>direction</u> :	Two-way		
L <u>a</u> st surfacing:	2004 year		
<u>S</u> urface class:	Bituminous		
Calibratio	n Item: BC	•	Ride guality: Good 📃
Structural <u>a</u> de	quacy: Good	Su	rface condition: New
<u>C</u> ompaction	quality: Good	S	Surface te <u>x</u> ture: Good
Aggregate descripti	on of the surface texture for the road s	ection	OK Cancel

Use existing network

The user can select a previously created road network. In version 2.0 of HDM-4 the vehicle fleet that uses the road network needs to be specified at the time that the road network is created. Thus by specifying the road network to be used in the analysis, the vehicle fleet is automatically selected.

Having created a new Strategy Analysis, the following screen is displayed.

👾 HDM-4 - [Strategy: 1. Long term budget forecasts and performance trends]	
workspace View Report/Chart Window Help	_ <u>8</u> ×
Define Strategy Details General Study Sections Specify Apenatives Study Description: Strategy Case Study 1 : Long term judget forecasts and budget trends.	
Generate Strategy Generate Gotimisation Gotimisation	
Currencies Reet: US Dollar * 1 = output currency Works: US Dollar * 1 = output currency Network: US Dollar * 1 = output currency Qutput: US Dollar @ Becount rate: 8 %	
Description of the Strategy Analysis	

3.2 Define Strategy Details

Strategy details that need to be defined are as follows:

3.2.1 General

Description

A brief description of the works involved in the strategy.

Optimisation method

Select the optimisation method as either:

- Maximise NPV
- Maximise dIRI
- Minimise cost for target IRI

Start year of the analysis period

Duration of the analysis period

Output currency

The units of currency in which the strategy analysis outputs are to be presented.

Conversion rate

The conversion factors between the output and vehicle fleet currency units, and that between output and road works currency units used in the analysis.
3.2.2 Study Sections

All the sections in the selected road network are available for analysis. The sections to be included in an analysis can be selected using the same two methods as described for Project Analysis (see Section B.3.2.2).

A pre-defined traffic growth set has to be assigned to each selected section. A copy facility is available to copy a growth set that has been assigned to one section to other sections.

3.3 Specify Alternatives

An alternative entitled Base Alternative is automatically created for each selected section, to which Maintenance and/or Improvement Standards can be assigned. The user can add as many alternatives to a section as required for the analysis of that section.

A section alternative is defined by firstly giving the alternative a name. Maintenance and/or Improvement Standards are then assigned, specifying the date from which the standard is effective. For Improvement Standards, the user has the option of including generated traffic and exogenous benefits and costs.

3.4 Generate Strategy

3.4.1 Perform Run

In strategy analysis, the only analysis option available in Perform Run is Life-Cycle Analysis. The Base Alternative is automatically selected using the Maintenance and/or Improvement Standards that have been previously assigned to this alternative.

Also in Perform Run, the user specifies the scope of the analysis to be undertaken.

Accident Costs

If accidents analysis is to be included, then unit costs for accidents should be specified for fatal, injury, damage only or all accidents.

Other Models

Other models that can be included in the analysis are **energy balance**, **vehicle emissions** and **acceleration effects**.

Asset Valuation

This optional component estimates the asset value of a network that is being analysed during the analysis period. This option is new in version 2 of HDM-4.

Selecting the **Start** button initiates the analysis. During the run, the status is displayed in terms of the stage of analysis reached and the percentage completion. The analysis can be stopped at any time by clicking the **Abort** button.

3.4.2 Unconstrained Programme

After running the analysis, the options with the highest NPV (net present value) are assigned for each representative section. This produces an unconstrained works programme, determined from the maintenance or improvement standards defined by the user. This result reflects the overall needs for road works.

If the needed budget for each budget period is below the given budget constraints, no further economic analysis is necessarily needed, and the unconstrained solution can be used as an optimal strategy. However, if the budget needs are higher than the available budgets, the user has two choices:

- 1. Review maintenance and improvement standards and then run the analysis again
- 2. Execute optimisation

As for programme analysis, users may select representative sections to be committed (i.e. given high priority for funding) from the unconstrained programme. The cost of the works for the manually selected sections will then be subtracted from the budgets before allocation of resources to other sections. If manual selection is used, there must be sufficient budget to cover the manual selections plus the base alternatives for all other sections.

The costs of works classified by the user as recurrent are not initially displayed in the unconstrained works programme. The user has the option to display the costs of the recurrent works.

3.5 Perform Budget Optimisation

The user can specify any number of budget scenarios to investigate. For each scenario the user specifies the budget available for different budget periods of the analysis period. Separate analyses are conducted for each budget scenario.

Once the budget optimisation has been performed, an optimised programme is generated for each budget scenario. The user needs to select from the pull-down menu the appropriate budget scenario to view the optimised programme for that budget scenario.

3.6 Generate Reports

The input data and the results of the analysis are presented in appropriately named reports that are stored in folders as listed in Section B3.6.

PART E PROJECT ANALYSIS CASE STUDIES

1 CASE STUDY 1 – UPGRADING A GRAVEL ROAD

1.1 Introduction

This case study presents the economic analysis of a project to upgrade an existing gravel road to a paved standard. The existing road is 50 km long and passes through varying topography. For this analysis the road has been split into three sections based on geometry, pavement condition and traffic volume. Traffic and condition data are available from surveys undertaken in 2005.

The purpose of the analysis is to assess the economic benefits resulting from the proposed investment. (This differs from a financial appraisal that is concerned with the means of financing a project and the financial profitability of the project). The economic feasibility of the project is assessed by comparison against a base-line project alternative (maintaining the existing gravel road). The timing of the upgrading is examined in the case study, as this is considered vital to its feasibility.

The example described below is an Analysis by Project case study, **Project 1a. Upgrading a gravel road (by project) – without sensitivity analysis**. Two further case studies exist in the same folder which are based on the same overall project.

Project 1b. Upgrading a gravel road (by project) – with sensitivity analysis investigates the effect of changes in the value of a number of key variables on the outcome of the economic analysis.

Project 1c. Upgrading a gravel road (by section) uses the Analysis by Section method to examine the viability of the individual physical sections of the overall project. In this case sensitivity analysis is not examined.

Projects 1b and 1c case studies are discussed later in this section.

These case studies are located in the **Projects** folder in the Workspace. Double-click on Project case study **1a. Upgrading a Gravel Road (by Project) – without sensitivity analysis**.

1.2 Define Project Details

In the **Define Project Details** screen, the following tab pages may be displayed:

- General
- Study Sections

1.2.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

This case study is presented as an Analysis by Project example. The analysis period is defined by the start year 2006 and a duration of 20 years (i.e. 2006 – 2025). The sections to be analysed are in the Road Network entitled Rural Roads, to which the Northern Province Vehicles have been previously assigned as the vehicle fleet. The currency being used in this analysis is US dollars.

📫 HDM-4 - [Projec	ct: 1a. Upgrading a gravel road (by project) - without sensitivity analysis]	
Workspace View	ew <u>R</u> eport/Chart <u>W</u> indow <u>H</u> elp	×
Define Project Details	General Study Sections	
Specify Alternatives	s	
Analyse Projects	Analyse hr: C. Sertion G. Broart	
Multi Criteria Analysis	a Start year: 2006 Analysis period: 20 years	
Generate Reports	Road Network: Rural Roads	
	Vehicle tjeet: Northem Province Vehicles	
	Reet: US Dollar × 1 = output currency	
	Works: US Dollar × 1 = output currency	
	Network: US Dollar × 1 = output currency	
	Qutput: US Dollar	
Save		
Close		
Project description		

1.2.2 Study Sections

Three road sections have been selected for analysis, namely Town A to Town B (B001-01), Town B to Town C (B001-02) & Town C to Town D (B001-03).

🕸 HDM	I-4 - [Project	: 1 a	. Upgrad	ding a grave	l road (by pro	oject) - without sen	sitivity analysis]			
Wor	kspace <u>V</u> iew	R	eport/Cha	art <u>W</u> indow	Help					_ 8 ×
	Define	Ge	neral St	udv Sections	1					
	Project		- Tortar	- C	1					1
	Details	[Inc	lude in		Section	Summary		Traffic Crowth	▲
-	Specify		Study	Analysis	ID	Description	Class	Pavement	Tranic Grower	
Ľ.	Atematives	ļ	¥	<u>v</u>	B001-03	Town C to Town D	Secondary or Main	Unsealed	Project 1	
	Analyse		<u></u>	<u>v</u>	B001-02	Town B to Town C	Tertiary or Local	Unsealed	Project 1	
	Projects				B001-01	Town A to Town B	Secondary or Main	Unsealed	Project I	
-	Multi Criteria Analysis									
1	Generate Reports									
	nogono									
		l	•							
+	C		Assian Gr	rowth Set., 1	Select by Criteri	a View/Edit Section	on View/Edit Fleet			Sections Network: 3
	odve		Conv G	muth Set	Linealact All	View/Edit Notwo				Study: 3
			Sobh Cl	own oc		wiew/Luit Metwo				
31	Close		<u>H</u> aste G	rowth Set	sections	cted				
Sections	selected for an	alus								

By double-clicking on the section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case Northern Province Vehicles) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays all the previously created sets. Double-clicking on the appropriate set (in this case Project 1) displays the details of the traffic changes over the analysis period.

The traffic growth rates for the motorised traffic in this case study are displayed below (nonmotorised traffic not used in this case study).

escription: Upgrading a gravel road								
otorised Growth Periods	Non-Motorised G	rowth Periods						
Vehicle	Annual % increase from year 1		1	<u>A</u> dd New Period <u>E</u> dit Period				
Medium Bus	2.00							
Artic Truck	2.00			<u>D</u> elete Period				
Heavy Truck	2.00							
Medium Truck	2.00			Note: years are				
Light Truck	2.00			defined relative to				
Light Goods Vehicle	4.00			analysis in which				
Medium Car	4.00		-	the traffic growth				
•				set is used.				
⊥ight Goods Vehicle Medium Car ∢	4.00			analysis in which the traffic growth set is used.				

For this case study, the road has been divided into three sections based on those physical attributes that vary along its length. The main characteristics of these three sections are summarised in Table E1.1.

Section ID	B001-01	B001-02	B001-03
Section Name	Town A to Town B	Town B to Town C	Town C to Town D
Length (km)	20	10	20
Carriageway width (m)	7	6	8
Number of lanes	2	2	2
AADT (2005)	500	250	750
Rise and Fall (m/km)	10	15	30
Horizontal curvature (°/km)	50	300	15
Altitude (m)	120	295	370
Year of last regravelling	2003	2003	2003
Gravel Thickness (mm) (in 2005)	100	100	100
Roughness (IRI) (in 2005)	7	7	7

Table E1.1 Characteristics of the Sections

Definition

Each road section is considered homogeneous in terms of its physical attributes (e.g. road class, climate, carriageway width, geometry, pavement condition, traffic flow, and axle loading). Note that no shoulders are specified, and the full width of gravel surfacing is assigned as carriageway width, since in practice shoulders on a gravel road are maintained as part of the carriageway. The selected road deterioration model calibration information is also identified on this screen, including the selection of material properties.

Definition Geomet	Town D	ement Condition Other Mo	otorised Traffic Non-mot	torised Traffic Asset Valuation				
Definition Geomet <u>N</u> ame: ID: Link Na <u>m</u> e: Link ID: Length: Cway <u>W</u> idth: Shoulder Width: Flow <u>D</u> irection: <u>S</u> urface Class:	ry Pave Town C B001-03 Link AD ML-023 20 8 0 Two-way Unseale	km km km km km km km km km km km km km k	storised Traffic Non-mol Speed Elow Type: Traffic Row <u>P</u> attem: <u>A</u> ccident Class: Climate <u>Z</u> one: <u>B</u> oad Class: Calibration Set: <u>C</u> alibration Item: Selected Calibratic Pavement type: Surface material:	torised Traffic Asset Valuation				
Internation				OK Cancel				

Geometry

This screen summarises existing geometric parameters (before upgrading) including those for horizontal and vertical alignment.

Section: Town C to Town D					X		
Definition Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic Asset Valuation							
				· ·			
<u>R</u> ise + Fall:	30	m/km	Speed Reduction Factors				
N <u>o</u> . of rises + falls:	3	no./km	Х <u>N</u> MT: 1	0.4 <= XNMT <= 1			
Superelevation:	3	%	Road side <u>friction</u> : 1	0.4 <= XFRI <= 1			
<u>A</u> vg horiz curvature:	15	deg/km	X <u>M</u> T: 1	0.4 <= XMT <= 1			
a <u>d</u> ral:	0.1	m/s²					
Speed limit:	100	km/h					
Speed limit <u>e</u> nforcement:	1.1						
A <u>l</u> titude:	370	m					
				OK Cance			
Average road rise plus fall (in m/k	m)						

Pavement

The surface and subgrade material types are given in this screen, together with the year of last regravelling (2003 for this case study).

Section: Town C to Town D
Definition Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic Asset Valuation
Surface Material: Lateritic gravel
Subgrade Material: Well-graded gravel-sands with small clay content, GC
Compaction method: Mechanical
Last regravel year: 2003
OK
Subgrade material

The material properties can be reviewed under **Configuration/RD Calibration Sets/Rural** in the Unsealed tab page.

<u>N</u> ame: Rural								
Model library (DLL): HDM-4 Default DLL								
RD Calibration Item	Plg	P02g	P425g	P075g	THG (mm)	PIs	P02s	
aterite Gravel	10.10	51.10	41.60	25.50	0.00	15.00	60.0	
(
New Item Copy Item Or Delete Item								

Condition

The information on this screen confirms a gravel thickness of 100 mm and a roughness of 7 IRI in 2005. Note that, to enable road condition to be modelled through the analysis period, condition data must be specified for the year prior to the start of the analysis period. In this case study the condition data refer to the end of 2005, with an analysis start year of 2006.

ction: Town C to Town D	x
Definition Geometry Pavement Condition Other Motorised Traffic Non-motorise	ed Traffic Asset Valuation
Condition at end of year 2005 Gravel Thickness (mm) 100.00 Roughness (IRI - m/km) 7.00	
	OK Cancel
rly condition data	

Other

The number of lanes (ELANES) is specified as 2 for the existing road. The ELANES of the road after improvement is defined within the Improvement Standard.

efinition Geometry Pavement Condition Other Motori	sed Traffic Non-motorised Traffic Asset Valuation
Separate NMT lanes Number of lanes: 0	Compaction (Bituminous only) Relative compaction: 0 %
Shoulders (Concrete only) Shoulder type: Non-concrete Midth of widening: 0 m	Previous surface condition (Bituminous only) Area of all structural cracking: 0 % Area of wide cracking: 0 1/2 %
	<u>E</u> LANES: 2
	OK Cancel

Motorised Traffic

The AADT for the section B001-03 (Town C to Town D) is 750 divided as shown between the various vehicle types within the Vehicle Fleet. If certain vehicle types are not represented on the road section being analysed, then a value of zero should be entered (as for 4WD & Minibus in this case study).

inition deometry 1 a	vement Condition	on Other	Motonsed frame	Non-motorised Traffic	Asset Valuation
Vehicle Fleet used for th	his section/netwo	rk: Northe	m Province venicles	3	
Survey Year:	2005				Edit Year
4WD	0.00				
Artic Truck	30.00				
Heavy truck	30.00				
Light Goods Vehicle	120.00				
Light Truck	120.00				
Medium Bus	30.00				
Medium Car	300.00				
Medium Truck	120.00				
Mini-bus	0.00				
Total AADT:	750.00				

Non-motorised Traffic

For this case study no NMT is specified.

Asset Valuation

Asset valuation is not considered in this case study (see Section 0 for an example of the use of the asset valuation functionality).

1.3 Specify Alternatives

A total of five project alternatives are considered in this case study for each section. The first alternative, **Base Alternative**, represents a continuation of current maintenance practice. The 2nd to 5th alternatives represent the implementation of the project to upgrade the existing gravel road to paved standard. The duration of the upgrade is two years for road sections B001-01 and B001-03, and one year for section B001-02. The upgrade alternatives include upgrading the road starting in the year 2006, 2008, 2010 or 2012.

The maintenance and improvement (upgrading) standards for the project alternatives are summarised in Table E1.2. The maintenance standards are stored in the **Works Standards** / **Maintenance Standards** folder and the improvement standards are stored in the **Works Standards** / **Improvement Standards** folder.

For the Base Alternative the Gravel Road Maintenance standard is applied to the three sections from the start of the analysis period (i.e. from 2006). For the Upgrading alternatives, the Upgrading improvement standard is applied in either year 2006, 2008, 2010, or 2012, with the Maintenance before Upgrading standard applied for the years prior to the start of the upgrading, followed by the Maintenance after Upgrading standard applied once the Upgrading has been completed.

It should be noted that only one Maintenance Standard or Improvement Standard will be effective in any analysis year. However a Maintenance Standard may include more than one **works item** which could be implemented in a given year, for example, grading and spot regravelling on unsealed roads, crack sealing and patching on bituminous roads. Details on the implementation of works are given in Volume 4, Analytical Framework and Model Descriptions.

	Standard	Works Items	Criteria
	Gravel Road Maintenance	Spot Regravelling	Gravel thickness < 100 mm Max quantity 100 m ³ /km/yr
	&	Heavy Motorised Grading	Every 180 days
Maintenance	Maintenance before Upgrading	Regravelling	Gravel thickness < 50 mm Final gravel thickness = 150 mm Initial IRI = 4
		Patch Potholes	Potholes > 50 no./km
	Maintenance	15 mm Reseal	Cracked carriageway area > 15%
	after 50 mm Overlay		6 < IRI < 12.5
	Opgrading	Reconstruction with 25 mm surface dressing	IRI > 10
Improvement	Upgrading	25 mm surface dressing	Scheduled for specified years Duration 2 years

Table E1.2Maintenance and Improvement Standards



The **Alternatives** Tab provides the means to showing the Works Standards (assignments) associated with each project alternative. For the selected alternative, the Works Standards assigned to a section can be reviewed by selecting that section as shown below. In this example, both **Maintenance Standards** and **Improvement Standards** are assigned. Post Improvement Maintenance Standards are also assigned at this point, as well as Generated Traffic and Social & Exogenous Costs and Benefits should they be included in the study.

Define Project	Alternatives									
Details	Navigation	Details								
Snach	Analysis by Project	Analysis by Project > U	Jpgrade 2008 > Town /	Ato Town B						
Alternatives	Base Atemative				Maintenance Standards					-
and the second	E Town Ato Town B									
Analyse Projects	2006 : Project 1 - Grav				Name				Code	Year
110,000	2006 - Project 1 - Gran	Design 1 Mins H	ofore Unaradica					D1	MDTT	2006
Multi Criteria	E- Town C to Town D	Project 1 • Mice L	leible opgrading		Add new maintenance assignm	ent			MBO	2000
Analysis	M 2006 : Project 1 - Grav									
Generate	De Upgrade 2008									
Reports	I lown Ato Town B									
	□ 1 2008 : Project 1 - B10									
	M Project 1 - Mtce a									
	Trans Day Trans C									
	Iown Bto Town C									
	2006 : Project 1 - Mto									
	2008 : Project 1 - Mto ⊡ 2008 : Project 1 - B10									ļ
	Iown B to Town C Iown C									
	■ ■ Town B to Town C ■ ■ Town B to Town C ■ ■ 2008 : Project 1 - Mto ■ ■ 2008 : Project 1 - Mto ■ ■ ■ Town C to Town D ■ ■ 2006 : Project 1 - Mto	•								
		•			Improvement Standards					
	Image: The second se			Marro	Improvement Standards	Var	Post Imp.	Generated Traffic	Si	ocial and
	Even Fis Town C Even C	•		Name	Improvement Standards	Year	Post Imp. Maint. Std.	Generated Traffic	Si Exi Bene	ocial and ogeneous efits & Costs
	Town Bits Town C 1 2005: Project 1 - Nico 1 2009: Project 1 - Nico 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Project 1 - B1001	-01 - Upgrade in 2008	Name	Improvement Standards	Year 2000	Post Imp. Maint. Std. 3 Project 1 - Mtce	Generated Traffic	Si Exi Bene	ocial and ogeneous efits & Costs
	Even Bit Sown C Even C = 1 Even	Project 1 - B1001	- 01 - Upgrade in 2008	Name	Improvement Standards	Year	Post Imp. Maint. Std. 3 Ptoject 1 - Mtce	Generated Traffic <mark>⊮ ×Edit</mark>	Si Exi Bene	ocial and ogeneous efits & Costs Edit
	Iown Bis Town C Iown Category Iown Bis Town C Iown Category	Project 1 - B1001	-01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008 ent	Post Imp. Maint. Std. 8 Project 1 - Mtce	Generated Traffic ⊻ ×Edit	Si Exi Bene	ocial and ogeneous efits & Costs Edit
	Iown Bio Jown C Image: Nonext - 1 Mice	Project 1 - B1001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2006 ent	Post Imp. Maint. Std. 3 Project 1 - Mice	Generated Traffic ⊻ ×Edit	Si Ex: Bene	ocial and ogeneous efits & Costs Edit
	Iown Bit Jown C Image: Note of the Note of	Project 1 - B1001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2000 ent	Post Imp. Maint. Std. 3 Project 1 - Mtca	Generated Traffic ⊻ xEdit	Si Ex: Bene	ocial and ogeneous efits & Costs Edit
	Iown Bit Jown C Image: Nonext 1 - Bit0 Image: Nonext 1 - Bit0<	Project 1 - B1001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008 ent	Post Imp. Maint. Std. 3 Project 1 - Mice	Generated Traffic ≝ ×Edit	Si Ex: Bene	ocial and ogeneous afits & Costs
	Image: Bit Sound 12005; Project 1 - Nico Image: 2005; Project 1 - Nico Image: Project 1 - Nico Image: Display in the state of the state	Project 1 - B1001	-01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008 ent	Post Imp. Maint. Std. 3 Project 1 - Mice	Generated Traffic	Si Ex: Bene	ocial and ogeneous efits & Costs Edit
		Project 1 - 81001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008 ent	Post Imp. Maint. Std. 3 Project 1 - Mtcc	Generated Traffic <u>K</u> × <u>Edit</u>	Si Ex Bene	ocial and ogeneous efite & Costs Edit
	Com Bit Sound Com Bi	Project 1-B1001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2000 ent	Post Imp. Maint. Std. 9 Project 1 - Mtcc	Generated Traffic	Si Ex: Bene	ocial and ogeneous stits & Costs Edit
Save	Even Bis Town L Even L Town Bis Town L Town C to Town B Town A to Town B Town A to Town B Town C to Town D Town C to Town D Town C to Town B Town C to Town C Town C to Town C Town C town C town C Town C town	Project 1 - B1001	- 01 - Upgrade in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008	Post Imp. Maint: Std. Project 1 - Mitce	Generated Traffic	Si Ex: Bene	ocial and ogeneous afite & Costs Edt
Sąve	Commission Commission Comm	Project 1 - 81001	- 01 - Upgrede in 2008	Name	Improvement Standards Add new improvement assignme	Year 2008 ent	Post Imp. Maint. Std. Project 1 - Mice	Generated Traffic	Si Ex Bene	ccial and operacuis etite & Costs Edk

1.4 Analyse Projects

1.4.1 Setup Run

The options selected in the **Setup Run** screen include the project base alternative for the economic analysis and the discount rate (10% in this case study, based on the published Government Accounting Rate of Interest, or advised by the appropriate Planning Authority). The additional models for accidents, energy balance, emissions, acceleration effects and asset valuation are not included in this analysis.

	rt/Chart Window Help		
Define Setup F	Run Sensitivity Run Analysis		
Details V i	Conduct Economic Analysis	Model Inclusion	
Specify Alternatives	ase alternative: Base Alternative	Energy Balance	
	Discount rate: 10 %	Emissions	
Projects		Agceleration effects	
Multi Criteria	Include Accident Costs	Log File	
Analysis	of US Dollar):	☐ Write Log file	
> Generate	Eatal 0 Damage: 0	Run Data Export Detail	
Regorts	Injury: 0 All: 0	Exclude annual <u>v</u> ehicle data	
		Exclude vehicle geriod data	
Ass	set valuation		
	Perform run with asset valuation		
Rur	in Data Export Directory		
D:\	\My Documents\Folder\HDMGlobal\Volume 2	2\Final workspace\Trial Project 1 a Browse	
	\My Documents\Folder\HDMGlobal\Volume 2	21/Final workspace/Tirial Project 1 a Browse	
	\My Documents\\Folder\HDMGlobal\Volume 2	2/Final workspace/Trial Project 1 a Browse	
	\My Documents\VFolder\HDMGlobal\Volume 2	2:Final workspace\Trial Project 1 a Browse	
Þ	\My Documente\Folder\HDMGlobal\Volume 2	2:Final workspace\Trial Project 1 a Browse	
	'My Documents'/Folder/HDMGlobal/Volume 2	2:Final workspace\Trial Project 1 aBrogge	
	-My Documento (Folder: HDMGlobal: Volume 2	2.Final workspace\Trial Project 1 aBrogge	
	-Wy Documento (Folder/HDMGlobal Volume 2	2:Final workspace\Trial Project 1 aBrogge	
	Wy Documents (Folder/HDMGlobal Volume 2	2:Final workspace\Trial Project 1 aBroggee	
Save	. My Documenta VFalder VHDMGlabal Valume 2	2:Final workspace\Trial Project 1 aBroggee	
Sgve	. My Documenta VFalder/HDMGlabal/Volume	2:Final workspace\Trial Project 1 aBrogge	
Sgre	-My Documento VFolder-HDMGlobal-Wolume 2	2.Final workspace\Trial Project 1 a	

For this case study (**Project 1a**), sensitivity analysis has not been selected (see **Project 1b** for sensitivity analysis).

1.4.2 Run Analysis

This starts the analysis and produces the output necessary for report generation.

1.5 Multi Criteria Analysis

Multi criteria analysis has not been used in this case study.

1.6 Generate Reports

The output reports from the analysis are produced and stored in the appropriate folders. The user may select **Generate Reports** to display the folders holding pre-defined report options. The pre-defined report categories are shown in the following screen in which two of the most relevant folders for this case study are open.



Traffic

Details on the traffic flows for each alternative over the 20-year analysis period are reported in this folder in both graphical and tabular form. For eample, the **AADT for Project Road Sections** graph illustrates the growth in AADT for each section. Traffic volumes are inextricably linked with project viability and therefore correct data and trends are critical. All trends are consistent with the input data.



Deterioration / Works Effects

The progressions of the various distresses for each alternative over the analysis period are reported in this folder in both graphical and tabular form. Also reported in this folder are the timings of the works carried out for each alternative during the 20-year period.

For example, the **Average Roughness by Project** graph displays the average annual roughness trend for each section-alternative. It helps confirm that modelled trends and works effects have been entered and modelled correctly. Failing to make such checks can lead to wasted effort. Users should also seek to get a 'feel' of model responses and relate this to real life experience. As shown in this example, the Base Alternative maintains a poor condition, with some variation due to maintenance, whereas the various upgrade alternatives are shown to improve in roughness at the specified time, and roughness slowly increases over a period of time, much as expected.



Other reports in this folder provide useful information for this case study. For example, the Pavement Condition Summary report provides in tabular form a summary of the performance of each section-alternative before and after upgrading. It is useful to identify changes in condition, both deterioration over time and improvements following treatment for each case, such as gravel loss, crack initiation and propagation, etc.

The Pavement Condition (Unsealed Pavements) report gives the condition of each unsealed section for each alternative up to the time that it is upgraded to a bituminous pavement, as shown for the upgrade in 2012 in the screen below.

HDM	<u>-4</u> Pa	vement Condition (U	nsealed Paveme	ents)			
Section: Alternativ Sensitivi	Town ve: Upgra ity: Base	a A to Town B ade 2012 Sensitivity Scenario					
Length:	20.00km	Width: 7.00m	Rise + Fall: 10.0	00m/km	Curvature: 5	0.00deg/km	Road Class: Secondary o
				Unseale	d Pavement		
Year	MT AADT		Pavement Type	Gravel Thickness (mm) THG	Mean Roughness IRI (m/km)		
2008	516	Before works	Gravel	63.54	13.96		
		After works	Gravel	74.48			
2007	533	Before works	Gravel	37.29	15.46		
		After works	Gravel	150.00			
2008	550	Before works	Gravel	112.05	8.32		
		After works	Gravel	112.05			
2009	567	Before works	Gravel	73.30	12.80		
		After works	Gravel	84.93			
2010	586	Before works	Gravel	45.37	15.38		
	1	After works	Gravel	150.00			
2011	605	Before works	Gravel	109.60	8.67		
		After works	Gravel	109.60			
2012	625	Before works	Gravel	68.32	13.29		
		After works	Gravel	68.32			
2013	645	Before works	Gravel	68.32	13.29		
		After works	STGB	* Upgraded	to a Bituminous	Pavement	

The Road Works Summary (by Section) report is useful for checking that treatments are triggered, and quantities and costs are calculated properly. Unsealed road treatments are shown to trigger at regular intervals, up to the point of upgrading. Beyond this a set of bituminous maintenance treatments are triggered in response to significant surface distress.

Road User Effects

The various components of road user effects are reported in this folder.

Cost Streams and Economic Evaluation

This folder contains the results of the economic analysis. Having verified the physical performance of the sections and the associated agency costs, it is appropriate to examine the economic data. The **Economics Indicator Summary** report shown below provides an appropriate summary and can be used to select the most viable alternative. Alternatively, the **Economic Analysis Summary** may be used to extract relevant information, but this is more useful when examining project sensitivity and the changes in costs and associated with individual components of a cost benefit analysis (see **Project 1b**).

HDM-4 RIGRWAY DEVELOPMENT & MANAGEMENT Sensitivity: Base Sensitivity Scenario	Economic Study Name: 1a. Up Run Date: 27-03- Currency: US Do Discount Rate: 10.009	Indicato ograding a grav 2006 Illar (millions) %	vel road (by	nmary project) - w	ithout sens	itivity analysis	5		
Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Age noy Capital Costs (CAP)	Increase In Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV = B+E-C)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Alternative Base Alternative	Present Value of Total Agency Costs (RAC) 2.610	Present Value of Agency Capital Costs (CAP) 1.665	Increase in Agency Costs (C) 0.000	Decrease In User Costs (B) 0.000	Net Exogenous Benefits (E) 0.000	Net Present Value (NPV = B+E-C) 0.000	NPV/Cost Ratio (NPV/RAC) 0.000	NPV/Cost Ratio (NPV/CAP) 0.000	Internal Rate of Return (IRR) 0.000
Alternative Base Alternative Upgrade 2008	Present Value of Total Agency Costs (RAC) 2.610 10.983	Present Value of Age noy Capital Costs (CAP) 1.665 10.738	Increase In Agency Costs (C) 0.000 8.374	De orease in User Costs (B) 0.000 12.810	Net Exogenous Benefits (E) 0.000 0.000	Net Present Value (NPV = B+E-C) 0.000 4.437	NPV/Cost Ratio (NPV/RAC) 0.000 0.404	NPV/Cost Ratio (NPV/CAP) 0.000 0.413	Internal Rate of Return (IRR) 0.000 16.3 (1)
Atternative Base Atternative Upgrade 2006 Upgrade 2006	Present Value of Total Agency Costs (RAC) 2.610 10.983 13.417	Present Value of Age noy Capital Costs (CAP) 1.665 10.738 13.417	Increase In Age noy Costs (C) 0.000 8.374 10.907	De crease In User Costs (B) 0.000 12.810 13.756	Net Exogenous Benefits (E) 0.000 0.000 0.000	Net Present Value (NPV = B+E-C) 0.000 4.437 2.949	NPV/Cost Ratio (NPV/RAC) 0.000 0.404 0.220	NPV/Cost Ratio (NPV/CAP) 0.000 0.413 0.220	0.000 16.3 (1) 12.9 (1)
Alternative Base Alternative Upgrade 2006 Upgrade 2006 Upgrade 2006	Present Value of Total Agency Cost (RAC) 2.610 10.983 13.417 9.935	Present Value of Age noy Capital Costs (CAP) 1.665 10.738 13.417 9.529	Increase In Age noy Costs (C) 0.000 8.374 10.807 7.325	De crease In User Costs (B) 0.000 12.810 13.756 9.308	Net Exogenous Benefits (E) 0.000 0.000 0.000 0.000	Net Pre-sent Value (NPV = 8+E-C) 0.000 4.437 2.949 1.983	NPV/Cost Ratio (NPV/RAC) 0.000 0.404 0.220 0.200	NPV/Cost Ratio (NPV/CAP) 0.000 0.413 0.220 0.208	0.000 16.3 (1) 12.9 (1) 13.2 (1)

A positive Net Present Value (NPV) is indicative of project economic viability, with the best timing coinciding with the maximum value. In this case a positive NPV is found immediately, therefore the project is viable. The NPV then increases as the project is delayed (to 2008), producing net benefits almost 50% greater than those estimated for the earlier timing. The NPV then tends to fall as upgrading is delayed further, to less than half that of the Upgrade 2008 alternative, thus confirming the importance of examining a range of timing alternatives.

A high NPV/C, similar to the Benefit Cost Ratio, confirms the relative value of the benefits per investment unit. Whilst this indicator is usually employed in ranking (or prioritisation) under budget constraint, it provides confirmation of the positive result. An Economic Internal Rate of Return (EIRR) greater than the discount rate is also indicative of project viability.

1.7 Sensitivity Analysis

Sensitivity analysis is carried out to examine the robustness of a project, in economic or financial terms, to changes in the magnitude of important variables. It may be undertaken as part of a broader scenario or risk analysis because the results of an appraisal are subject to uncertainty. However, for the latter to be done comprehensively, ideally a probability based approach should be used. This is usually only appropriate where risks (and associated probabilities) are well defined.

The 'sensitivity analysis' functionality within HDM-4 allows a relatively simplified examination of uncertainty by allowing the user to employ higher and lower figures than those expected, and to determine how sensitive the economic decision criteria are to such changes. The variables chosen are a matter of judgement, but for most 'capital' road projects, project viability should be tested for variations in traffic, project costs and timing. Depending on the project other factors may be examined, including generated traffic, time and accident savings, shadow prices, maintenance and special factors, such as the effects of complementary investments, or the effect of management or regulatory actions.

Project 1b. Upgrading a gravel road (by project) – with sensitivity analysis investigates the effect of changes in the value of a number of key variables on the outcome of the economic analysis.

The effect of timing was considered in Proejct 1a, and therefore the additional scenarios which were examined included variations in the following variables, each one at a time:

- Base (or Normal) AADT (+/- 25%)
- Normal traffic growth (+/- 25%)
- Capital costs (+/- 25%)

This case study is located in the **Projects** folder in the Workspace. Double-click on Project case study **1b. Upgrading a Gravel Road (by project) – with sensitivity analysis**.

The additional steps and results are described below.

1.7.1 Defining Scenarios

Scenarios to be examined in a sensitivity analysis are defined in the following screen, which is accessed through **Analyse Projects/Sensitivity** tab page.

-	1-4 - [Projec	ct: 1b	. Upgrading a gravel road	(by proje	ct) - with s	ensitivity	analysis]													_
Wor 🖌	rk <u>s</u> pace <u>V</u> iev	N <u>R</u> e	eport/Chart <u>W</u> indow <u>H</u> elp																	
•	Define Project Details	Set	tup Run Sensitivity Run An	alysis rsis																1
-	Specify Alternatives			Traffic					Veh Use				Net Bens							-
->	Analyse Projects		Description	MT Normal AADT	NM Normal AADT	Normal Traffic Growth	Growth After Diversion	Gener- ated Traffic	Op. Weight	ESALF	AKM	HRWK	Capital	Recurrent	Special	MT VOC	MT Time	NM VOC & Time	Accidents E	
			Base Sensitivity Scenario	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
-	Multi Criteria		High AADT	1.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	Analysis		Low AADT	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
æ	Commente	1	High growth	1.00	1.00	1.25	5 1.00	1.00	1.00	1.00	1.00	0 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
X//	Reports		Low growth	1.00	1.00	0.75	5 1.00	1.00	1.00	1.00	1.00	0 1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
\sim			High Capital Cost	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0 1.00	1.25	1.00	1.00	1.00	1.00	1.00	1.00	
			Low Capital Cost	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0 1.00	0.75	1.00	1.00	1.00	1.00	1.00	1.00	
			▲dd New Scenario []	<u>_</u> elete Scen:	ano													1		•
+																				

In Project 1a this screen would have been blank except for the presence of the Base Sensitvity Scenario, therefore the other scenarios have been added. The % variations noted in the above scenarios have been introduced as multiplication factors (e.g. 25% is presented by the factor 1.25, etc).

1.7.2 Run Analysis

This starts the analysis and produces the output necessary for report generation, and is executed in the normal manner.

1.7.3 Generate Reports

A full set of reports are available for all scenarios. The user may select **Generate Reports** to display the folders holding pre-defined report options which they consider relevant to interpreting the results of this case study. Both input and output/analysis reports should be examined. The following discussion concentrates on the latter, specifically those contained in the **Cost Streams and Economic Evaluation** folder.

Comparison of Cost Stream (Discounted and Undiscounted)

These comprise two separate reports (see below) which contain a summary of the changes in road agency cost and road user costs, and the net social/exogenous benefits and total benefits. Each project alternative/scenario is reported separately. Having verified that traffic and physical parameters have changed in accordance with expectations, these reports are useful for verifying changes in costs have been computed and reported correctly as they are key to the project outcomes.

In the Base Sensitivity Scenario shown below, the first year capital costs are of the order of \$2.55 million. In the high capital cost scenario shown in the following figure, the first year costs have risen to approximately \$3.2 million (+ 25%) thus confirming the desired change.



H D M - 4 Section Alterna Sensitiv	Comparison of the comparison of the comparison of the comparison of the compared of the comparison of	of Cost Stream Town B 008 al Cost	s (Discounted))								
Sect ID: Length:	B001-01 20.00 km	Width: 7.00) m	Road Class: Sec Rise+Fall: 10.0	ondary or Main 00 m/km	Curva	ture: 50.00 deg/k	sm				
Year	Increase	in Road Ageno	cy Costs			Saving	s in Road User	Costs			Net	Total
	Capital	Recurrent	Special	Norma	I (+ Diverted)	Traffic		Generated Trai	ffic	Accident	Exogenous	Benefits
	Works	Works	Works	MT VOC	MT Time	NMT Time & Operation	MT VOC	MT Time	NMT Time & Operation	Cost Reduction	Benefits	
2006	3.188	-0.047	0.000	-0.081	-0.015	0.000	0.000	0.000	0.000	0.000	0.000	-3.217
2007	2.685	-0.026	0.000	0.026	0.006	0.000	0.000	0.000	0.000	0.000	0.000	-2.627
2008	0.000	-0.024	0.000	0.186	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.242
2009	0.000	-0.038	0.000	0.357	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.471

Economic Analysis Summary

This report (shown below) contains a summary of the key economic values for each project alternative/sensitivity scenario.

VAY DEVELOPMENT & MANAG	ement s	Study Name: 1b. I Run Date: 27-0 Currency: US [Discount: 10.0 alysis Mode: Ana	Jpgrading a gra 3-2006 Jollar (millions) 0% ysis-by-Project	vel road (by p	vroject) - with se	nsitiv			
rnative: Upgrade 2006 sitivity Scenario: Base	vs Alternativ Sensitivity So	ve: Base Alterna cenario	tive						
rnative: Upgrade 2006 sitivity Scenario: Base	vs Alternativ Sensitivity So Inc	ve: Base Alterna cenario rease in Road A	tive gency Costs	Savings in MT VOC	Savings in MT Travel Time	Savings ir NMT Trave	Reductior in Accident	Ne ^r Social /	Ne
rnative: Upgrade 2006 sitivity Scenario: Base	vs Alternativ Sensitivity So Inc Capital	ve: Base Alterna cenario rease in Road A Recurrent	gency Costs Special	Savings in MT VOC	Savings in MT Travel Time Costs	Savings ir NMT Trave & Operating Costs	Reductior in Accident Costs	Ne' Social / Exogenous Benefits	Ne Economi Benefit (NPV
rnative: Upgrade 2006 isitivity Scenario: Base	vs Alternativ Sensitivity So Inc Capital 11.21	ve: Base Alterna cenario rease in Road A Recurrent -2.06	gency Costs Special	Savings in MT VOC 30.34	Savings in MT Travel Time Costs 6.70	Savings ir NMT Trave & Operating Cost: 0.00	Reductior in Accident Costs 0.00	Ne Social / Exogenous Benefits 0.00	Ne Economi Benefit (NPV 27.8

Results of the sensitivity analysis have been summarised in Table E1.3, Table E1.4 and Table E1.5. For this analysis, only the 2008 timing alternative was examined as this was previously shown to provide the most viable option.

 Table E1.3

 Comparison of NPV (millions) and EIRR by AADT Scenario

Economic Indicator	Low	Most Likely	High
NPV (Discounted)	- 0.02	4.44	8.81
EIRR	10.0	16.3	21.6

Table E1.4Comparison of NPV (millions) and EIRR by Normal Traffic Growth Scenario

Economic Indicator	Low	Most Likely	High
NPV (Discounted)	3.2	4.44	5.73
EIRR	14.8	16.3	17.7

Table E1.5 Comparison of NPV (millions) and EIRR by Capital Cost Scenario

Economic Indicator	Low	Most Likely	High
NPV (Discounted)	6.7	4.44	2.17
EIRR	22.0	16.3	12.6

In the above tables, the 'Most Likely' scenario corresponds with the Base Alternative Scenario.

With the exception of the low initial AADT scenario, all scenarios have confirmed the viability of the project in terms of a) positive NPV, and b) an EIRR greater than the test discount rate of 10%. However, even the low initial AADT scenario was marginal, thus confirming that the viability of the project is relatively robust.

1.8 Comparison with Analysis by Section

As a more general comment, whilst the NPV is positive in all Alternatives in the above case study, the relatively low NPV/C and EIRR suggest certain aspects of the overall project are marginal. This has been investigated further using the **Analysis by Section** method of analysis, (see **Project 1c. Upgrading a gravel road (by section)** in the Projects folder).

Results from this analysis are shown in Table E1.6. These results confirm that each section is viable to a greater or lesser degree, with the section with the lowest AADT of 250 being the non-viable for all of the the alternatives investigated, and that with the highest AADT of 750 being the most viable. Such analysis confirms the concept of 'Breakeven Traffic Volume' associated with improvement standards.

 Table E1.6

 Comparison of NPV from Analysis by Section and Analysis by Project

			Net Present V	alue (millions)	
Section	AADT	Upgrade 2006	Upgrade 2008	Upgrade 2010	Upgrade 2012
A - B	500	0.761	1.037*	0.524	0.576
B – C	250	- 0.856	- 0.698	- 0.523	- 0.453
C - D	750	3.044	3.129*	1.982	1.862
Total NPV (for A	Il sections)	2.949	3.438*	1.983	1.985

* Most viable timing alternative for each section, and for All sections

B - C is not viable for any of the chosen investment alternatives

2 CASE STUDY 2 – PAVED ROAD REHABILITATION

2.1 Introduction

The name of this case study is **2. Paved Road Rehabilitation**. This case study presents the economic analysis of alternative rehabilitation standards for two typical study sections chosen from a representative set of strategic sections for the entire road network. The two sections represent existing roads which carry 12,500 and 40,000 vehicles per day (AADT) and exhibit moderate levels of roughness and surface distress. This case study evaluates several possible future rehabilitation alternatives including a thin overlay to restore surface smoothness, a structural overlay and full pavement reconstruction.

The objective of the case study is to present the definition of section alternatives appropriate to this type of analysis and demonstrate the HDM-4 deterioration model for paved roads. The definition and timing of the Maintenance Standards are discussed, and the results are examined.

The case study is located in the **Projects** folder in the Workspace. Double-click on the Project case study **2. Paved Road Rehabilitation** to open the case study.

2.2 Define Project Details

In the **Define Project Details** screen, the following tab pages may be displayed:

- General
- Study Sections

2.2.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

HDM-4 - [Projec	ct: 2. Paved Road Rehabilitation]	
Workspace View	w Report/Chart Window Help	-
Define	General Study Sections	
Details		
Specify Alternatives	Description: Priject 2. Paved Road Rehabilitation	
Analyse Projects		
Multi Criteria	Analyse by: Section C Project	
Analysis	Start vear: 2006 Analysis period: 15 years	
Generate Reports	Road Network: Route 1	
~ -	Vehicle Eleet: National Reet	
	Reet: Malaysian Ringgit × 1 = output currency	
	Works: US Dollar × 1 = output currency	
	Network: Malaysian Ringgit × 1 = output currency	
	Qutput: Malaysian Ringgt 💌	
Save		
Close		
)	
ation of the analysis	is period	

This case study is presented as an Analysis by Section example. The analysis period is defined by the start year 2006 and a duration of 15 years (i.e. 2006 - 2025). The section to be analysed is in the Road Network entitled Route 1, to which the National Fleet has been previously assigned as the Vehicle Fleet. The currency being used for this analysis is the Malaysian Ringgit.

2.2.2 Study Sections

The road sections selected for analysis are VH-Fair-2 and M-Fair-2.

🕸 HDM	I-4 - [Projec	t: 2.	Paved F	Road Rehabi	litation]					_ 8 ×
🛃 Wor	rkspace ⊻iev	B	eport/Ch	art <u>W</u> indow	Help					X
	Define Project	Ge	eneral S	tudy Sections						
	Detailo	[Inc	lude in		Section Summ	ary		Traffic Growth	<u> </u>
J.	Specify		Study	Analysis	ID	Description	Class	Pavement	franc crown	
L Ť	Alternatives		Ľ	×	VH-Fair-2	VH Traffic, Fair, 2-lane	Primary or Trunk	Bituminous	Project 2	
	Anahan		<u>×</u>	<u>×</u>	M-Fair-2	M Traffic, IRI-3.0, Fair, 2-lane	Primary or Trunk	Bituminous	Project 2	
	Projects									
J.	Multi Criteria									
	Analysis									
1	Generate Regorts									
	1	l	•							 Sections
Å	Save		Assign <u>G</u>	rowth Set	Select by <u>C</u> riteri	a View/Edit Section	View/Edit <u>F</u> leet			Network: 32
			Copy G	rowth Set	Unselect All	View/Edit Network				oruny. z
3	Close		Paste G	irowth Set	 Show unseled sections 	cted				
Sections	selected for a	nalys	sis							

By double-clicking on the section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case National Fleet) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays all the previously created sets. Double-clicking on the appropriate set (in this case Project 2) displays the details of the traffic changes over the analysis period.

escription: Paved Road	Rehabilitation	
otorised Growth Periods		
Vehicle	Annual % increase from year 1	Add New Period
Motorcycles	3.50	
Motor Car	3.50	Delete Period
2-axle Truck	3.50	
3-axle Heavy Truck	3.50	Note: years are
Bus	3.50	defined relative to
4+axle Artic	3.50	the start year of the
Utilities van	3.50	▼ the traffic growth
•		set is used.

The traffic growth rates for the motorised traffic in this case study indicate that the motorised traffic is expected to grow by 3.5% per year. Non-motorised traffic is not used in this case study.

Section details are described below, concentrating on section VH-Fair-2.

Definition

The speed-flow type and the traffic flow pattern of the existing road is illustrated in this screen. The carriageway width is 7m, with two directional traffic flow. The pavement type is an asphalt mix on an asphalt pavement, and this pavement type will be retained except in the case where full reconstruction takes place.

	×
Definition Geometry Pavement Condition Other Motorised Tra	ffic Asset Valuation
Name: VH Traffic, Fair, 2-lane Spee	d <u>Fl</u> ow Type: Two Lane Road
ID: VH-Fair-2 Traffic	Flow Pattem: Free-Flow
Link Name: Ac	cident Class: Two Lane Road
Lin <u>k</u> ID:	Climate Zone: Tropical Humid
Length: 1 km	Road Class: Primary or Trunk
Cway <u>W</u> idth: 7 m	
Shoulder Width: 1 m Ca	libration Set: National
Flow Direction: Two-way	ibration Item: High traffic
Surface Class: Bituminous	cted Calibration Item Summary
Pa	vement type: Asphalt Mix on Asphalt Pavement
Surf	ace material: Asphaltic Concrete
	OK Cancel
	Cander

The **Calibration Set** assigned to the section is the National set. Two **Calibration Items** are used in this case study; High Traffic (used for VH-Fair-2) and Low Traffic (used for M-Fair-2). These alter the performance characteristics of the network, and include differences related

to the calibration of the cracking and roughness models, and structural rutting. Details may be viewed from within the Configuration folder, as illustrated with the National calibration set below.

In the second																	
ame: Inational																	
ninous Concrete Unsea	aled																_
el library (DLL): HDM-4 De	efault DLL															-	🔍 Bro
RD Calibration Item	∠ CDS	CDB	CRT	RRF	Kcia	Ксра	Kciw	Ксрм	Kcit	Kopt	Kvi	Kvp	Kpic	Kpir	Крр	Keb	Ktd
raffic	1.00	0.00	0.00	1.00	1.30	0.77	1.00	1.00	1.00	1.00	4.00	0.25	1.00	1.00	1.00	1.00	1.00
							1										
iew ken I Ba Copy I	item 👔 Delet	e tem					1										

Geometry

Typical geometry characteristics have been employed based on network-wide averages.

efinition Geometry Paver	ment Cor	ndition Other N	lotorised Traffic Asset Valuatio	n]	
		1	- Speed Reduction Factors		
<u>H</u> ise + Fall:	25	m/km			
No. of rises + falls:	2	no./km	X <u>N</u> MT: 1	0.4 <= XNMT <=	1
Superelevation:	2.5	%	Road side friction: 1	0.4 <= XFRI <= 1	
<u>Avg</u> horiz curvature:	40	deg/km	X <u>M</u> T: 1	0.4 <= XMT <= 1	
a <u>d</u> ral:	0.1	m/s²	,		
Speed limit:	90	km/h			
Speed limit <u>e</u> nforcement:	1.1				
Aļtitude:	0	m			
	·				
				ОК	Cancel
	lle Cener Lord	<u></u>			

Pavement

The pavement type has been defined as asphalt mix on asphalt pavement (AMAP) and was last reconstructed in 1996, with a rehabilitation applied in 2001 as entered under Previous works. The structural number, SN, of the pavement layers above the subgrade is 4.7, with a

subgrade of 7.6% CBR, giving a SNP value of 5.7. For the pavement reconstruction alternative assigned to this case study, a similar SN value has been assigned.

Burfacing Pavement type: Asphalt Mix on Asphalt Pavement Material type: Asphaltic Concrete Most recent surfacing thickness: 40 mm Previous/old surfacing thickness: 160 mm Previous works (HDM-4 Work Types) 1896 year Last reconstruction or new construction: 1996 year Last rehabilitation (overlay): 2001 year	Strength Calculated Dry season model parameters SNP: 5.70 DEF: 0.40 mm [1] © Structural Number: 4.7 Subgrade CBR: 7.6 % © Dry Season © Wet Season [2] © Cglculated SNP: Calculate SNP Road base (for stabilised base only) Base thickness: mm
Last regurfacing (resealing): 2001 year Last greventative treatment: 2001 year	Eesilient modulus: GPa

Condition

The condition of the road section at the end of 2005 is specified, with the analysis commencing in 2006. At a roughness of 3.4 IRI, it is possible that an intervention could be justified given the level of traffic applied to each section. Cracking has also initiated, and therefore can be expected to progress if left untreated.

Contactoria or your	2005		
Boughness (IBL - m/km)	3.40		
All Structural Cracks (%)	2.80		
Wide Structural Cracks (%)	0.00		
Thermal Cracks (%)	0.00		
Ravelled area (%)	0.00		
Number of Potholes (No./km)	0.00		
Edge break area (m²/km)	0.00		
Mean rut depth (mm)	5.60		
Rut depth standard deviation (mm)	1.70		
Texture depth (mm)	0.70		
Skid resistance (SCRIM 50km/h)	0.50		
Drainage	Excellent 💌		

Other

For this case, this screen provides the possibility of selecting or specifying a number of relevant parameters, whose significance is as follows:

- Drainage enables the selection of drain type, including 'No change in drainage effects'
- **Relative compaction** affects the initial densification component of pavement rutting, and the structural component of rut progression
- Previous surface condition in practice affects the effectiveness of particularly thin layers, through relection cracking

Section: VH Traffic, Fair, 2-lane	×
Definition Geometry Pavement Condition Other Motors	ed Traffic Asset Valuation
Separate NMT lanes	Compaction (Bituminous only)
Number of lanes:	Relative compaction: 95 %
Shoulders (Concrete only)	Previous surface condition (Bituminous only)
Shoulder type: Non-concrete	Area of all structural cracking: 0 %
₩idth of widening: 0 m	Area of wide cracking: 0 %
,	Transverse thermal cracks: 0 no/km
Drainage	
Drain type: No change in drainage effect 💌	<u>E</u> LANES: 2
	OK Cancel
Model seperate lanes for non-motorised traffic	

Motorised Traffic

The AADT of 40000 in 2005 has been distributed between the various vehicle types in the selected Vehicle Fleet. If certain vehicle types do not operate on the selected road section, then a value of zero should be assigned for those particular types. The National vehicle fleet has no NMT vehicles.

/ehicle Fleet used for	this section/netv	ork: Nation	al Fleet	 	
Survey Year:	2005			 	Edit Year
2-axle Truck	4000.00				
3-axle Heavy Truck	1400.00				
4+axle Artic	1000.00				
Bus	800.00				
Motor Car	18000.00				
Motorcycles	10800.00				
Utilities van	4000.00				
Total AADT:	40000.00				

Asset Valuation

Asset valuation is not considered in this case study.

2.3 Specify Alternatives

The four alternatives considered in this case study are described in Table E2.7.

Alternative	Works Items	Criteria			
	Edge Repair	Edge break > 1 m ² /km			
1	Pothole Patching	Potholes > 1 no./km			
Alternative	Patching Wide Cracks	Wide Cracks > 5%			
	Pavement Reconstruction – 150mm asphalt	IRI > 10			
	Edge Repair	Edge break > 1 m ² /km			
2	Pothole Patching	Potholes > 1 no./km			
GAT03	Patching Wide Cracks	Wide Cracks > 5%			
	40mm Overlay	3 < IRI < 5 Minimum interval 5 years			
	Edge Repair	Edge break > 1 m ² /km			
2	Pothole Patching	Potholes > 1 no./km			
GASO4-5	Patching Wide Cracks	Wide Cracks > 5%			
	80mm Overlay	4.5 < IRI < 6.5 Minimum interval 7 years			
	Edge Repair	Edge break > 1 m ² /km			
4	Pothole Patching	Potholes > 1 no./km			
GAFR6	Patching Wide Cracks	Wide Cracks > 5%			
	Pavement Reconstruction – 150mm asphalt	IRI > 6			

Table E2.7Maintenance Alternatives

Alternative 1 is the Base Alternative. It comprises routine maintenance which includes edge repairs, pothole patching and patching of areas affected by wide cracks. In addition, a reconstruction is applied if the roughness level reaches 10 IRI. A high standard of routine maintenance is specified because of the traffic level and road importance. The three other alternatives include the same routine maintenance, with different periodic maintenance items.

The four alternatives are assigned to the two road sections as shown in the Specify Alternatives screen below.

Define Project Details	Alternatives	(∽Details	
Specify	Analysis by Section	Analysis by Section	Cartion Number
Alternatives	Base Alternative	Section Name	ID Alternatives
Analyse Projects	GAFR6	VH Traffic, Fair, 2-lane VH Traffic, Fair, 2-lane	VH-Fair-2 4 VH-Fair-2 4
Multi Criteria	2006 : Project 2 - Full Rec GASO4-5		
Analysis	2006 : Project 2 - Structur		
Generate Reports	2006 : Project 2 - Thin Ov		
	Base Alternative		
	GAFR6		
	2006 : Project 2 - Full Rec		
	2006 : Project 2 - Structur		
	GATO3		
Save			_
		Copy Section's Alternatives Paste Section's Alternatives Details	
100			

The Alternatives tab provides the means of showing the Works Standards associated with each section alternative. For the selected alternative, the Works Standards assigned to a different section can be reviewed by selecting that section as shown below. In this example, only Maintenance Standards are assigned.

HDM-4 - [Project	2. Paved Road Rehabilitation] Report/Chart Window Help										_
Define Project Details	Alternatives	Details									
Specify Alternatives	Analysis by Section	Analysis by Section > N	M Traffic, IRI-3.0, Fair,	2-lane > GAFR6	Maintenance S	tandards					
Analyse Projects	Base Alternative 2006 : Project 2 - Do Mini				Name					Code	Year
Multi Criteria Analysis	GASO4-5	Project 2 - Full Rei	construction @ 6 IRI		Add new main	tenance assignment			GA	FR6	2006
Generate Reports	GATO3										
	Base Atternative										
	GANNE 2006 : Project 2 - Full Rec										-
	GATO3				Improve	ment Standards					
				Name	improve		Year	Post Imp. Maint, Std.	Generated Traffic	S Ex Ben	ocial and ogeneous efits & Costs
					Add new impro	vement assignment.					
Save	4P	Copy Assignments	Paste Assignments	Remove Improve	ment Remove Maint	enance					
Close			Loore / Boghmonta								

2.4 Analyse Projects

2.4.1 Setup Run

The options selected in the Setup Run screen are Conduct Economic Analysis using a discount rate of 12%. The additional models for accidents, energy balance, emissions, acceleration effects and asset valuation are not included in this analysis.

Setup Run Sensitivity Run Analysis		
Conduct Economic Analysis	Model Inclusion	
Base alternative: Base Attemptive *	Egergy Belance Egessons Appeleration effects	
Average accident Costs Average accident category cost (in thousands of Malaysian Rengot)	Log Fie	
Eacal 0 Qamaga 0 Ingay 0 GE 0	Run Data Expot Detal F Exclude annual yehole data F Exclude vehicle gerod data	
Asset valuation		
Eerform run with asset valuation		
Run Data Export Directory		
D:\Greg\HDM-4\Case Studies\Eng\RunData	Вгодзе	
D1Greg1HDM41Case Studen Eng1RunData	Erge.	

2.4.2 Run Analysis

This starts the analysis and produces the output necessary for report generation.

2.5 Multi Criteria Analysis

Multi criteria analysis has not been used in this case study.

2.6 Generate Reports

The output reports from the analysis can be found by clicking Generate Reports. The following selection of reports are recommended for this case study and comments are made on the outcome of the case study.

Traffic

The AADT for Section Alternative (Graph) report allows the user to view the growth in AADT for each section. Traffic volume is inextricably linked with project viability and therefore correct data and trends are critical. Inspection of this report will confirm that trends are consistent for both sections.

Deterioration / Works Effects

The Average Roughness by Section (Graph) report is useful for verifying trends in roughness, and to confirm that the resetting of roughness after works. These are revealed to be consistent with the specification of the works standards as shown by the graph below.

The deterioration trends are also consistent for each section-alternative, suggesting that the routine works are being triggered in a similar manner.



The Pavement Condition (Bituminous Pavement) report lists in tabular form the individual distresses and other parameters, such as AADT, traffic loading (YE4) and pavement strength (SNP). Trends can be examined for each section-alternative

The Road Works Summary (by Section) report is useful for checking treatments are triggered, and quantities and costs are calculated correctly. In this case study, the 40 mm overlay specified in Alternative 2 (see Table E2.7) is triggered in Year 1, which is consistent with the intervention level being exceeded.

Section: Alternativ Sensitivit Surface (Length:	M Traffic, IRI-3.0, Fair, 2 ve: GATO3 y: No Sensitivity Analysis (Class: Bituminous 1.00km	-lane Conducted	Road Class: Prim Width: 7.00	ary or Trunk m	
Year	Description	Code	Economic Cost	Financial Cost	Work Quantity
2006	40 mm Overlay @ 3 IRI	OV403	77,700.0	85,400.0	7,000.00 sq. m
	Prep. Edge Repair		748.6	828.4	25.73 sq. m
2007	Routine edge	ROEDGE	482.8	581.1	42.73 sq. m
2008	Routine edge	ROEDGE	517.5	622.8	45.79 sq. m
2009	Routine edge	ROEDGE	555.9	669.1	49.20 sq. m
2010	Routine edge	ROEDGE	597.3	718.9	52.86 sq. m
2011	Routine edge	ROEDGE	641.9	772.5	56.80 sq. m
2012	40 mm Overlay @ 3 IRI	OV403	77,700.0	85,400.0	7,000.00 sq. m
	Prep. Edge Repair		1,776.5	1,965.8	61.05 sq. m
2013	Routine edge	ROEDGE	741.6	892.5	65.63 sq. m
2014	Routine edge	ROEDGE	795.5	957.4	70.40 sq. m
2015	Routine edge	ROEDGE	855.1	1,029.2	75.68 sq. m
2016	Routine edge	ROEDGE	919.4	1,106.6	81.37 sq. m
2017	Routine edge	ROEDGE	988.8	1,190.0	87.50 sq. m
2018	40 mm Overlay @ 3 IRI	OV403	77,700.0	85,400.0	7,000.00 sq. m
	Prep. Edge Repair		2,738.7	3,030.4	94.11 sq. m
2019	Routine edge	ROEDGE	1,144.1	1,376.9	101.25 sq. m
2020	Routine edge	ROEDGE	1,228.4	1,478,4	108.71 sq. m

Cost Streams and Economic Evaluation

This folder contains the results of the economic analysis. The Economic Analysis Summary report indicates that:

- The thin overlay solution produces the maximum Net Present Value (NPV) for each section, this being indicative of the most viable section-alternative. In this case it confirms that early intervention is beneficial.
- The NPV/CAP indicator identifies the structural overlay as being the best solution, and is applicable in circumstances where ranking (or prioritisation) under budget constraint is appropriate. Whilst this is not appropriate in this case, it is an interesting finding.
- An Economic Internal Rate of Return (EIRR) greater than the specified discount rate is also indicative of project viability. For this case the maximum EIRR coincides with the most viable section-alternative. The values are extremely high, again confirming the benefits of selecting a thin overlay.



Economic Indicators Summary

Study Name: 2. Paved Road Rehabilitation Run Date: 11-07-2006 Currency: Malaysian Ringqit (millions) Discount Rate: 12.00%

Section: M Traffic, IRI-3.0, Fair, 2-lane Sensitivity No Sensitivity Analysis Conducted

Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Cosits (CAP)	increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV = B + E-C)	NPV/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GAFR6	0.178	0.107	0.092	0.301	0.000	0.209	1.178	1.947	107.4 (1)
GASO4-5	0.124	0.087	0.039	0.688	0.000	0.649	5.226	7.485	131.4 (1)
GATOS	0.143	0.137	0.058	0.900	0.000	0.842	5.874	6.148	62.9 (1)

Figure in brackets is number of IRR solutions in range -90 to +900

Section: VH Traffic, Fair, 2-lane Sensitivity No Sensitivity Analysis Conducted

Alternative	Present Value of Total Agenoy Costs (RAC)	Present Value of Agency Capital Costs (CAP)	Increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exoge nous Benefits (E)	Net Present Value (NPV = B + E-C)	NP V/Cost Ratio (NPV/RAC)	NPV/Cost Ratio (NPV/CAP)	Internal Rate of Return (IRR)
Base Alternative	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GAFR6	0.174	0.096	0.092	0.666	0.000	0.573	3.301	5.974	387.9 (1)
GASO4-5	0.176	0.097	0.094	2.530	0.000	2.435	13.858	25.078	267.6 (1)
GATOS	0.222	0.142	0.140	3.332	0.000	3.192	14.394	22.521	203.4 (1)
Figure in brackets is number of IRR solutions in range -90 to +900									

3 CASE STUDY 3 – CAPACITY IMPROVEMENTS

3.1 Introduction

This case study presents the economic analysis of widening a paved road. The existing road is 7m wide, with an AADT of 15,000 in 2005. In addition, the non-motorised transport (NMT) was 400 in 2005, comprising pedestrians, animal carts, and bicycles. Three widening alternatives are considered, widening by 1m, widening by 3m, and adding two extra lanes. The analysis assumes that routine maintenance is undertaken on a condition responsive basis for all alternatives.

The objective of this case study is to demonstrate the congestion analysis of HDM-4, with particular reference to specification of the input data and examination of the results.

This case study is located in the **Projects** folder in the Workspace. Double-click on the Project case study **3a. Capacity Improvements – without sensitivity analysis** to open the case study. A second case study, **3b. Capacity Improvements – with sensitivity analysis** exists in the same folder, which is based on the same overall project, and is discussed later in this section.

3.2 Define Project Details

In the **Define Project Details** screen, the following tab pages may be displayed:

- General
- Study Sections

3.2.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

	ew Report/Chart Window Heb	
ingpace view	en Ebordorar Timon Teb	
Define	General Study Sections	
Details		
Specify	Description:	
Alternatives	a la companya de la c	
- Analyse		
Projects		
m Multi Criteria	Analyse by: C Section IP Project	
Analysis	Start year: 2006 Analysis period: 20 years	
Generate		
Reports	Road Network: Northen Province	
	Vehicle Bett: Northern Province Vehicles	
	- Currencies	
	Fleet: US Dollar × 1 = output currency	
	Works: US Dollar × 1 = output currency	
	Network: US Dallar × 1 = output currency	
	Quiput: US bolar	
Save		
VIOI LIOSE		
Liose		

This case study is presented as an Analysis by Project example. The analysis period is defined by the start year 2006 and a duration of 20 years (i.e. 2006 - 2025). The section to be analysed is in the Road Network entitled Northern Province, to which the Northern Province Vehicles have been previously assigned as the Vehicle Fleet. The currency being used for this analysis is US dollars.

3.2.2 Study Sections

The only road section selected for analysis is the Capital City to Port section.

HDM-4 - [Project: 3a. Capacity improvements - without sensitivity analysis]	
Workspace View Report/Chart Window Help	
Define Project Details	
Speofy Atematives Study Analvis D Description Capital City to Port Primary Atematives	ass Pavement Traffic Growth or Trunk Bituminous Project 3
Analyse Projects	
Multi Criteria Analysis	
Cenerate Regords	
•	
Assign Growth Set Select by Orteria View/Edt Section	View/Edt Beet
Loop Growth Set Unselect All Wew/Edit Network Close Easter Growth Set Shgw unselected sections	
Sections selected for analysis	

By double-clicking on the section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case Northern Province Vehicles) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays all the previously created sets. Double-clicking on the appropriate set (in this case Project 3) displays the details of the traffic changes over the analysis period.

The traffic growth rates for both the motorised and non motorised traffic in this case study are displayed below.

3 🗙	Traffic Growth Set: Proje	×		ect 3	Traffic Growth Set: Proje
ements	Name: Project 3 Description: Capacity imp Motorsed Growth Periods		owth Periods]	rovements	<u>Name</u> : Project 3 Description: Capacity Imp Motorised Growth Periods
Annual % increase from year 1 2.00 3.00 5.00 Mote: years are defined relative to the start year of the analysis in which the traffic growth set is used.	Vehicle Animal carts Bicycles Person	Add New Period Edit Period Delete Period Note: years are defined relative to the start year of the analysis in which the traffic growth set is used.	×urrende j	Annual % increase from year 1 3.00 3.00 3.00 3.00 4.00 4.00	Vehicle Medium Bus Artic Truck Heavy Truck Medium Truck Light Truck Light Goods Vehicle Medium Car I IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
، ۱۰		bits traffic growth set is used.		4.00	Medium Car

The section details that have particular relevance to this case study are described below.

Definition

The speed flow type of the existing road is specified as Two Lane Road. The existing carriageway width is 7 m, with two directional traffic flow. The speed flow type defines the capacity of the existing road. In this case study, the capacity of the road will be increased as a result of Improvement works. The capacity of the road after improvement is defined by the speed flow type specified within the Improvement Standard.

5	Section: Capital City to Port 🛛 🛛 🗙									
Definition Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic Asset Valuation										
	<u>N</u> ame:	Capital City to Port			Speed How Type:	Two Lane Road				
	<u>I</u> D:	A003-01			Traffic Flow Pattem:	Commuter				
	Link Na <u>m</u> e:	Link Sea	a Port		<u>A</u> ccident Class:	Two Lane Road 💌				
	Lin <u>k</u> ID:	TL-10			Climate <u>Z</u> one:	Subtropical-Hot Sub-Humid				
	<u>L</u> ength:	10	km		<u>R</u> oad Class:	Primary or Trunk				
	Cway <u>W</u> idth:	7	m							
	Shoulder Width:	1	m		Calibration Set:	Northen Province				
	Flow Direction:	Two-way			Calibration Item:	City to Port				
	Surface Class:	Bituminous			- Selected Calibratio	on Item Summary				
		_			Pavement type:	Asphalt Mix on Granular Base				
					Surface material:	Asphaltic Concrete				
						UK Cancel				
N	lame of section									

Geometry

As there are NMT's on the existing road, speed reduction factors have been assigned for the non motorised traffic as well as for the motorised traffic.
ection: Capital City to Port						x
Definition Geometry Paver	nent Con	dition Other M	lotorised Traffic I	Non-motorised Tr	affic Asset Valu	ation
Rise + Fall	50	m/km	Speed Reductio	n Factors		
No. of rises + falls:	2	no./km	x	<u>N</u> MT: 0.7	0.4 <= XNMT <=	= 1
Superelevation:	3	%	Road side <u>f</u> ri	ction: 0.7	0.4 <= XFRI <=	1
<u>Avg</u> horiz curvature:	50	deg/km		X <u>M</u> T: 0.9	0.4 <= XMT <=	1
a <u>d</u> ral:	0.1	m/s²				
Speed limit enforcement:	110	km/h				
Atitude:	1	m				
					ОК	Cancel
verage road rise plus fall (in m/	km)					

Pavement

The pavement type has been defined as asphalt mix on granular base (AMGB) and was originally constructed in 1995. The Previous works indicates that the pavement type is unchanged as no periodic maintenance (i.e. overlay, surface dressings, etc) has been carried out to date.

The structural number, SN, of the pavement layers above the subgarde is 3.3, with a subgrade of 8% CBR, giving a SNP value of 4.35. For the improvement works assigned to this case study, a value of 3,3 has been specified for the structural number, SN.

Last regurfacing (resealing): 1995 year <u>Resilient modulus</u> : GPa Last greventative treatment: 1995 year	Suffacing Pavement type: Asphalt Mix on Granular Base Material type: Asphaltic Concrete Most recent suffacing thickness: 100 mm Previous/old suffacing thickness: 0 mm Previous works (HDM-4 Work Types)	Calculated Dry season model parameters SNP: 4.35 DEF: 0.62 mm [1] ① Structural Number: 3.3 Subgrade CBR: 8 % ① Dry Season ① Wet Season [2] ① Calculated SNP: Calculate SNP: Road base (for stabilised base only) Base thickness: mm
	Last regulfacing (resealing): 1995 year Last greventative treatment: 1995 year	<u>R</u> esilient modulus: GPa

Condition

The condition of the road section at the end of 2005 is specified, with the analysis commencing in 2006.

Condition at end of year	2005		
Roughness (IRI - m/km)	6.00		
All Structural Cracks (%)	10.00		
Wide Structural Cracks (%)	5.20		
Thermal Cracks (%)	0.00		
Ravelled area (%)	12.00		
Number of Potholes (No./km)	0.00		
Edge break area (m²/km)	10.00		
Mean rut depth (mm)	10.00		
Rut depth standard deviation (mm)	2.00		
Texture depth (mm)	0.50		
Skid resistance (SCRIM 50km/h)	0.40		
Drainage	Good 💌		

Other

The number of lanes (ELANES) is specified as 2 for the existing road. The ELANES of the road after improvement is defined within the Improvement Standard.

ction: Capital City to Port	
efinition Geometry Pavement Condition Other Motoris	ed Traffic Non-motorised Traffic Asset Valuation
Separate <u>NMT lanes</u> <u>N</u> umber of lanes: 0	Compaction (Bituminous only) Relative compaction: 97 %
Shoulders (Concrete only)	Previous surface condition (Bituminous only)
Shoulder type: Non-concrete	Area of all structural cracking: 0 %
\underline{W} idth of widening: 0 m	Area of wide cracking: 0 %
- Drainage	
Drain type: No change in drainage effect	ELANES: 2
	OK Cancel
el seperate lanes for non-motorised traffic	

Motorised Traffic

The AADT of 1500 in 2005 has been classified between the various vehicle types in the selected Vehicle Fleet. If certain vehicle types do not operate on the selected road section, then a value of zero should be assigned for those particular types (4WD and Mini bus in this case study).

Survey Year: 2005 4wD 0.00 Artic Truck 375.00 Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Goods Vehicle 3000.00 Medium Bus 750.00 Medium Car 7500.00 Medium Truck 1500.00 Minibus 0.00 Total AADT: 15000.00	<u>E</u> dit Year
Survey Year: 2005 4wD 0.00 Artic Truck 375.00 Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Goods Vehicle 3000.00 Medium Bus 750.00 Medium Car 750.00 Medium Car 7500.00 Mini-bus 0.00 Total AADT: 15000.00	<u>E</u> dit Year
Survey Year: 2005 4wD 0.00 Artic Truck 375.00 Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Goods Vehicle 375.00 Medium Bus 750.00 Medium Car 750.00 Medium Car 750.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	<u>E</u> dit Year
4wD 0.00 Artic Truck 375.00 Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Goods Vehicle 3000.00 Medium Bus 750.00 Medium Car 750.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	<u>gui rea</u>
Artic Truck 375.00 Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Truck 750.00 Medium Bus 750.00 Medium Car 7500.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	
Heavy truck 1125.00 Light Goods Vehicle 3000.00 Light Truck 750.00 Medium Bus 750.00 Medium Car 7500.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	
Light Goods Vehicle 3000.00 Light Truck 750.00 Medium Bus 750.00 Medium Car 7500.00 Mini-bus 0.00 Total AADT: 15000.00	
Light Truck 750.00 Medium Bus 750.00 Medium Car 7500.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	
Medium Bus 750.00 Medium Car 7500.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 1500.00	
Medium Car 7500.00 Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	
Medium Truck 1500.00 Mini-bus 0.00 Total AADT: 15000.00	
Mini-bus 0.00 Total AADT: 15000.00	
Total AADT: 15000.00	

Non Motorised Traffic

Similarly the NMT of 400 have been classified between the NMT types created in the selected Vehicle Fleet.

Section: Capital City to Port	×
Definition Geometry Pavement Condition Other Motorised Traffic Non-motonsed Traffic	C Asset Valuation
Vehicle Fleet used for this section / petwork: Northern Province Vehicles	
Survey Year: 2005	<u>E</u> dit Year
Animal carts 40.00	
Person 200.00	
Total AADT: 400.00	
	OK Cancel
	Cancer
Non-motorised Traffic	

Asset Valuation

Asset valuation is not considered in this case study.

3.3 Specify Alternatives

The four alternatives considered in this case study are described in Table E3.1.

Alternative	Description
1	This is the base alternative. Routine maintenance (crack sealing and pothole patching) is undertaken each year, as necessary, based on the pavement condition. In addition, a 50 mm overlay is applied when the roughness level reaches 6 IRI.
2	With this alternative, the existing road is widened by 1 m during the first 2 years of the analysis period (i.e. in 2006-07). The maintenance regime of Alternative 1 (Routine + 50 mm overlay), which is condition responsive, is effective from year 3 (i.e. from 2008).
3	With this alternative, the existing road is widened by 3 m during the first 2 years of the analysis period (i.e. in 2006-07). The condition responsive maintenance regime of Alternative 1 is effective from year 3 (i.e. from 2008).
4	With this alternative, the existing road is widened by adding two lanes during the first 3 years of the analysis period (i.e. in 2006-08). The condition responsive maintenance regime of Alternative 1 is effective from year 4 (i.e. from 2009).

Table E3.1 Project Alternatives

The Maintenance Standard (Routine + 50 mm overlay) comprises the following works items:

Crack sealing if area of wide structural cracking ≥ 10% of carriageway area

Patching potholes if no. of potholes \geq 10 / km

50 mm overlay if roughness > 6 IRI

Each widening alternative includes this Maintenance Standard providing condition responsive routine pavement works and condition responsive overlay, effective from the year following completion of the widening works. This Maintenance Standard has been defined as the base alternative.

Each widening alternative is scheduled to start in year 1 of the analysis period (year 2006), with a construction period of two or three years A summary of the costs and widths of the widening alternatives is given in Table 2, together with the existing road.

		Duration	Economic cost	After V	Videning
Alternative	Widening	of works (years)	of widening (US\$/km)	Carriageway width (m)	Speed-flow relationship
1	None	-	-	(7)	(Two lane road)
2	+1 m	2	32,000	8	Two lane road
3	+3 m	2	102,000	10	Wide two lane
4	+2 lanes	3	238,000	14	Four lane road

Table E3.2Summary of Widening Alternatives

The speed-flow type determines the capacity of the road section. The base alternative (Alternative 1) has been assigned the speed-flow type for a two-lane road. The same speed-flow type has been assigned to Alternative 2. For Alternatives 3 and 4, the capacity of the widened road section will be increased and therefore revised speed-flow types have

been specified under the respective Improvement Standards. The capacities and jam speeds for the four alternatives are given in Table E3.3.

Alternative	Speed Flow	Free Flow Capacity	Nominal Capacity	Ultimate Capacity	Jam Speed km/h
1 & 2	Two lane road	140	1260	1400	25
3	Wide two lane	320	1440	1600	30
4	Four lane road	800	1900	2000	40

Table E3.3Capacities of the Alternatives

Note: Capacities are in PCSE / lane / hr

The various widening alternatives have an impact on the speed reduction due to NMT, MT, and roadside friction. For the existing road section, these data are specified under Geometry in the section details (see Section 3.2.2). For the widening alternatives, the data are specified under Geometry within the Improvement Standard. The values assigned for each alternative are given in Table E3.4.

		Speed limit	Spee	ed reduction fac	ctors
Alternative	Widening	km/h	NMT	МТ	Roadside friction
1	None	100	0.7	0.9	0.7
2	+1 m	100	0.75	0.9	0.7
3	+3 m	100	0.9	1	0.8
4	+2 lanes	120	1	1	1

Table E3.4Speed Limit and Speed Reduction Factors

The alternatives are assigned to the selected road section as shown in the Specify Alternatives screen below.

HDM-4 - [Project: 3a. Capacity improvements - without	sensitivity analysis]	_ 8
Workspace View Report/Chart Window Help		
Define Alternatives		
Project Navigation	- Details	
	Analysis by Project	
Atematives	Alternative Name	New Diverted
📄 🔤 Capital City to Port	Alicinauve Mallie	Sections Traffic
Analyse 2006 : Project 384: Re	tin 1: Base case without widening	× Add × Edit
Capital City to Port	3: Widening by 3m	× Add × Edt
Multi Criteria 2006 : Project 3 - Part	4 : Lane addition (2 lanes)	× Add × Edit
Analysis 2008 : Project 384: Ri	uti Add new alternative	
Generate 3 : Widening by 3m		
Reports Capital City to Port	n	
	uti	
E 4 : Lane addition (2 lanes)		
Capital City to Port	A	
2009 : Project 384: R	utin in the second s	
Save		
		<u> </u>
	Add Alternative Copy Alternative Paste Alternative Delete Alternative	
	,	
ningt description		

3.4 Analyse Projects

3.4.1 Setup Run

The options selected in the Setup Run screen are Conduct Economic Analysis using a discount rate of 10%, with the 'without widening' alternative selected as the base alternative. The additional models for accidents, energy balance, emissions, acceleration effects and asset valuation are not included in this analysis.

Workspace View Report/Chart Window Help	analysisj	
Define Setup Run Sensitivity Run Analysis		<u>-10</u> ,
Project Details Specify Alematives Conduct Economic Analysis Base atemative: 1: Base case without widen' Discount gite: 10 % Projects Multi Citeria Multi Citeria Multi Citeria Mayses Projects	Model Inclusion Egergy Balance Egergy Balance Egergy Balance Regressions Agceleration effects Log File Write Log file Pun Data Export. Detal Exclude annual whicle data Exclude vehicle gerod data	
Asset valuation Eerform run with asset valuation Run Data Export Directory D:\Greg\HDM4\Case Studies.\V2.0\Vol 2 Greg\Run	Data	
Sgyre		
Close		

For this case study (**Project 3a**), sensitivity analysis has not been selected (see **Project 3b** for sensitivity analysis relevant to this case study).

3.4.2 Run Analysis

This starts the analysis and produces the output necessary for report generation.

3.5 Multi Criteria Analysis

Multi criteria analysis has not been used in this case study.

3.6 Generate Reports

The output reports from the analysis are produced and stored in the appropriate folders.



Traffic

Details on the AADT, motorised and non motorised traffic flows for each alternative over the 20-year analysis period are reported in this folder in both graphical and tabular form.

Also reported are the volume/capacity ratios, which are of particular relevance to this case study. The volume/capacity ratios are reported for 5 time periods for Alternative 1 because the traffic flow pattern, Commuter, was split into these periods. For the widening alternatives volume/capacity ratios are reported for only one time period, once construction has been completed, because the Free Flow traffic pattern was used, which had been defined with one traffic period. However, during the construction period of the widening (i.e. initial 2 or 3 years), the five time periods of the Commuter traffic flow pattern were applicable.

Section: Alternative: Sensitivity:	Capital City 4 : Lane ado No Sensitivi	to Port lition (2 Ianes) ty Analysis Co	nducted			
Sect ID: A Length: 10	003-01 0.00 km	Width: 7.00 m	Roa Roa	ad Class: Prim tise+Fall: 10.0	ary or trunk 10 m/km	Curvature: 50.00 deg/km
	Period 1	Period 2	Period 3	Period 4	Period 5	
2006	0.830	0.760	0.640	0.440	0.060	
2007	0.860	0.790	0.660	0.460	0.070	
2008	0.890	0.820	0.680	0.480	0.070	
2009	0.100					
2010	0.100					
2011	0.110					
2012	0.110					
2013	0.110					
2014	0.120					
2015	0.120					
2016	0.130					
	0 130					
2017	0.150					

Deterioration / Works Effects

The progression of the various distresses for each alternative over the analysis period are reported in this folder in both graphical and tabular form. The Average Roughness by Section (Graph) report illustrates the roughness progression for each alternative. In the graph shown below, for example, the roughness of the base alternative is reduced at the end of the first year because the overlay works item has been triggered.



Also reported in this folder are the timing of the works carried out for each alternative during the 20-year period. In the Road Works Summary (by Section) report shown below, the overlay being triggered for the base alternative in year 2006 discussed above, is listed.

ΗI	D M - 4	Road Worl	ks Summary (b	y Section)	
IGHWAY D	EVELOPMENT & MANAGEMENT	Study Name: 3 Run Date: 1 Currency: U	a. Capacity improvements 1-07-2006 S Dollar	s - without sensitivit	y analysis
te: only se Section: Alternativ Sensitivity Surface C Length:	Capital City to Port Capital City to Port 1 : Base case without wi No Sensitivity Analysis (Iass: Bituminous 10.00km	are displayed. dening Conducted	Road Class: Pri Width: 7.0	mary or Trunk 10m	
Year	Description	Code	Economic Cost	Financial Cost	Work Quantity
2006	Overlay 50mm at 6 IRI	OVL50	1,050,000.0	1,260,000.0	70,000.00 sq. m
	Prep. Edge Repair		9,386.7	11,264.0	670.48 sq. n
2014	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. n
2015	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. n
2016	Patching Potholes	PATPOT	2,996.5	3,595.8	249.71 sq. r
	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. r
2017	Patching Potholes	PATPOT	1,483.6	1,780.3	123.63 sq. r
	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. r
2018	Patching Potholes	PATPOT	1,979.5	2,375.4	164.96 sq. r
	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. r
2019	Patching Potholes	PATPOT	2,396.4	2,875.7	199.70 sq. r
	Crack Sealing	CRKSL	0.0	0.0	0.00 sq. r
2020	Overlay 50mm at 6 IRI	OVL50	1,050,000.0	1,260,000.0	70,000.00 sq. r
	Prep. Patching		2,596.9	3,116.2	216.40 sq. n
	Prep. Edge Repair		176,400.0	211,680.0	12,600.00 sq. r
2021	Patching Potholes	PATPOT	0.0	0.0	0.00 sq. r
Total cost	for the section:		2,297,239,5	2,756,687,3	

Road User Effects

The various components of road user effects are reported in this folder. Also reported in this folder are the road user costs for the non motorised traffic. Of particular relevance to this case study are the effects of the widening alternatives on vehicle speeds of both the motorised and non motorised traffic.

Cost Streams and Economic Evaluation

This folder contains the results of the economic analysis. The Economic Analysis Summary report indicates that the widening by 3 m alternative produces the highest benefit (NPV).

HIGHWAY DEVELOPMENT & MANAGEMENT RIGHWAY DEVELOPMENT & MANAGEMENT RUN DATE: 11-07-2006 Currency: US Dollar (millions) Discount Rate: 10.00%									
Sensitivity Analysis Conducted Alternative	Present Value of Total Agency Costs (RAC)	Present Value of Agency Capital Costs (CAP	increase in Agency Costs (C)	Decrease in User Costs (B)	Net Exogenous Benefits (E)	Net Present Value (NPV = B+E-C)	NPV/Cost Ratio (NPV/RAC)	NPV/Cos Ratic (NPV/CAP	internal Rate of Returr (IRR)
1 : Base case without widening 2 : Widening by 1m 3 : Widening by 3m 4 : Lane addition (2 lanes)	1.386 1.674 2.279 3.366	1.326 1.316 1.905 2.962	0.000 0.288 0.893 1.980	0.000 26.344 31.669 24.148	0.000 0.000 0.000 0.000	0.000 26.055 30.776 22.168	0.000 15.562 13.504 6.586	0.000 19.795 16.155 7.434	0.000 72.0 (2) 63.7 (2) 33.7 (1)
						Figure in t	brackets is number	of IRR solutions in	range -90 to +900

3.7 Sensitivity Analysis

Project 3b. Capacity improvements – with sensitivity analysis investigates the effect of changes in the value of a number of key variables on the outcome of the economic analysis.

The scenarios which were examined included variations in the following variables, each one at a time:

- Normal traffic growth (+/- 70%), equivalent to a growth of between 1% and 5% for most vehicles
- Capital costs (+ 25% and + 50%)
- A combination of high capital cost (+25%) and low traffic growth (-70%)

This case study is located in the **Projects** folder in the Workspace. Double-click on Project case study **3b. Capacity improvements – with sensitivity**.

The additional steps and results are described below.

3.7.1 Defining Scenarios

The various scenarios are defined in the following screen, and accessed through the **Analyse Projects/Sensitivity** tab page.



3.7.2 Run Analysis

This starts the analysis and produces the output necessary for report generation, and is executed in the normal manner.

3.7.3 Generate Reports

A full set of reports are available for all scenarios. The user may select **Generate Reports** to display the folders holding pre-defined report options which they consider relevant to interpreting the results of this case study. Both input and output/analysis reports should be examined. The following discussion concentrates on the effects of the scenarios examined on the congestion performance of the alternatives, and effect on economic viability.

Volume/Capacity Ratios by Traffic Flow Period (Graph)

This report is accessed through the Traffic folder. The resulting graph for the 1m widening alternative/low traffic growth scenario is shown below, noting that excess capacity exists for the duration of the project analysis.



Economic Analysis Summary

Economic Analysis Summary Study Name: 3b. Capacity improvements - with sensitivity analysis Run Date: 11-07-2006 Currency: US Dollar (millions) Discount: 10.00% Analysis Mode: Analysis-by-Project									
ternative: 2 : Widening by ensitivity Scenario: Base	1m vs Alterna Sensitivity Scen	tive: 1 : Base cas ario	e without wideni	ng Oscience in	0	0i	Reduction		
ternative: 2 : Widening by nsitivity Scenario: Base	1m vs Alterna Sensitivity Scen	tive: 1 : Base cas ario Increase in Roa	e without widenin d Agency Costs	ng Savingsin MT VOC	Savings in MT Travel Time	Savings in NMT Travel	Reduction in Accident	Nel Social /	Ne
ternative: 2 : Widening by nsitivity Scenario: Base	1m vs Alterna Sensitivity Scen Capital	tive: 1 : Base cas iario Increase in Roa Recurrent	e without widenin d Agency Costs Special	ng Savingsin MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Nei Social / Exogenous Benefits	N Econom Benefi (NP)
ternative: 2 : Widening by Insitivity Scenario: Base Undiscounted	1m vs Alterna Sensitivity Scen Capital -0.58	tive: 1 : Base cas ario Increase in Roa Recurrent 0.37	e without widenin d Agency Costs Special 0.00	ng Savingsin MTVOC 41.79	Savings in MT Travel Time Costs 43.32	Savings in NMT Travel & Operating Costs -0.01	Reduction in Accident Costs 0.00	Net Social / Exogenous Benefit: 0.00	N Econom Benefi (NP' 85.2

The Economic Analysis Summary report has been used to populate Table E3.5, Table and Table E3.7 which form the basis for interpreting the results of the sensitivity analysis.

Table E3.5

Comparison of NPV (millions) and EIRR by Traffic Growth Scenario

Widening Alternative	Indicator	Low	Most Likely	High
1 m	NPV	10.37	26.06	35.69
1 111	EIRI	48.8	72.0	119.7
2 m	NPV	12.37	30.78	46.33
5 11	EIRI	42.6	63.7	93.0
Additional Janaa	NPV	4.97	22.17	36.64
Auditional lanes	EIRI	18.3	33.7	48.0

Table E3.6Comparison of NPV (millions) and EIRR by Capital Cost Scenario

Widening Alternative	Indicator	Most Likely	High	Very High
1 m	NPV	26.06	26.06	26.06
1 111	EIRI	72.0	80.8	No solution
3 m	NPV	30.78	30.63	30.49
5 11	EIRI	63.7	64.6	65.8
Additional Janaa	NPV	22.17	21.75	21.34
Auditional lattes	EIRI	33.7	32.5	31.4

Table E3.7

Comparison of NPV (millions) and EIRR by High Cost/Low Growth Scenario

Widening Alternative	Indicator	Most Likely	High Capital Cost / Low Growth
1 m	NPV	26.06	10.35
1 111	EIRI	72.0	50.8
2 m	NPV	30.78	12.21
5 111	EIRI	63.7	42.2
Additional lance	NPV	22.17	4.54
Additional laries	EIRI	33.7	17.3

All of the scenarios confirm the 3m widening alternative as the most viable, even where combinations of factors are examined as shown in Table E3.7.

4 CASE STUDY 4 – CONSTRUCTION OF A NEW BYPASS

4.1 Introduction

This case study presents the economic analysis of a project to construct a bypass around a town centre. The objective is to demonstrate the specification of the bypass (as a section alternative within a project alternative), and to examine the resulting traffic diversion effects.

Four existing road sections, A, B, C & D represent the network at a town centre. The proposed project is the construction of a bypass, represented by one section (Section E), 10 km long. The case study considers four project alternatives as follows:

- Alternative 1: Base alternative without the bypass
- Alternative 2: Bypass constructed to a width of 8 m over a period of 2 years
- Alternative 3: Bypass constructed to a width of 10 m over a period of 3 years
- Alternative 4: Bypass constructed to a width of 14 m over a period of 4 years

The AADT values on the four existing sections at the start of the analysis period are as follows:

Section A	10,000
Section B	4,000
Section C	6,000
Section D	8,000

The traffic flows (AADT) on each section after bypass construction will normally be derived using an external traffic demand model (i.e. derived outside HDM-4). In this case study the AADT on Sections A & B are assumed to be only marginally affected after the construction of the bypass, whereas on Sections C & D there are significant reductions in the traffic flows after construction. The AADT is reduced on Section C to 1,000 and on Section D to 3,000. The bypass section (Section E) will have an AADT of 5,000 when opened (i.e. 2008 for Alternative 2, 2009 for Alternative 3 and 2010 for Alternative 4).

New construction sections, such as a bypass, need to be created in the **New Construction Sections** folder in the Workspace, prior to their inclusion in an analysis.

For this case study, three new construction sections have been created, each representing the three construction options for the bypass. The screen from the 4 lanes alternative shown below, indicates that the Speed Flow Type has been set to Four Lane Road as the width of the new bypass is 14 metres.

New Construction	Section: F	Project 4: Section E (4 land	es)	X
Definition Costs	Geometry	Pavement Condition Ot	her Motorised Traffic	Non-motorised Traffic Asset Valuation
<u>N</u> ame:	Project 4:	Section E (4 lanes)	Speed <u>Fl</u> ow Type:	Four Lane Road
<u>I</u> D:	Sect E		Traffic Flow Pattern:	Commuter
Link Na <u>m</u> e:	New Link		<u>A</u> ccident Class:	Four Lane Road
Lin <u>k</u> ID:	NEW1		Climate <u>Z</u> one:	Subtropical-Hot Sub-Humid
Length:	10	km	<u>R</u> oad Class:	Primary or Trunk
Cway <u>W</u> idth:	14	m		
S <u>h</u> oulder Width:	1.5	m	Calibration Set:	Section E
Flow Direction:	Two-way	•	Calibration Item:	Section E - 4 lanes
Surface Class:	Bituminou	s 💌	- Selected Calibratio	on Item Summary
			Pavement type:	Asphalt Mix on Granular Base
			Surface material:	Asphaltic Concrete
				OK Cancel
Name of section				

The construction of the 4 lanes bypass will take 4 years as described in the Costs tab page.

New Construction Section: Project 4: Section E (4 lanes)
Definition Costs Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic Asset Valuation
Economic cost: Enancial cost: Selvage value: 10 % Manual cost target 25 25 25 25 0 %
* construction costs are expressed in the current works currency (US Dollar)
OK Cancel
Economic cost per km of the new construction

The construction is 100 mm of asphalt on a granular base (AMGB) and will be completed in 2009 (i.e. in the fourth year of the analysis period).

Surfacing Pavement type: Asphalt Mix on Granular Base Material type: Asphaltic Concrete Most recent surfacing thickness: 100 Previous/old surfacing thickness: 0 Previous/old surfacing thickness: 0 Previous/old surfacing thickness: 0 Previous/old surfacing thickness: 0 Previous works (HDM-4 Work Types)	Strength Calculated Wet season model parameters SNP: 4.15 DEF: 0.67 mm [1] © gructural Number: 3.1 Subgrade CBR: 8 % © py Season © Wet Season [2] © Calculated SNP: Calculate SNP Road base (for stabilised base only) Base thickness: mm Bestlient modulus: GPa
,	OK Cance

The AADT on the new bypass will be 5,000 when opened (i.e. in 2010 for the 4 lanes alternative) as specified in the Motorised Traffic tab page.

v Construction S	ection: Pr	oject 4: Se	ction E (4	lanes)					
efinition Costs	Geometry	Pavement	Condition	Other	Motorised	Traffic	Non-motorised	d Traffic	Asset Valuatio
Vehicle Fleet use	d for this se	ection/netwo	rk: Northen	n Provinc	e Vehicles				
Survey Ye	ear:	2010						Ec	lit Year
4WD		0.00							
Artic Truck		250.00							
Heavy Truck		250.00							
Light Goods Veh	icle !	500.00							
Light Truck		0.00							
Medium Bus		250.00							
Medium Car	3	00.00							
Medium Truck		500.00							
Mini-bus		250.00							
Total AAI	DT: 50	00.00							
								ОК	Cancel
orised Traffic									

The case study is located in the **Projects** folder in the Workspace. Double-click on the Project case study **4. Construction of a new bypass** to open the case study.

4.2 Define Project Details

In the Define Project Details screen, the following tab pages may be displayed:

- General
- Study Sections

4.2.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

As mentioned in Section B2.2, analyses involving new sections and diverted traffic can only be performed using the Analysis by Project method of analysis.

📫 HDM-4 - [Project	t: 4. Construction of new bypass]
Workspace View	v Beport/Chert Window Help
Define Project Details	General Study Sections
Specify Alternatives	Description: Project 4: Construction of a new bypess
Analyse Projects	Analyse by: C Section C Project
Analysis	Start year: 2006 Analysis period: 20 years
Regorts	Road Betwork: [Northern Province]
	Works: US Dollar × 1 = output clarency Works: US Dollar × 1 = output currency
	Network: US Dollar × 1 - output currency
	Qutput: US Dollar
Save	
Close	
Project description	

The analysis period is defined by the start year 2006 and a duration of 20 years (i.e. 2006 - 2025). The existing sections (A, B, C & D) to be analysed are in the Road Network entitled Northern Province, to which the Northern Province Vehicles have been previously assigned as the Vehicle Fleet. The currency being used for this analysis is US dollars.

4.2.2 Study Sections

The four sections in the Northern Province road network selected for this analysis are displayed below. The new bypass (Section E) will be added in the Specify Alternatives screen (see Section E4.3).

HDM	- 4 - [Projec ksnace View	t: 4. Construct	tion of new t Window	v bypass] Heln																							-			-	-																																																								2	9														
>	Define Project	General Stu	dy Sections																_	_																																			_	_															_																Ī	Ī						_								
~	Details	L	1.5		C . K . C	·		1		-		_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	_	-	-	-	-	-	-	-	-	-	-	-	_	_	_	_	-	_	_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Constitu	Inclu	de in		Sections	ummary		Traffic Growth																														h	th	vth	wth	wth	wth	wth	wth	wth	wth	wth	wth	owth	owth	owt	row	irow	irow	àrov	Gro	Gri	a Gr	c G	c G	c G	c G	c G	c G	G	Gr	Grr	Gro	âro	irov	owti	wth	wth	vth	wth	wth	wth	vth	vth	vth	vth	vth	λth	th	h	i.				i .	h	vth	wth	With	ow	iow	10%	iro	àra	ârd	ârd
۲	Alternatives	Study	Analysis	Cost D	Description	Liass	Pavement	Desired 4: Continue D	-	4				4	47	47	-	-	4	4	47	47	48	4	4	-	-	-	-	-	-	-	-	-	-	-	_			- D							P	D		Care I			- 1 ² - 1	- 6	a Kina	- 6.					n	· · ·	· · ·								- 61 -	-			- D				- D	- D	- D	- D		- D		_	_	-	_	_	_	_				i.	1.1	- 12 -	- 61	- 12		
				Secto	Section D	Primary or trunk	Bituminous	Project 4: Section D		-					- 7	-17	-8	-8	-82	-82	-17	-17	-8	-1	-	_											_	0	10	<u>nu</u>	<u>n D</u>	<u>n D</u>	<u>n D</u>	n D	JnD	<u>n v</u>	on D	on D	onD	lion	::ion i	tion	200r	Stion	2001	COO	300	ect	Sec	sec o	sec o	5 ec	5 ec	Sec	bec)ec	ect	900	300	200	200	aoni	onL	nD	<u>n U</u>	<u>n D</u>	<u>n D</u>	<u>n U</u>	<u>n D</u>	10	10	10	<u>- 10</u>	10	10	-	2	2	<u>_</u>	<u>_</u>	2	-	<u></u>	un L	on	:10P	-00	200	200	C0	100	100
_	Analyse	<u> </u>	<u>×</u>	Sectu	Section L	Primary or trunk	Bituminous	Project 4: Section L		-					-	- 7	-1	-1	-8	-8	-17	-17	-8	-1	-	_											<u>(</u>	<u>ь</u>	10	10	nu D	n L	nu nu	un L	Jnu	Jnu	on L	on u	onu	lion (aon	tion	ation	ction	CUDE	200	300	ect	5ec	sec °	sec °	sec c	sec c	sec c	bec	ec	ect	acti	300	2000	200	aon	onu	Jn L	n L	nu nu	n L	nu D	n L	10	10	10	10	16		+	<u>~</u>	÷	<u>_</u>	<u>_</u>	~	는	<u>n L</u>	un u	on	aor	-001	200	200	C0	100	100
2	Projects	<u> </u>	<u>×</u>	Secta	Section B	Primary or trunk	Bituminous	Project 4: Section B	-	-					-	- 7	-1	-1	-8	-8	-17	-17	-8	-1	-	_											_	B	1B	18	n B	Jn B	n B	JN B	JN B	JUL R	on B	on B	on B	lion t	aon i	tion	ation	ction	2001	CUD	300	ect	bec	sec °	sec °	sec c	sec c	sec	bec	ec	ect	acti	300	1000	200	aoni	on B	JN B	n B	n B	n B	n B	n B	18	18	18	18	18	18	B	5	÷	-	-	5	B	18	on E	on	aor	-001	200	200	C0	100	100
	-			SectA	Section A	Primary of trunk	Bituminous	Project 4: Section A	-						1	1					el l	d.		al i	_	2	-	-	-	-	-	-	-	-	-	-	÷	A.	IA.	лA	nA	n A	.n.e)n A)n A	on A	on A	on A	onA	lion /	:10n /	tion	;tior	stior	2001	Ctio	300	.ect	sec	sec	sec	sec	sec	sec	sec	ec	ect	300	300	.000	2001	aon	on e	лA	nA	.n.e	nA	nA	nA	1A	1A	1A	nА	1A	18	A	ì	h	÷	÷	<u>۸</u>	A	28	on e	.on	:10r	-001	200	200	CO	100	100
	Multi Criteria																																																																																																					
-	Analysis																																																																																																					
_																																																																																																						
6	Generate																																																																																																					
7	Reports																																																																																																					
		<u> </u>							_	_	_	_	_	_	_	-	_	_	_	_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	_	_	_	_	_	_	_	_	_	_	_	_	_	_	-	_	_	_	-	-	-	_	_	_	_	-	_	_	-	-	-	-	_	-	_	_	_	_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	_	-	-	-	-	-	_	_	_
÷		Assign Gra	uth Cat	Salast by Crite	in Manu/Edit Se	otion 1 Maur/	Edit Elevet																																																																																															
	Save	Assign Gro	wth Set	Select by Unte	na View/Edit 36	view/t	dit <u>r</u> ieet																																																																																															
<u> </u>		Copy Gro	wth Set	Unselect A	I View/Edit Ne	twork																																																																																																
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ns	selected for a	nalvsis																																																																																																				

By double-clicking on the section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case Northern Province Vehicles) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays all the previously created sets.

Name	Description (optional)		New Growth Set.
Project 1	Upgrading a gravel road		
Project 3	Capacity Improvements		Copy
Project 4: Section A	Section A		
Project 4: Section B	Section B		Delete
Project 4: Section C	Section C		Edit
Project 4: Section D	Section D		
Project 4: Section E (2 lanes)	Section E - 2 lanes		
Project 4: Section E (wide 2 - lanes)	Section E - wide 2 lanes		
Project 4: Section E (4 lanes)	Section E - 4 lanes		
			UK
		.Η	Cancel

For this case study (Project 4) several traffic growth sets have been created: one for each of the existing four sections and one for each of the three bypass construction alternatives. Double-clicking on one of the sets displays the details of the traffic changes over the analysis period for that set.

The traffic growth rates for Sections A, B, C & D are the same (Section A displayed below), Section E takes 2, 3 or 4 years to construct as described in Section E4.1. Therefore the growth rate is specified from the year that the bypass is opened (in year 3 for the 2 lanes altenative shown below).

Name: Project 4: Sec	tion A		Name: Project 4: Sec	tion E (2 lanes)			
scription: Section A			Description: Section E - 2	anes			
torised Growth Periods	Non-Motorised Growth Per	iods	Motorised Growth Periods	Non-Motorised G	rowth Periods		
Vehicle	Annual % increase from year 1	Add New Period	Vehicle	Annual % increase from year 1	Annual % increase from year 3	-	Add New Period
Medium Bus	2.00		Medium Bus	0.00	3.00		
Artic Truck	2.00	Delete Period	Artic Truck	0.00	3.00		Delete Period
Heavy Truck	2.00		Heavy Truck	0.00	3.00		
fedium Truck	2.00	Note: years are	Medium Truck	0.00	3.00		Note: years are
ight Truck	0.00	 defined relative to 	Light Truck	0.00	0.00	-	defined relative to
ight Goods Vehicle	2.00	the start year of the	Light Goods Vehicle	0.00	3.00		the start year of th
Medium Car	5.00	✓ the traffic growth	Medium Car	0.00	6.00	-	the traffic growth
Ú.		set is used.					set is used.

The section details can be accessed by double-clicking on the section shown in the Study Sections tab page. All four sections were originally constructed in 2002. The construction was 100 mm of asphalt on a granular base (AMGB) in all cases. Other basic section details are given in Table .

Table E4.1 Section Details

	Section A	Section B	Section C	Section D
Length (km)	6	3	5	7
Carriageway width (m)	8	7.3	7.3	8
Speed Flow Type	Two Lane Wide	Two Lane Standard	Two Lane Standard	Two Lane Wide
AADT (2005)	10,000	4,000	6,000	8,000

The traffic composition for each section is given in the Motorised Traffic tab page which are shown below.

Section A	Section: Section B
Section: Section A X Definition Geometry Pavement, Condition Other Motorised Traffic Non-instantial Asset Valuation Vehicle Reat used for this section/instance. Nothern Province Vehicles Starvey Year 2006 Value 500.00 Ario: Track 500.00 Heavy Track 500.00 Upti Goods Vehicle 1000.00 Light Track 500.00 Medium Bas 500.00 Medium Track 1000.00 Minimum Sec 6000.00 Medium Track 10000.00 Minimum Sec 10000.00 Minimum Sec 10000.00	Section: Section 8 X [Definition] Geometry Pavement. Condition Other: Motional Traffic Non-motioned Traffic Asset Valuation Vehicle Reet used for this section/instead. Northern Province Vehicles
OK Cencel	OK Cencel Motorised Traffic

Section: Section C 🛛 🗙	Section: Section D
Definition Geometry Pervenent Condition Other Monimed Traffic Non-instanced Traffic Asset Valuation Vehicle Fleet used for this section/instance Nothern Province Vehicles	Definition Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic Asset Valuation Vehicle Survey Year 2005 Aric Track 400.00 Heaver Track 400.00 Light Track 0.00 Mediam Rus 400.00 Mediam Track 0.00 Media
OK Cencel	OK Cencel

4.3 Specify Alternatives

The four alternatives considered in this case study are described in Table E4.2.

Alternative	Description
1	This is the base alternative. Routine maintenance (crack sealing and pothole patching) is undertaken each year on all four sections based on their pavement condition. In addition, a 50 mm overlay is applied when the roughness level reaches 6 IRI.
2	With this alternative, the existing four sections are maintained as in Alternative 1. In addition the new bypass is constructed to a width of 8 metres over the first 2 years of the analysis period and then maintained using the condition responsive maintenance regime of Alternative 1.
3	With this alternative, the existing four sections are maintained as in Alternative 1. In addition the new bypass is constructed to a width of 10 metres over the first 3 years of the analysis period and then maintained using the condition responsive maintenance regime of Alternative 1.
4	With this alternative, the existing four sections are maintained as in Alternative 1. In addition the new bypass is constructed to a width of 14 metres over the first 4 years of the analysis period and then maintained using the condition responsive maintenance regime of Alternative 1.

Table E4.2 Project Alternatives

The Maintenance Standard (Routine + 50 mm overlay) comprises the following works items:

Crack sealing if area of wide structural cracking ≥ 10% of carriageway area

Patching potholes if no. of potholes \geq 10 / km

50 mm overlay if roughness > 6 IRI

To assign a new section to a project alternative, the user needs to click on the **Add** button in the **New Sections** column of the alternative being created.



The options available to add as a new section are those that have been previously created in the **New Construction Section** folder (see Section 4.1). A Construction start year needs to be specified and a Traffic growth set needs to be selected from those previously created. In this case study, three traffic growth sets have been created – one for each bypass construction alternative. The appropriate one should be assigned to each alternative.

ew Construction Section Option	x
New construction section:	OK
Project 4: Section E (2 lanes)	Cancel
N Project 4: Section E (4 lanes)	
N Project 4: Section E (wide 2 la	
Select a new construction section from the list above. The list contains those new sections which are appropriate to this study (i.e. use same vehicle fleet as study), and which have not already been used in the current project alternative.	
Construction start year: 2006	
Iraffic growth set: <undefined></undefined>	

As a result of new construction, traffic may be diverted from existing road sections. To assign new traffic levels for existing sections, the user needs to click on the **Edit** button in the **Diverted Traffic** column for the appropriate alternative.

In this case study, the AADT on Sections A & B are marginally reduced to the values at the start of the analysis period, whereas on Sections C & D the AADT are significantly reduced upon opening of the new bypass. The AADT for the four sections are specified for the first year of opening for each bypass construction alternative. For example, for the 4 lanes alternative shown below, the AADT is specified for the year 2010.

For the new traffic levels on each existing section, the traffic composition and the traffic growth rates need to be specified. The screen for entering this information is accessed by either clicking on the Edit Diversion Details button or by double-clicking on the New AADT value. The growth rates for the new AADT on the existing sections have been reduced from those specified for the base alternative.



The Maintenance Standard (Routine + 50 mm overlay) is assigned from the year 2006 to Sections A, B, C & D in all four alternatives. The same maintenance standard is assigned to Section E (new bypass) from the year of opening of the bypass (2008 for 2 lanes, 2009 for wide 2 lanes and 2010 for 4 lanes).

4.4 Analyse Projects

4.4.1 Setup Run

The options selected in the Setup Run screen are Conduct Economic Analysis using a discount rate of 10%, with the 'base case without bypass' alternative selected as the base alternative. The additional models for accidents, energy balance, emissions, acceleration effects and asset valuation are not included in this analysis.

rkgpace View	r Beport/Chart Window Bep		
Define Project	Setup Run Senativity Run Analysia		
Detais	- 🖓 Conduct Economic Analysis	Model Inclusion	
Atematives	Base attemative: 1. Base Case Without Bypas	☐ Epergy Balance ☐ Emasons	
Analyse Projects	The second se	C Agceleration effects	
Multi Criteria	Average accident category cost (in thousands	Leg Fie	
Analysis	of US Dollar)	1 Write Log file	
Regota	I have be a set of the	Exclude annual gehicle data	
	- Reset unk office	Exclude vehicle gerod data	
	Eerform run with asset valuation		
	- Run Data Export Directory		
	C\Program Files\HDM-4 Version 2\Case Studies\Eng	VRunData Brogse	
Save			
-			

For this case study, sensitivity analysis has not been selected.

4.4.2 Run Analysis

This starts the analysis and produces the output necessary for report generation.

4.5 Multi Criteria Analysis

Multi criteria analysis has not been used in this case study.

4.6 Generate Reports

The output reports from the analysis are produced and stored in the appropriate folders.

Traffic

Details on the traffic flows for each alternative over the 20-year analysis period are reported in this folder in both graphical and tabular form. Also reported are the volume/capacity ratios.

The traffic levels over the analysis period are shown below for the 'wide 2 lanes' alternative. The graph illustrates the reductions in AADT for Sections A, B, C & D when the bypass is opened in year 4.



Deterioration / Works Effects

The progression of the various distresses for each alternative over the analysis period are reported in this folder in both graphical and tabular form. Also reported in this folder are the timing of the works carried out for each alternative during the 20-year period.

The Road Works Summary (by Year) report lists the works activities for each alternative, year by year. As shown in this report for Alternative 3, the 'wide 2 lanes' construction takes place during the first 3 years. Routine maintenance activities that occur on the existing sections in the first few years of the analysis period are also shown below.

Alternative: Sensitivity:	3: With Bypass No Sensitivity	s (Section E - wide 2 lanes Analysis Conducted))			
Year	Section	Works Description	Code	Economic Cost	Financial Cost	Work Quantity
2006	Project 4: Secti	on E (New Section: Projec	t 4: Sectio	1,162,120.0	1,360,000.0	1.00 kn
			Total Annual Cost:	1,162,120.0	1,360,000.0	
2007	Project 4: Secti	on E (New Section: Projec	t 4: Sectio	1,127,940.0	1,320,000.0	1.00 kn
			Total Annual Cost:	1,127,940.0	1,320,000.0	
2008	Project 4: Secti	on E (New Section: Projec	t 4: Sectio	1,127,940.0	1,320,000.0	1.00 kn
			Total Annual Cost:	1,127,940.0	1,320,000.0	
2010	Section A	Crack Sealing	CRKSL	26,316.8	31,580.2	5,263.36 sq. n
			Total Annual Cost:	26,316.8	31,580.2	
2011	Section A	Patching Potholes	PATPOT	516.7	620.1	43.06 sq. n
	Section B	Patching Potholes	PATPOT	112.0	134.4	9.33 sq. n
	Section D	Patching Potholes	PATPOT	190.9	229.1	15.91 sq. n
			Total Annual Cost:	819.7	983.6	
2012	Section A	Patching Potholes	PATPOT	221.1	265.3	18.43 sq. n
		Crack Sealing	CRKSL	26,316.8	31,580.2	5,263.36 sq. n
	Section B	Patching Potholes	PATPOT	47.5	57.1	3.96 sq. n
	On ation D	Crack Sealing	CRKSL	12,007.1	14,408.5	2,401.41 sq. n
	Section D	Patching Potholes	CRKSI	76.9	92.3	0.41 sq. n
		Crack Sealing		32,024.7	39,149.0	0,024.94 SQ. II

At the end of this report the total costs for each alternative for each year are summarised.

	ase Case Without Bypass	bass (Section E - 2 lanes)	Section E - wide 2 lanes)	bass (Section E - 4 lanes)
2006	0.00	1,367,500.00	1,162,120.00	1,196,500.00
2007	0.00	1,367,500.00	1,127,940.00	1,196,500.00
2008	0.00	0.00	1,127,940.00	1,196,500.00
2009	0.00	0.00	0.00	1,196,500.00
2010	57,019.78	26,316.82	26,316.82	57,019.78
2011	21,660.90	825.79	819.66	803.03
2012	69,744.01	71,473.90	71,294.10	69,471.32
2013	20,717.16	21,305.17	21,363.56	21,232.92
2014	69,727.91	69,639.09	69,550.85	69,618.86
2015	20,609.77	20,252.07	20,239.02	20,260.85
2016	69,584.97	69,196.95	69,200.35	69,312.60

Road User Effects

The various components of road user effects are reported in this folder.

Cost Streams and Economic Evaluation

This folder contains the results of the economic analysis. In the Economic Indicators Summary report, the results of this analysis indicates that Alternative 2 (2 lanes) produces the highest benefits of the three bypass construction alternatives.

PART F PROGRAMME ANALYSIS CASE STUDIES

1 CASE STUDY 1 – PRIORITISED WORKS PROGRAMME

1.1 Introduction

This case study demonstrates the application of Programme Analysis in the production of a prioritised works programme for part of a road network, using the life cycle analysis method described in Section 0.

The objective is to prepare a prioritised list of road projects from a candidate list of road sections that are in a range of conditions. The analysis is expected to investigate the long term investment levels to meet the agency's target intervention levels, and to examine the impact of possible budget constraints.

The case study is located in the **Programmes** folder in the Workspace. Double-click on **1**. **Works Programme** to open the case study.

1.2 Define Project Details

In the **Define Programme Details** screen, the following tab pages may be displayed:

- General
- Study Sections

1.2.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

📫 HDM-4 - [Progra	ime: 1. Works Programme]	_ @ ×
🖶 Workspace View	Report/Chart Window Help	_ 8 ×
Define Programme Details Specify Alternatives	General Study Sections Study Description: Programme 1. Works Programme - Life Cycle Analysis	
Generate Programme	Type of analysis: C Life cycle C Multi-Year Forward Programme	
Perform Budget Optimisation	Start year: 2006 Analysis period: 15 years	
Generate Regorts	Road Network: State Roads	
	Currences Fleet: Malaysian Ringgt x 1 = output currency Works: US Dollar x 1 = output currency Network: Malaysian Ringgt x 1 = output currency Qutput: Malaysian Ringgt X Decount rate: 12	
Save		

This case study uses the life-cycle method of analysis. The analysis period is defined by the start year 2006 and a duration of 15 years (i.e. 2006 - 2020). The sections to be analysed are in the Road Network entitled State Roads, to which the National Fleet has been previously assigned as the Vehicle Fleet. The discount rate has been selected as 12% and the currency being used for this analysis is Malaysian Ringgit.

1.2 Study Sections

The road sections selected for analysis comprise a total of 29 bituminous sections.

🕸 HDM	l-4 - [Progra	mme: 1. Works	s Program	me]				
🔛 Wor	kspace ⊻iew	Report/Chart	Window	Help				_ [8] ×
		(a (a	0					
	Programme	General Study	Sections					
	Details						Nur	ther selected sections: 29
	Course .							
	Alternatives	Include in		Se	ection Summary		Traffic Growth	
——		study	Group	ID 01.01.0001	Description	Pavement	0 1	
-	Generate			0101010001	010-101-000-1	Bituminous	Programme I	
	Programme			0101020001	010-102-000-1	Bituminous	Programme I Programme 1	
	Defer			0101020001	010-107-000-1	Dituminous	Programma 1	
_	Budget			0101090001	010-107-000-1	Bituminous	Programme 1	
1 ×	Optimisation	×		0101100001	010.110.000.1	Bituminous	Programme 1	
A	Counts			0101110001	010-111-000-1	Bituminous	Programme 1	
1 1 200	Benorts	×		0101130001	010-113-000-1	Bituminous	Programme 1	
	nogono	1		0101155291	010-115-529-1	Bituminous	Programme 1	
		×.		0101155671	010-115-567-1	Bituminous	Programme 1	
		V		0101240001	010-124-000-1	Bituminous	Programme 1	
		×		0101270001	010-127-000-1	Bituminous	Programme 1	
		1		010760001	010-76-000-1	Bituminous	Programme 1	
		M		010770001	010-77-000-1	Bituminous	Programme 1	
		<u>×</u>		010800001	010-80-000-1	Bituminous	Programme 1	
		<u>×</u>		010810001	010-81-000-1	Bituminous	Programme 1	
		×		010840001	010-84-000-1	Bituminous	Programme 1	
		<u>×</u>		010850001	010-85-000-1	Bituminous	Programme 1	
				010860001	010-86-000-1	Bituminous	Programme 1	
				010900001	010-90-000-1	Bituminous	Programme 1	
				010910001	010-91-000-1	Bituminous	Programme 1	
				010920001	010-92-000-1 Short	Bituminous	Programme I	
				010920861	010-92-086-1	Bituminous	Programme I	
				010922731	010-92-273-1	Dituminous	Programme I	
				010340001	010-34-000-1 010-94-990-1 Chort	Bituminous	Programme 1	
				010950001	010-95-000-1	Bituminous	Programme 1	
				010000001	010 00 000 1	Dicaminode	n i	
		Assign Growt	h Set	Select by Criteria.	View/Edit Section	. View/Ed	lit Fleet	
+		0.0		I have been All	Ver de la Num d			
	S <u>a</u> ve	Copy Grown	n Set	Unselect All	View/Edit Network.			
		Paste Grow	th Set	 Show unselect 	Groups	1		
	~			sections		_		
1341	Liose							
Sections	celected for a	nalueie						
Incorrous.	succession of a	rugala						

Double-clicking on a section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case National Fleet) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays all the previously created sets.

Double-clicking on the appropriate set (in this case Programme 1) displays the details of the traffic changes over the analysis period. The traffic growth rates for this case study indicate that the traffic is expected to increase at a rate of 4.5% per year.

scription: Works Progra	amme		
torised Growth Periods			
	Annual %		Add New Period
Vehicle	increase from year 1		<u> </u>
Motorcycles	4.50		
Motor Car	4.50		Delete Period
2-axle Truck	4.50		
3-axle Heavy Truck	4.50		Note: years are
Bus	4.50		defined relative to
4+axle Artic	4.50		the start year of the
Utilities van	4.50	-	the traffic growth
4			set is used.

Definition

Definition Geome	0 00-1 try Pave	ement Condition Other Mo	torised Traffic Asset Vi	aluation
<u>N</u> ame:	010-101	-000-1	Speed <u>Fl</u> ow Type:	Two Lane Road
<u>I</u> D:	0101010	0001	Traffic Flow Pattern:	Free-Flow
Link Na <u>m</u> e:	010-101	KM-101.71KM[L-3-F-2(CR810)]	<u>A</u> ccident Class:	Two Lane Road 💌
Lin <u>k</u> ID:	010		Climate <u>Z</u> one:	Tropical Humid
Length:	0.71	km	<u>R</u> oad Class:	Primary or Trunk
Cway <u>W</u> idth:	6.2	m		
Shoulder Width:	6.1	m	Calibration Set:	State
Flow <u>Direction</u> :	Two-wa	y 💌	Calibration Item:	Low Traffic - AMAP
Surface Class:	Bitumino	ous 💌	Selected Calibratio	on Item Summary
			Pavement type:	Asphalt Mix on Asphalt Pavement
			Surface material:	Asphaltic Concrete
				OK Cancel
Length of section (in l	(m)			OK Cancel

The State calibration set is assigned to the road sections in this case study. Details may be viewed within the Configuration folder. The State calibration set has two **Calibration Items** defined: High Traffic – AMAP and Low Traffic – AMAP. These calibration factors alter the performance characteristics of the network for each associated distress.

Name: State			
Bituminous Concrete Unsealed	1		
Model library (DLL): HDM-4 Defa	ılt DLL		Browse
RD Calibration Item	Pavement Type	Surface Material	CDS
ligh Traffic - AMAP	Asphalt Mix on Asphalt Pavement 💌	Asphaltic Concrete	• 1.00
.ow Traffic - AMAP	Asphalt Mix on Asphalt Pavement	Asphaltic Concrete	▼ 1.00
(T T
New Item	🕎 Delete Item		
			OK Cancel

Geometry

The geometry characteristics of each section are described in this screen.

Section: 010-101-000-1			×
Definition Geometry Pavement	Condition Other M	lotorised Traffic Asset Valuation	
<u>R</u> ise + Fall:	m/km	- Speed Reduction Factors	
No. of rises + falls: 2	no./km	X <u>N</u> MT: 1	0.4 <= XNMT <= 1
Superelevation: 2.5	5 %	Road side <u>friction</u> : 1	0.4 <= XFRI <= 1
<u>Avg horiz curvature</u> : 52	deg/km	X <u>M</u> T: 1	0.4 <= XMT <= 1
a <u>d</u> ral: 0.1	m/s²		
Speed limit: 100	0 km/h		
Speed limit enforcement: 1.1			
A <u>t</u> itude: 47	m		
			OK Cancel
Average road rise plus fall (in m/km)			

Pavement

The pavement type, years of construction and periodic maintenance, and pavement strength are detailed on this screen.

urfacing Pavement type: Asphalt Mix on Asphalt Pavement Material type: Asphaltic Concrete Most recent surfacing thickness: 135 mm Previous/old surfacing thickness: 25 mm	Strength Calculated Dry season model parameters SNP: 3.50 DEF: 0.88 mm [1] (* gtructural Number: 2.45 Subgrade CBR: 8 % (* Dry Season (* Wet Season
Previous works (HDM-4 Work Types) Last reconstruction or new construction: 1995 year Last rehabilitation (overlay): 2000 year Last regurfacing (resealing): 2000 year Last greventative treatment: 2000 year	Izi Calculated SNP: Laculate SNP: Road base (for stabilised base only) Base thickness: mm Besilient modulus: GPa

Condition

The roughness of the selected sections varies from approximately 2 to 6.5. This indicates that some sections are overdue for treatment whereas others are likely to last a considerable time before requiring periodic maintenance. Many sections are also affected by low to moderate amounts of surface cracking and rutting of varying extent.

			 _	
Condition at end of year	2005			
Roughness (IRI - m/km)	2.84			
All Structural Cracks (%)	1.50			
Wide Structural Cracks (%)	0.50			
Thermal Cracks (%)	0.00			
Ravelled area (%)	1.00			
Number of Potholes (No./km)	0.00			
Edge break area (m²/km)	0.00			
Mean rut depth (mm)	6.15			
Rut depth standard deviation (mm)	2.10			
Texture depth (mm)	0.70			
Skid resistance (SCRIM 50km/h)	0.50			
Drainage	Excellent 💌			
		_		
			_	

Other

The value of ELANES for all the sections is 2.

ition Geometry Pavement Condition Other Moto	rised Traffic Asset Valuation
Separate NMT lanes	Compaction (Bituminous only)
Number of lanes: 0	Relative compaction: 95 %
Shoulders (Concrete only)	Previous surface condition (Bituminous only)
Shoulder type: Non-concrete	Area of all structural cracking: 0 %
Width of widening: 0 m	Area of wide cracking: 0 %
	Transverse thermal cracks: 0 no/km
Drainage Drain type: No change in drainage effect 💌	ELANES: 2

Motorised Traffic

The initial AADT values in 2005 for the sections in this case study range from approximately 8,000 to 12,000.

venicle rieet used for	this section/networ	Tieer		
Survey Year:	2005		<u>E</u> dit Yea	ar
2-axle Truck	790.10			
3-axle Heavy Truck	276.54			
4+axle Artic	197.52			
Bus	158.02			
Motor Car	3555.45			
Motorcycles	2133.27			
Utilities van	790.10			

Asset Valuation

Asset valuation is not considered in this case study.

1.3 Specify Alternatives

The two Maintenance Standards that are considered in this case study are described in Table F1.1.

Alternative	Works Items	Criteria			
1 Bass	Edge Repair	Edge break > 1 m ² /km			
	Pothole Patching	Potholes > 1 no./km			
Alternative	Patching Wide Cracks	Wide Cracks > 5%			
	Pavement Reconstruction – 150mm asphalt	IRI > 10			
	Edge Repair	Edge break > 1 m ² /km			
	Pothole Patching	Potholes > 1 no./km			
	Patching Wide Cracks	Wide Cracks > 5%			
2	40 mm Overlay	IRI > 3 & AADT > 15000 Minimum interval 5 years			
Compound Standard	40 mm Overlay	IRI > 4.5 & AADT < 15000 Minimum interval 5 years			
	80 mm Overlay	4 < IRI < 6.5 & AADT > 15000 Minimum interval 7 years			
	Reconstruction – 150 mm asphalt	IRI > 5 & AADT > 15000			
	Reconstruction – 150 mm asphalt	IRI > 6 & AADT < 15000			

Table F1.1 Maintenance Alternatives

Alternative 1 is the Base Alternative. It comprises routine maintenance which includes edge repairs, pothole patching and patching of areas affected by wide cracks. In addition, a reconstruction is applied if the roughness level reaches 10 IRI. The other alternatives include the same routine maintenance, with different periodic maintenance items.

Sixteen section-alternatives have been specified for each section. They comprise the Base Alternative and 15 periodic maintenance options comprising the Compound Standard timed to start in Year 1, Year 2, etc up to Year 15, the final year of the analysis. Where the Compound Standard is delayed, the Base Alternative is applied.

This method of creating alternatives allows the optimum timing of major treatments to be investigated, and therefore provides a wider choice of section-alternatives for analysis under budget constraint. If it is not possible to choose an alternative for a section at the ideal timing, then this method allows selection in another year still to occur.

Define	Alternatives							
Details	Navigation)etails					
0 1	Analysis by Section	A	nalysis by Section > 010-101-000-1					
Alternatives	E 010-101-000-1	-116		Asr	Assignments			
Generate	Base Alternative		Alternative Name	Maintenance	Improvements (Post Imp. Maint.?)			
Programme	Periodic 2006		Base Alternative	1 1	×			
Defen	Periodic 2007		Periodic 2006	1	×			
Budget	Periodic 2008		Periodic 2007	2	×			
Optimisation	Periodic 2009		Periodic 2008	2	×			
-	Periodic 2011		Periodic 2009	2	×			
Generate	Periodic 2012		Peridoc 2010	2	×			
Reports	Periodic 2013		Periodic 2011	2	×			
	Periodic 2014		Periodic 2012	2	×			
	Periodic 2015		Periodic 2013	2	×			
	Periodic 2016		Periodic 2014	2	×			
	Periodic 2017		Periodic 2015	2	×			
	Periodic 2018		Periodic 2016	2	×			
	F Periodic 2019		Periodic 2017	2	×			
	F Periodic 2020		Periodic 2018	2	х			
	F = 010-102-000-1		Periodic 2019	2	×			
	H		Periodic 2020	2	×			
	010-107-000-1		Add new alternative					
	010-109-000-1							
	010-110-000-1							
	010-111-000-1							
	010.113.000.1							
	010,115,529,1							
	010 115 567 1							
	010 124 000 1							
	010-124-000-1							
	010-12/-000-1							
	010-76-000-1							
	010-77-000-1							
	010-80-000-1							
-								
Save	010-84-000-1							
1.11	010-85-000-1				•			
1	010-86-000-1	-1	dd Alternative Conv Alternative Paste Alternative Delete Alternative					
Close	1 010 00 000 1		Lo Alemanye Zoby Alemanye Laste Alemanye Delete Alemanye					

1.4 Generate Programme

1.4.1 Perform Run

The destination of the outputs from the analysis are specified in the Run Set-up dialogue. Options are available for the inclusion of the other models.

Run Setup	×
Multi-Year Foward Programme Perform run without economic analysis Unconstrained Programme) Perform run with economic analysis Constrained Programme - required before budget optimisation) Life Cycle Analysis Base alternative: Base Alternative Run Data Export Detail Exclude annual vehicle data Exclude vehicle geriod data Asset valuation Perform run with asset valuation Run Data Export Directory	Model Inclusion Epergy Balance Emissions Model acceleration effects Include Accident Costs In Economic Analysis Average accident category cost (in thousands of Malaysian Ringgit): Eatal: Damage: Injury: All accidents: Log File Write Log file
D:\Greg\HDM-4\Case Studies\Eng\RunData	<u>B</u> rowse
To reduce the size of the exported run data omit the Vel	OK Cancel

Clicking 'Start' executes the run and enables the results of the unconstrained programme analysis to be viewed.

1.4.2 Unconstrained Programme

Having completed the run, the Unconstrained Programme can be viewed by pressing the associated tab.

Programme	Perform Run Unconstrained	Programme										
Details	Budget Scenario: Unconstr	rained Programme	•									
Specify	Life Cycle Analysis - performe	ed at 12-07-2006										
Generate	Road Section	Road class	Length	MT AADT	Pavement	Road Works	Year	Cost (m#)	Recurrent Cum, Cost	Capital Cum, Cost	NPV/CAP	<u> </u>
Programme	010-94-990-1 Short	Primary or Trunk	0.01	8256	Bituminous	Recon @ 6 IVLL &	2006	0.00		0.00	1.98	
	010-84-000-1	Primary or Trunk	0.51	8628	Bituminous	Thin Overlav > 4.51	2007	0.04		0.04	12.43	
Perform	010-127-000-1	Primary or Trunk	1.16	13070	Bituminous	Thin Overlav > 4.51	2007	0.15		0.19	9.06	
Budget	010-90-000-1	Primary or Trunk	0.52	9016	Bituminous	Thin Overlav > 4.51	2008	0.05		0.24	10.47	
Optimisation	010-109-000-1	Primary or Trunk	0.98	14273	Bituminous	Thin Overlav > 4.51	2009	0.09		0.33	14.40	
Generate	010-86-000-1	Primary or Trunk	3.45	9846	Bituminous	Thin Overlay > 4.51	2010	0.28		0.61	14.22	
Reports	010-92-000-1 Short	Primary or Trunk	0.09	9846	Bituminous	Thin Overlay > 4.51	2010	0.01		0.62	13.55	
	010-76-000-1	Primary or Trunk	0.68	9846	Bituminous	Thin Overlav > 4.51	2010	0.06		0.68	13.07	
	010-115-567-1	Primary or Trunk	8.39	14915	Bituminous	Thin Overlav > 4.51	2010	0.78		1.46	12.51	
	010-92-273-1	Primary or Trunk	1.72	9846	Bituminous	Thin Overlay > 4.51	2010	0.17		1.63	10.82	
	010-101-000-1	Primary or Trunk	0.71	10289	Bituminous	Thin Overlay > 4.51	2011	0.06		1.69	13.66	
	010-85-000-1	Primary or Trunk	0.51	10289	Bituminous	Thin Overlav > 4.51	2011	0.04		1.73	12.84	
	010-80-000-1	Primary or Trunk	0.50	10289	Bituminous	Thin Overlav > 4.51	2011	0.04		1.77	12.78	
	010-81-000-1	Primary or Trunk	2.97	10289	Bituminous	Thin Overlay > 4.51	2011	0.26		2.03	12.77	
	010-97-000-1	Primary or Trunk	3.68	10289	Bituminous	Thin Overlav > 4.51	2011	0.32		2.35	12.58	_
	010-77-000-1	Primary or Trunk	2.45	10289	Bituminous	Thin Overlav > 4.51	2011	0.22		2.57	12.20	
	010-96-000-1	Primary or Trunk	0.51	10289	Bituminous	Thin Overlav > 4.51	2011	0.05		2.62	10.44	
	010-94-000-1	Primary or Trunk	0.99	10289	Bituminous	Thin Overlav > 4.51	2011	0.07		2.69	10.21	
	010-91-000-1	Primary or Trunk	0.99	10289	Bituminous	Thin Overlav > 4.51	2011	0.11		2.80	9.80	
	010-107-000-1	Primary or Trunk	1.98	15586	Bituminous	Thin Overlay @ 3 IF	2011	0.16		2.96	9.69	
	010-115-529-1	Primary or Trunk	0.04	15586	Bituminous	Structural Overlay @	2011	0.01		2.97	8.94	
	010-111-000-1	Primary or Trunk	1.93	15586	Bituminous	Thin Overlav @ 3 IF	2011	0.17		3.14	8.36	
	010-113-000-1	Primary or Trunk	2.52	15586	Bituminous	Structural Overlay @	2011	0.51		3.65	8.31	
	010-110-000-1	Primary or Trunk	1.00	15586	Bituminous	Structural Overlay @	2011	0.18		3.83	7.17	
	010-124-000-1	Primary or Trunk	2.98	15586	Bituminous	Thin Overlav @ 3 IF	2011	0.33		4.16	7.02	
	010-95-000-1	Primary or Trunk	0.51	10752	Bituminous	Thin Overlay > 4.51	2012	0.05		4.21	9.80	
	010-127-000-1	Primary or Trunk	1.16	16288	Bituminous	Thin Overlav @ 3 IF	2012	0.15		4.36	9.06	
	010-102-000-1	Primary or Trunk	0.71	10752	Bituminous	Thin Overlav > 4.51	2012	0.06		4.42	7.98	
	010-103-000-1	Primary or Trunk	3,87	10752	Bituminous	Thin Overlav > 4.51	2012	0.35		4.77	6.22	
~	010-92-086-1	Primary or Trunk	0,19	10752	Bituminous	Thin Overlav > 4.51	2012	0.03		4.80	4.11	
		D	0.00	17707	Damain	This Overlag O DIE	2014	0.00		4.00	14.40	-

The screen displays the selected sections and treatments for the section-alternative, one per section, which has the highest NPV. This can include the base case, which by definition has a NPV of zero, or a particular section with a positive NPV. Key parameters shown include the treatment year, capital cost, cumulative capital costs and NPV/CAP, the latter being the preferred prioritisation indicator for capital budgeting.

In this screen the following two options can also be selected:

Select sections for Manual assignment (shown in the bottom left of the screen). This
allows works which have an NPV of zero or greater to be selected as committed works
and the budget reserved for their treatment. Where budget optimisation is performed the
total value of the works for these sections is removed from the available budget prior to
performing budget optimisation.

 Selecting **Display recurrent works** (shown in the bottom right of the screen) shows the treatments and associated costs for all recurrent works in addition to the capital works.

It is useful at this point to scroll through the active screen and note the capital budget distribution by year as this will be important for assessing investment needs and for budget optimisation purposes.

1.5 Perform Budget Optimisation

1.5.1 Define Budget

For this case study the year-by-year cumulative unconstrained capital budget is summarised in Table F1.2. A total of 10.52 million is required to cover the captal costs of the prioritised works. Three budget scenarios are also shown which require approximately 90%, 75% and 50% of the unconstrained budget over a period of 15 years. These budet scenarios will be considered, together with an unconstrained budget of 11 million, in the budget optimisation procedure.

Veer	Cumulative	Budget	Budget Need		Budget Scenario			
(millions)		Period	Period Period		75%	50%		
2006	0.00	1	0.10	0.5	0.5	0.5		
2007	0.19	I	0.19	0.5	0.5	0.5		
2008	0.24	2 0.14		0.5	0 5	0.5		
2009	0.33	2	0.14	0.5	0.5	0.5		
2010	1.63	3	3 93	1	1	0.75		
2011	4.16	5	5.05	1	I	0.75		
2012	4.80		4 1.51	2.5	2	1.5		
2013	4.80							
2014	4.89	4						
2015	5.67							
2016	6.42							
2017	6.57							
2018	7.08	5	4.85	4.5	3.5	1.75		
2019	8.67							
2020	10.52							
			Total	9	7.5	5.0		

Table F1.2 Capital Costs and Budget Scenarios

The budget scenarios that are to be investigated need to be defined. These include a time profile of the budget.

W HDM-4 - [Progra Workspace View	nme: 1. Works Programme] Report/Chart <u>Wi</u> ndow <u>H</u> elp	_ 5
Define Programme Details	Define Budget Optimised Programme Budget Scenarios	
Specify Renatives Perform Budget Budget Reports	Selected Name Description Ø 75% Long Term 75% Long Term Need Ø 50% Long Term 50% Long Term Ø 30% Long Term 50% Long Term	Number Budget Periods Number Vesat Add Budget Scenario Edit Budget Scenario 5 15 5 15 5 15
S <u>a</u> ve	Analysis Stage: Click on Start to begin the analysis	
Close		

The three constrained budget scenarios have been split into 5 time periods as defined in Table F1.2.

Budget Scenario) Details - 75	5% Long Term Need			×					
Name: 75% Long Term Need										
Description: 7	5% Long Term	Need								
Pudest Datali										
Budget Details										
Start of year	End of year	Capital Budget		Insert period						
1	2		0.500000	Append period						
3	4		0.500000							
5	6		1.000000							
7	10		2.000000	Delete period						
11	15		3.500000	Delete period						
The capital bu millions of Mala	dget is expres: aysian Ringgit	sed in Σ	7.5							
			OK	Cancel						
A unique name to i	dentify the Bu	dget Scenario								

1.5.2 Optimised Programme

Having set up the budget scenarios, then the user needs to click on Perform Budget Optimisation to produce the Optimised Programmes for each defined scenario.
Details												
Specify	Budget Scenario:	75% Long Term Need	•									
	Ontining of about	50% Long Term Need										
Alternatives	Optimisation of alter	5% Long Term Need										
	Boad Sect	10% Long Term Need		MT	Pavement	Boad Works	Year	Cost	Recurrent	Capital	NPV/CAP	· ·
Generate		Unconstrained Programme		AADT				(m#)	Cum. Cost	Cum. Cost		
Programme	010-127-000-1	Primary or Trunk	1.16	16288	Bituminous	Thin Overlay @ 3 IF	2012	0.15	•	2.49	9.06	
Perform	010-110-000-1	Primary or Trunk	1.00	17021	Bituminous	Structural Uverlay @	2013	0.18	•	2.67	9.35	
Budget	010-109-000-1	Primary or Trunk	0.98	17787	Bituminous	Thin Uverlay @ 3 IF	2014	0.09	•	2.76	14.40	
Optimisation	010-94-000-1	Primary or Trunk	0.99	11/41	Bituminous	Thin Uverlay > 4.51	2014	0.07	•	2.83	14.05	
Generate	010-92-086-1	Primary or Trunk	0.19	11741	Bituminous	Thin Uverlay > 4.51	2014	0.03	•	2.86	5.81	
Reports	010-102-000-1	Primary or Trunk	0.71	12270	Bituminous	Hecon @ 6 (VL,L &	2015	0.29	•	3.15	3.15	
	010-84-000-1	Primary or Trunk	0.51	12822	Bituminous	Thin Uverlay > 4.51	2016	0.04	•	3.19	12.43	
	010-90-000-1	Primary or Trunk	0.52	12822	Bituminous	Thin Overlay > 4.51	2016	0.05	•	3.24	10.47	
	010-107-000-1	Primary or Trunk	1.98	19423	Bituminous	Thin Overlay @ 31F	2016	0.15	•	3.40	9.69	
	010-111-000-1	Primary or Trunk	1.93	19423	Bituminous	Thin Overlay @ 31F	2016	0.17	•	3.07	8.36	
	010-113-000-1	Primary or Trunk	2.52	19423	Bituminous	Recon @ 5 IRI (H, 1	2015	0.15	•	4.51	4.28	
	010-127-000-1	Primary or Trunk	1.15	20298	Bituminous	Thin Overlay @ 3 F	2017	0.15	•	4.75	9.06	
	010-86-000-1	Primary or Trunk	3.40	14002	Bituminous	Thin Overlay > 4.51	2018	0.28	•	5.04	14.22	
	010-76-000-1	Primary or Trunk	1.72	14002	Bituminous	Thin Overlay > 4.51	2018	0.06	•	5.10	13.07	
	010-52-273-1	Primary or Trunk	1.72	22165	Bituminous	Thin Overlay > 4.51 This Overlay @ 215	2018	0.17	•	0.27 E 20	14.40	
	010-103-000-1	Primary or Trunk	0.38	14622	Bituminous	Thin Overlay @ 3 in	2013	0.09	•	0.30 E 42	14.40	
	010 92 000 1 Short	Primary or Trunk	0.71	14632	Dituminous	Thin Overlay 24.51 Thin Overlay 24.51	2013	0.00		5.42	12.65	
	010 02 000 1 0100	Primary or Trunk	2.03	14632	Dituminous	Thin Overlay 24.51 Thin Overlay 24.51	2013	0.01		5.45 E.CO	12.00	
	010 97 000 1	Primary or Trunk	2.37	14632	Dituminous	Thin Overlay 24.51 Thin Overlay 24.51	2013	0.20		5.65	12.00	
	010-37-000-1	Primary or Trunk	0.51	14632	Bituminous	Thin Overlay 24.51	2013	0.32		6.01	12.00	
	010-80-000-1	Primary or Trunk	0.51	14632	Bituminous	Thin Overlay 24.51 Thin Overlay 34.51	2013	0.04		60.0 60.0	12.04	
	010-77-000-1	Primary or Trunk	2.45	14632	Bituminous	Thin Overlay > 4.51	2019	0.04		6.03	12.70	
	010-96-000-1	Primary or Trunk	0.51	14632	Bituminous	Thin Overlay > 4.51	2019	0.05		6.36	10.44	
	010-91-000-1	Primary or Truck	0.91	14632	Bituminous	Thin Overlau > 4.51	2019	0.03		6.30	9.80	
	010-95-000-1	Primary or Trunk	0.55	14632	Bituminous	Thin Overlau > 4.51	2019	0.05		6.52	9.80	
	010-115-529-1	Primary or Trunk	0.01	22165	Bituminous	Thin Overlay @ 3 IF	2019	0.00		6.52	8.94	
	010-94-000-1	Primary of Trunk	0.99	15290	Bituminous	Thin Overlay @ 3 IF	2020	0.07		6.59	14.05	
	010-92-086-1	Primary or Trunk	0.00	15290	Bituminous	Thin Overlay @ 3 IF	2020	0.03		6.62	5.81	
	010-94-990-1 Short	Primary or Trunk	0.01	15290	Bituminous	Structural Overlay @	2020	0.00		6.62	1.98	
Save	dia and a second a se	- analy of Hunk	0.01	. 5200	o Raminous	o nacianal o volidy e	2020	5.00		0.02		· · · ·

As can be seen in the screen for the 75% budget constraint, the cumulative capital costs of 6.62 million are within the budget constraint of 7.5 million.

1.6 Generate Reports

Having run the analysis it is now possible to **Generate Reports** and perform a similar check of key reports to ensure the data inputs and modeling are as expected. These should be examined and verified as any subsequent results are dependent on the performance of individual sections, with results aggregated to represent the network.

For Programme and Strategy analysis case studies a wider selection of reports are available, and examples of a selection of useful reports for the particular case study are given below. The following screen shows the list of reports available in the Programme and Strategy Analysis folder.



The Optimum Section Alternatives (Constrained Budget/Unconstrained Budget) report presents the list of section-alternatives (one per section) chosen for each section as a result of the constrained or unconstrained analyses as shown below.

HD.	M - 4	Optimu Study Name: Run Date: Currency:	IM Se 1. Works 12-07-200 Malaysiar	Programme 6 n Ringgit (millions)	rnative	es (Unconstra	ained Bud	lget)	
Section	Road Class	Length (Km)	Suntace Class	in Itial AADT	Alternative Desc.	Average Rough ness IRI	Discounted Agency Financial Capital Costs	Discounted Agency Financial Recurren Costs	Nə Prəsən Value
010-101-000-1	Primary or Trunk	0.710	Bituminous	8,256	Periodic 2006	3.6	0.05	0.02	0.53
010-102-000-1	Primary or Trunk	0.710	Bituminous	8,256	Periodic 2006	3.6	0.06	0.03	0.41
010-103-000-1	Primary or Trunk	3.870	Bituminous	8,256	Periodic 2006	3.5	0.33	0.09	1.77
010-107-000-1	Primary or Trunk	1.980	Bituminous	12,507	Periodic 2006	2.8	0.15	0.05	1.19
010-109-000-1	Primary or Trunk	0.980	Bituminous	12,507	Periodic 2006	3.2	0.12	0.01	1.40
010-110-000-1	Primary or Trunk	1.000	Bituminous	12,507	Periodic 2006	2.9	0.12	0.04	0.79
010-111-000-1	Primary or Trunk	1.930	Bituminous	12,507	Periodic 2006	2.7	0.15	0.03	1.06
010-113-000-1	Primary or Trunk	2.520	Bituminous	0	Periodic 2006	3.0	0.35	0.05	2.58
010-115-529-1	Primary or Trunk	0.040	Bituminous	12,507	Periodic 2006	3.0	0.00	0.00	0.03
010-115-567-1	Primary or Trunk	8.390	Bituminous	12,507	Periodic 2006	3.3	0.93	0.18	9.80
010-124-000-1	Primary or Trunk	2.980	Bituminous	0	Periodic 2006	2.9	0.29	0.04	1.71
010-127-000-1	Primary or Trunk	1.160	Bituminous	0	Periodic 2006	3.0	0.26	0.00	1.97
010-76-000-1	Primary or Trunk	0.680	Bituminous	8,256	Periodic 2006	3.6	0.05	0.02	0.56
010-77-000-1	Primary or Trunk	2.450	Bituminous	8,256	Periodic 2006	3.6	0.17	0.06	1.76
010-80-000-1	Primary or Trunk	0.500	Bituminous	8,256	Periodic 2006	3.6	0.03	0.01	0.36
010-81-000-1	Primary or Trunk	2.970	Bituminous	8,256	Periodic 2006	3.6	0.21	0.08	2.22
010-84-000-1	Primary or Trunk	0.510	Bituminous	8,256	Periodic 2006	3.6	0.05	0.02	0.49
010-85-000-1	Primary or Trunk	0.510	Bituminous	8,256	Periodic 2006	3.6	0.03	0.01	0.37
010-86-000-1	Primary or Trunk	3.450	Bituminous	8,256	Periodic 2006	3.5	0.25	0.05	3.03

At the end of this report a summary is given for the complete set of selected alternatives, including average IRI, discounted capital and recurrent costs and the total Net Present Value of the particular scenario. Summarising this data for each scenario enables a comparison across scenarios to be made, on the assumption that a common base case has been applied.

For the scenarios examined, a summary of the results is presented in Table F1.3.

Soonaria	Average	Disco	Discounted Agency Costs					
Scenario	IRI	Capital	Recurrent	Total				
Unconstrained	3.35	4.34	1.05	5.39	38.76			
90% need	3.96	2.86	1.93	4.79	27.84			
75% need	4.11	2.67	1.97	4.64	23.35			
50% need	4.58	1.59	2.48	4.07	14.90			

 Table F1.3

 Summary of Constrained Budget Scenario Analysis

The results confirm the magnitude of the NPV is proportional to the investment cost. However, a relatively similar NPV/C can be achieved where funds are lower, this being a result of the optmisation process selecting the 'optimum' combination of section-alternatives including timing options.

The Roughness: Average for Road Network by Budget Scenario graph presents the average roughness weighted by length for each scenario.



The long term performance is shown to vary considerably depending on budget availability. In this case, the unconstrained budget enables conditions to be held relatively constant over a period of years, whereas in the other cases conditions worsen as the available budget decreases. This information assists in examining the impact of budget constraints on road users.

Reports such as the Work Programme Optimised (or Unconstrained) by Year (or by Section), display the lists of physical works carried out. They are of practical benefit to those charged with planning and implementing works and provide an indicative list of requirements. Verification of the outputs should be undertaken on a selection of sections prior to accepting the results of the analysis and commencing the project preparation stage.

Year	Section	Road Class	Length (km)	Surface Clas	AADT	Work Description	NPV/CAP	Financial Costs	Cum. Costs
2006	010-94-990-1 Short	Primary or Trunk	0.0	Bituminous	8256	Recon @ 6 (VL,L & M)	1.982	0.004	0.004
2007	010-84-000-1	Primary or Trunk	0.5	Bituminous	8628	Thin Overlay > 4.5 IRI (V	12.425	0.039	0.043
	010-127-000-1	Primary or Trunk	1.2	Bituminous	13070	Thin Overlay > 4.5 IRI (V	9.061	0.153	0.196
2008	010-90-000-1	Primary or Trunk	0.5	Bituminous	9016	Thin Overlay > 4.5 IRI (V	10.466	0.048	0.244
2009	010-109-000-1	Primary or Trunk	1.0	Bituminous	14273	Thin Overlay > 4.5 IRI (V	14.399	0.086	0.330
2010	010-92-000-1 Short	Primary or Trunk	0.1	Bituminous	9846	Thin Overlay > 4.5 IRI (V	13.548	0.006	0.336
	010-78-000-1	Primary or Trunk	0.7	Bituminous	9846	Thin Overlay > 4.5 IRI (V	13.068	0.057	0.393
2011	010-101-000-1	Primary or Trunk	0.7	Bituminous	10289	Thin Overlay > 4.5 IRI (V	13.655	0.058	0.451
	010-85-000-1	Primary or Trunk	0.5	Bituminous	10289	Thin Overlay > 4.5 IRI (V	12.838	0.043	0.494
	010-80-000-1	Primary or Trunk	0.5	Bituminous	10289	Thin Overlay > 4.5 IRI (V	12.775	0.042	0.536
	010-97-000-1	Primary or Trunk	3.7	Bituminous	10289	Thin Overlay > 4.5 IRI (V	12.578	0.323	0.859
	010-115-529-1	Primary or Trunk	0.0	Bituminous	15586	Structural Overlay @ 4 IF	8.939	0.005	0.864
	010-110-000-1	Primary or Trunk	1.0	Bituminous	15586	Structural Overlay @ 4 IF	7.165	0.182	1.048
2012	010-88-000-1	Primary or Trunk	3.5	Bituminous	10752	Thin Overlay > 4.5 IRI (V	15.061	0.285	1.331
	010-81-000-1	Primary or Trunk	3.0	Bituminous	10752	Thin Overlay > 4.5 IRI (V	13.208	0.260	1.590
	010-127-000-1	Primary or Trunk	1.2	Bituminous	16288	Thin Overlay @ 3 IRI (>F	9.061	0.153	1.744
	010-113-000-1	Primary or Trunk	2.5	Bituminous	16288	Structural Overlay @ 4 IF	8.593	0.515	2.258
2014	010-109-000-1	Primary or Trunk	1.0	Bituminous	17787	Thin Overlay @ 3 IRI (>F	14.399	0.086	2.344
2015	010-92-086-1	Primary or Trunk	0.2	Bituminous	12270	Recon @ 6 (VL,L & M)	2.759	0.078	2.422
2016	010-84-000-1	Primary or Trunk	0.5	Bituminous	12822	Thin Overlay > 4.5 IRI (V	12.425	0.039	2.461
	010-90-000-1	Primary or Trunk	0.5	Bituminous	12822	Thin Overlay > 4.5 IRI (V	10.466	0.048	2.509
2017	010-127-000-1	Primary or Trunk	1.2	Bituminous	20298	Thin Overlay @ 3 IRI (>F	9.061	0.153	2.662
2018	010-76-000-1	Primary or Trunk	0.7	Bituminous	14002	Thin Overlay > 4.5 IRI (V	13.068	0.057	2.719
2019	010-88-000-1	Primary or Trunk	3.5	Bituminous	14632	Thin Overlay > 4.5 IRI (V	15.061	0.285	3.004

PART G STRATEGY ANALYSIS CASE STUDIES

1 CASE STUDY 1 – LONG TERM NETWORK NEEDS

1.1 Introduction

The subject of this strategy analysis is a network of state roads. Due to lack of funding in recent years, the network is in generally poor condition exhibiting high levels of roughness with many links being single or intermediate lane. There is a large backlog of works needed to provide the service levels expected of this road network. The needed works encompass periodic maintenance of those roads in good or fair condition, rehabilitation or reconstruction of roads in poor condition and widening to two lane where traffic levels justify it.

This case study covers approximately 1,000 km of the road network, with the essential data being inventory (in particular pavement width), traffic and pavement condition (roughness).

The objectives of the study are:

- Determine the network needs the unconstrained optimum solution with no budget constraints
- Examine the effects of constrained budgets over a 5-year period on network service levels and the distribution of expenditure between maintenance, rehabilitation and improvement works

1.2 Road Network

The network under study has a significant length of single (3 - 4 m) and intermediate (5 - 6 m) lane sections. Although most are of sealed standard, on many sections the surfacing has deteriorated severely with roughness in excess of 10 IRI. Traffic levels range from a few hundred to several thousand vehicles/day. The traffic mix contains a high proportion of two wheelers, three wheelers and agricultural tractors. There is also a significant volume of non-motorised traffic, mainly cycles and bullock carts.

A network matrix comprises a series of representative sections defined by ranges of the parameters that are of the most significance to the study being performed. For this case study the parameters selected to form the matrix are traffic volume (6 categories), carriageway width (3 categories) and roughness (5 categories). Thus the network matrix potentially comprises 90 (6 x 3 x 5) representative sections (network cells). However, some combinations do not exist in the road network (e.g. high traffic levels on narrow roads). The number of representative sections used in the analysis was 54, although all possible representative sections were created in the Road Network.

Traffic

The distribution in terms of AADT for the six traffic categories used in this case study are shown in Table G1 for both Motorised and NMT vehicle classes.

		Repre	esentative AA	DT by Traffic	Category	
Vehicle Type	1	2	3	4	5	6
	<500	500 - 1000	1000 - 2000	2000 - 5000	5000 - 10000	> 10000
Two wheeler	184	427	997	2560	3372	6744
Three wheeler	3	11	45	95	713	1425
Car	25	66	145	287	715	1429
Jeep	37	97	149	332	664	1329
Minibus	3	19	36	47	197	394
Bus	19	53	126	226	387	775
Light truck	7	17	40	153	611	1221
Medium truck	18	107	118	431	1186	2373
Heavy truck	2	24	110	260	253	506
Truck/trailer	7	8	13	37	48	96
Tractor	54	106	215	274	1058	2116
Total Motorised	359	935	1994	4702	9204	18408
Animal cart	53	86	164	207	264	527
Bicycle	70	336	536	2035	2665	5331
Total NMT	123	422	700	2242	2929	5858

Table G1.1 Traffic Categories

Roughness

The range and representative values for each of the five roughness categories are shown in Table G1.2.

	Roughness (IRI)						
Category	Range	Representative Value					
1	< 4	3					
2	4 – 6	5					
3	6 – 8	7					
4	8 – 10	9					
5	> 10	12					

Table G1.2 Roughness Categories

Carriageway Width

Three carriageway width categories were used, representing single, intermediate and two lane roads. The range and representative values for each category are shown in Table G1.3. There were no four lane roads in the network being studied.

Category	Carriagew		
	Range	Lanes	
1	< 4	3.5	Single
2	4 – 6	5.5	Intermediate
3	> 6	7.0	Two

Table G1.3 Carriageway Width Categories

1.3 Define Project Details

In the **Define Strategy Details** screen, the following tab pages may be displayed:

- General
- Study Sections

1.3.1 General

The information displayed in the General screen includes the study description, analysis type, analysis period, the pre-defined Road Network and Vehicle Fleet, and the currency to be used for the analysis.

HDM-4 - [Strate	egy: Long Term Network Needs]	
Workspace View	w Report/Chart <u>W</u> indow <u>H</u> elp	<u>_ 8</u>
Define Strategy Details Specify Alternatives	General Study Sections	
Generate Strategy Perform Budget Optimisation	Optimisation C Maximise NPV C Maximise dJRI method: C Minimise gost for target IRI Start year: 2006 Analysis period: 20 years Boad Network: MP Network	
Reports	Vehicle Ret: MP Vehicles Currencies I Ret: Indan Rupee Yorks: Indan Rupee	
Save	reov Analysis	

The optimisation method selected for this case study is Maximise NPV. The analysis period is defined by the start year 2006 and a duration of 20 years (i.e. 2006 - 2025). The sections to be analysed are in the Road Network entitled MP Network, to which the MP Vehicles have been previously assigned as the Vehicle Fleet. The currency being used for this analysis is Indian Rupees and the discount rate has been set to 12%.

1.3.2 Study Sections

In this case study, 54 representative sections have been selected for analysis. Each representative section was given an identifier signifying the traffic category, the roughness category and the carriageway width category. Thus section T1R2W3 had the representative values from traffic category 1, roughness category 2 and carriageway width category 3.

0M-4 - [Strateg	y: Long Term Netw	ork Needs]				
/orkspace ⊻iew	Report/Chart Win	dow <u>H</u> elp				
0.0		. 1				
Strategy	General Study Sec	ions				
Details						
	Include in	Secti	ion Summary		Traffic Growth	
Atomatives	Study	D Description	Class	Pavement		
Atomativos	14H5	V3 14H5W3	Secondary or main	Bituminous	MP	
Generate	M 14H5	v2 14H5w2	Secondary or main	Bituminous	MP	
Strategy	14R5	V1 T4R5W1	Secondary or main	Bituminous	MP	
ouolog)	14R4	V3 T4R4W3	Secondary or main	Bituminous	MP	
Perform	M 1484)	V2 T4R4W2	Secondary or main	Bituminous	MP	
Budget	14R4	V1 T4R4W1	Secondary or main	Bituminous	MP	
opumisation	14R3	√3 14H3W3	Secondary or main	Bituminous	MP	
Generate	14B3	√2 T4R3W2	Secondary or main	Bituminous	MP	
Reports	14R3	v1 T4R3W1	Secondary or main	Bituminous	MP	
	14R2	v3 T4R2v/3	Secondary or main	Bituminous	MP	
	14B2	√2 T4R2W2	Secondary or main	Bituminous	MP	
	14R1	V3 T4R1W3	Secondary or main	Bituminous	MP	
	13R5	V3 T3R5V3	Secondary or main	Bituminous	MP	
	M T3R5	V2 T3R5W2	Secondary or main	Bituminous	MP	
	13R5	v1 T3R5W1	Secondary or main	Bituminous	MP	-
	13R4	v/3 T3R4v/3	Secondary or main	Bituminous	MP	
	13R4	√2 T3R4W2	Secondary or main	Bituminous	MP	
	13R4	v1 T3R4W1	Secondary or main	Bituminous	MP	
	🗾 🗾 T3R3	v/3 T3R3v/3	Secondary or main	Bituminous	MP	
	13R3	v1 T3R3W1	Secondary or main	Bituminous	MP	
	13R2	V3B T3R2V/3B	Secondary or main	Bituminous	MP	
	13B2	√3A T3R2W3A	Secondary or main	Bituminous	MP	
	13R2	V1A T3R2W1A	Secondary or main	Bituminous	MP	
	13R1	v3 T3R1W3	Secondary or main	Bituminous	MP	
	12R5	√3 T2R5W3	Secondary or main	Bituminous	MP	
	12R5	v2 12H5W2	Secondary or main	Bituminous	MP	
	12R5	v1C T2R5W1C	Secondary or main	Bituminous	MP	
	12R5	V1B T2R5W1B	Secondary or main	Bituminous	MP	
	12H5	V1A I2H5W1A	Secondary or main	Bituminous	MP	
	✓ T2R5	v1A T2R5W1A	Secondary or main	Bituminous	MP	
Cours	Assign Growth Set	Select by Criteria	View/Edit Section View	v/Edit Fleet	1	Sections Network: 95
Jave	Copy Growth Se	t Unselect All	view/Edit Network			Study: 54
Close	Paste Growth Se	t Show unselected sections				
selected for an	alueis					

By double-clicking on the section gives access to the section details. However, the **Traffic Growth** details can only be seen and edited through the **Vehicle Fleets** folder. To access the Traffic Growth Sets that have been previously created, the user needs to open the appropriate vehicle fleet (in this case MP Vehicles) in the Vehicle Fleet folder and click on the Edit Traffic Growth Sets button which then displays the previously created sets.

Double-clicking on the appropriate set (in this case MP) displays the details of the traffic changes over the analysis period. The MP traffic growth rate has been created with three traffic growth periods; from year 1, from year 6 and from year 11.

<u>N</u> ame: MP				
scription: MP				
,				
otorised Growth Periods	Non-Motorised G	rowth Periods	1	
	Annual %	Annual %	Annu	Add New Period
Vehicle	increase	increase	incre	
	from year 1	from year 6	from y	Edit Penod
M/cycle	6.50	5.90		
3 wheeler	5.50	5.00		Delete Period
Car	14.50	14.00		
Jeep	6.00	4.75		Note: years are
Minibus	7.35	6.20		defined relative to
Bus	7.90	8.10		the start year of the
Liaht Truck	8.50	7.50		analysis in which
			<u> </u>	eet is used
				30113 0300.

The section details are are described below.

Definition

The representative section T3R5W1 is illustrated which indicates that the traffic on this section is as detailed for category 3 (see Table G1.1), the roughness is 12.5 (category 5) and the carriageway width category is 1. The carriageway width for this representative section is 3.5 m and the selected Speed Flow Type reflects this width.

The length indicates that there were a total of 48.6 km of this type of road in the network. Note that the length of road is the total length of road in the network of this type, which is not necessarily a continuous length.

efinition Geomet	ny Pave	ement Condition	Other Mo	torised Traffic Non-mo	torised Traffic Asset Valu	iation		
<u>N</u> ame:	T3R5W	1		Speed <u>Fl</u> ow Type:	SF3	•		
<u>I</u> D:	T3R5W	1		Traffic Flow Pattem:	MP	•		
Link Na <u>m</u> e:	MP			<u>A</u> ccident Class:	AC3	-		
Lin <u>k</u> ID:	MP			Climate <u>Z</u> one:	MP	•		
Length:	48.6	km		Road Class:	Secondary or main	•		
Cway <u>W</u> idth:	3.5	m						
Shoulder Width:	1	m		Calibration Set:	MP			
Flow Direction:	, Two-wa	y 🔻		Calibration Item:	PMC	•		
Surface Class:	Bitumino	ous 🔻		Selected Calibration Item Summary				
				Pavement type:	Asphalt Mix on Granular B	Base		
				Surface material:	Asphaltic Concrete			
						0		
					OK	Cance		

Geometry

The geometry characteristics were held constant for all representative sections.

Section: T3R5W1					×
Definition Geometry Pavement Con	dition Other M	lotorised Traffic Non-mot	torised Tr	affic Asset Valu	uation
Rise + Fall:	m/km	- Speed Reduction Facto	rs ——		_
No. of rises + falls: 2	no./km	X <u>N</u> MT:	1	0.4 <= XNMT <	= 1
Superelevation: 2.5	%	Road side <u>friction</u> :	1	0.4 <= XFRI <=	1
Avg horiz curvature: 15	deg/km	X <u>M</u> T:	1	0.4 <= XMT <=	1
a <u>d</u> ral: 0.1	m/s²				
Speed limit: 100	km/h				
Speed limit <u>e</u> nforcement: 1.1					
Aţtitude: 1000	m				
				OK	Cancel
Annual data da Gillo anti A					

Pavement

The pavement characteristics were varied with roughness category. It was assumed that sections with higher roughness would be older and have weaker pavement structures. The roughness category for this section (T3R5W1) was the highest (IRI > 10), and thus the pavement details indicate that the road was 20 years old in 2005, with no periodic maintenance over the past 15 years.

Surfacing Pavement type: Asphalt Mix on Asphalt Pavement Material type: Asphaltic Concrete Most recent surfacing thickness: 30 mm Previous/old surfacing thickness: 50 mm Previous works (HDM-4 Work Types) Last reconstruction: 1985 year Last rehabilitation (overlay): 1990 year Last regurfacing (resealing): 1990 year	Strength Calculated Dry season model parameters SNP: 2.61 DEF: 1.40 mm [1] If Survey season Number: Subgrade CBR: 5 % © Dry Season Wet Season [2] C Calculated SNP: Calculated SNP: Calculate SNP Road base (for stabilised base only) Base thickness: Bestiment modulus: GPa
Last greventative treatment: 1990 year	

Condition

A roughness of 12.0 has been used as the representative roughness for category 5. High representative values for the other distresses were used in conjunction with this roughness category.

	1.000		
Condition at end of year	2005		
Roughness (IRI - m/km)	12.00		
All Structural Cracks (%)	50.00		
Wide Structural Cracks (%)	25.00		
Thermal Cracks (%)	0.00		
Ravelled area (%)	25.00		
Number of Potholes (No./km)	0.00		
Edge break area (m²/km)	30.00		
Mean rut depth (mm)	20.00		
Rut depth standard deviation (mm)	6.00		
Texture depth (mm)	0.50		
Skid resistance (SCRIM 50km/h)	0.40		
Drainage	Fair 🔻		

Other

All values were held constant for all the representative sections with the exception of ELANES which was related to pavement width. A value for ELANES of 1 was used for single lane sections, 1.5 for intermediate lane and 2 for two-lane roads.

finition Geometry Pavement Condition	er Motoris	ed Traffic	Non-motorised Traf	fic Asset \	aluation
Separate <u>N</u> MT lanes		Compac	tion (Bituminous only	ı)	
Number of lanes: 0			Relative <u>c</u> ompaction	n: 95	%
Shoulders (Concrete only)		Previou	s surface condition (Bituminous c	only)
Shoulder type: Non-concrete		Area of a	all str <u>u</u> ctural cracking	j: 0	%
\underline{W} idth of widening: 0 m		ŀ	Area of <u>w</u> ide cracking	g: 0	%
		Trans	overse thermal crack	s: 0	no/km
Drain type: Shallow - soft	•		<u>E</u> LANE:	5: 1	

Motorised Traffic

The total motorised AADT on this representative section is 1994 and the AADT for the individual vehicle classes are as listed for traffic category 3 in Table G1.1.

Vehicle Fleet us	ed for this sect	on/network:	MP	 	 		
3 wheeler	45.00			 	 	Edit	Year
Bus	126.00						
Car	145.00						
Heavy Truck	110.00						
Jeep	149.00						
Light Truck	40.00						
M/cycle	997.00						
Medium Truck	118.00						
Minibus	36.00						
Tractor	215.00						
Truck/trailer	13.00						
Total AADT:	1994.00				•		

Non-motorised Traffic

The non-motorised traffic is listed on this screen. The distribution of the NMT between carts and cycles for this representative section is as listed in Table G1.1 for traffic category 3.

Section: T3R5W1	×
Definition Geometry Pavement Condition Other Motorised Traffic Non-motorised Traffic	Asset Valuation
Vehicle Fleet used for this section/network: MP Survey Year: 2004 Cart 164.00 Cycle 536.00 Table 536.00 Table 536.00	Edit Year
	OK Cancel
ivon-motorised traffic	

1.3.3 Asset Valuation

This case study contains asset valuation, allowing the asset value of the total network to be estimated over time under different investment levels. To apply asset valuation in HDM-4, inputs are required in both the section details and in the works items details. The asset valuation screen from the section details is shown below.

Replacement cost: 2.7702e+0	08						
Asset valuation method for Ro	ad Pavement Li Production base	ayers					
Initial roughness: 2.5	IRI (m/km)						
Teminal roughness: 12	IRI (m/km)						
Year <u>a</u> sset component age defir	ned for: 2005	year					
Asset Component	Replacement cost (%)	Residual value of asset component (%)	Useful life compo	of asset nent	Age of compor year 2	asset nent in 2005	
Road formation and sub-grade	5.00	0.00	10,000.00	years	50.00	years	
Road pavement layers	60.00	75.00					
Footways, footpaths and cycle-ways(NMT lanes)	0.00	0.00	0.00	years	0.00	years	
Bridges and structures	31.00	0.00	50.00	years	25.00	years	
	4.00	0.00	20.00	years	10.00	years	
Traffic facilities, signs and road furniture							

For all the sections used in this case study, the condition based asset valuation method has been chosen. Also in each case the initial roughness has been set to 2.5 IRI and the terminal roughness to 12 IRI.

The replacement costs for the three categories of road used in this case study are summarised in Table G1.4. The replacement costs in Table G1.4 are given on a per km basis, whereas the costs in the asset valuation screen are the total costs for the section (i.e. takes into account the length of the section).

	Single Lane	Intermediate	Two Lane
Total Cost (Rs/km)	5,700,000	8,200,000	9,900,000
Earthworks	5%	5%	5%
Pavement	60%	60%	58%
Footways etc.	0%	0%	0%
Bridges and culverts	31%	31%	33%
Road furniture	4%	3%	3%

Table G1.4Replacement Costs

As condition based depreciation is selected for the pavement component, values are not needed for useful life and age as these are defined in terms of roughness. The value of 75% for residual value of the pavement is to reflect the fact that the pavement structure will still contribute to performance after maintenance (overlays) is applied. These remaining input values used in this case study are summarised in Table G1.5.

	Residual Value	Useful Life	Age in 2005
Earthworks	0%	10,000	50
Pavement	75%	n/a	n/a
Footways etc.	0%	0	0
Bridges and culverts	0%	50	25
Road furniture	0%	20	10

Table G1.5 Asset Valuation Data

The asset valuation details required in relation to works standards are stored in the works items/asset valuation tab page for each works item within a maintenance standard as shown below. The exceptions are routine maintenance activities such as edge repair, which do not require asset valuation details.

For maintenance standards, the only input relates to the pavement. If condition based depreciation is used, the useful life of the item is not needed and the only input is residual value.

Asset Valuation Proportion of the cost of new work % 100.00 %	Residual value of new work %	Useful life of Years 0.00	new work ESAL 0.00
Proportion of the cost of new work % 100.00	Residual value of new work % 25.00	Useful life of Years 0.00	f new work ESAL 0.00
100.00	25.00	Years 0.00	ESAL 0.00
100.00	25.00	0.00	0.00
100.00	25.00	0.00	0.00
%			
%			

For the maintenance standards used in this case study, the residual values for each works item are listed in Table G1.6.

Table G1.6 Works Items Residual Values Works Item Residua

Works Item	Residual Value
Overlays (20, 30, 40, 110 & 140 mm)	25%
Reconstruction (40 & 100 mm)	50%

For improvement standards more comprehensive inputs are needed, as shown below.

mprovement Standard: Widen to 7m				2
General Design Intervention Costs Construct	tion Pavemen	t Geometry	Effects As	set Valuation
Asset Component	Proportion of the cost of	Residual value of pew work %	Useful life o	f new work
	Herr Wolk /8	nem mont /s	Years	ESAL
Road formation and sub-grade	10.00	100.00	0.00	
Road pavement layers	90.00	50.00	0.00	0.00
Footways, footpaths and cycle-ways(NMT lanes)	0.00	0.00	0.00	
		[ОК	Cancel
nter parameter values for different asset component	ts			

For the improvement standards used in this case study, the asset valuation details are summarised in Table G1.7. The per cent of asset decommissioned has been set at 50% to represent the removal and replacement of existing pavement layers.

		Proportion of Cost	Residual Value	Useful Life
	Earthworks	0%	0%	0
Reconstruction	Pavement	100%	50%	n/a
	Footways etc.	0%	0%	0
	Earthworks	10%	100%	0
Widening	Pavement	90%	50%	n/a
	Footways etc.	0%	0%	0

Table G1.7Asset Valuation Details for Improvement Standards

1.4 Specify Alternatives

The types of roadworks applied in this case study were as follows:

- Renewal thin overlay using various types of asphaltic material and thickness depending on the level of traffic
- Rehabilitation thick overlay
- Reconstruction rebuilding of the base and surfacing layers, while retaining the existing width
- Widening rebuilding the sub-base, base and surfacing layers to a standard two lane width of 7m
- Routine patching potholes and edge repair

The works items and the intervention criteria within each maintenance and improvement standard are listed in Table G1.8.

Works Type	Standard	Works Items	Criteria				
	Doutino	Edge Repair	Edge break > 1 m ² /km				
	Routine	Patch Potholes	Potholes > 10 no./km				
		20 mm Overlay	AADT < 2000 & IRI < 6				
	Renewal	30 mm Overlay	2000 < AADT < 10000 & IRI < 6				
		40 mm Overlay	AADT > 10000 & IRI < 6				
	Pehabilitation	110 mm Overlay	AADT < 10000 & 5 < IRI < 12				
	Renabilitation	170 mm Overlay	AADT > 10000 & 5 < IRI < 12				
		20 mm Overlay	AADT < 2000 & 5 < IRI < 6 or AADT < 2000 & IRI < 6 & 10 < ACA < 20				
Maintenance	Long Term Maintenance Policy	30 mm Overlay	2000 < AADT < 10000 & 5 < IRI < 6 or 2000 < AADT < 10000 & IRI < 6 & 10 < ACA < 20				
		40 mm Overlay	AADT > 10000 & 5 < IRI < 6 or AADT > 10000 & IRI < 6 & 10 < ACA < 20				
		110 mm Overlay	6 < IRI < 12				
		Reconstruct – 40 mm surface	AADT < 500 & IRI > 12				
		Reconstruct - 100 mm surface	AADT > 500 & IRI > 12				
	Reconstruct 40	Pavement reconstruction with 40 mm surface	IRI > 10				
Improvement	Reconstruct 100	Pavement reconstruction with 100 mm surface	IRI > 10				
	Widen to 7m	Widen to 7 m	AADT > 1000				

Table G1.8Works Items and Intervention Criteria

Alternatives that apply a maintenance or improvement standard are assigned to each section with an effective year within the 5-year planning period. The Long Term Maintenance Policy (LTMP) is assigned as the Base Alternative to each section after the 5-year planning period, i.e. from year 2011.

Not all standards need to be tested for all sections; for example, widening does not need to be assigned to the lower traffic sections, the renewal alternative does not need to be assigned to sections with high roughness, etc. The alternatives that have been assigned to each section are listed in Table G1.9. Routine maintenance is applied to all the sections.

Section	Renewal	Rehab	Recon 40	Recon 100	Widening
T1R1W1 - W3	Y				
T1R2W1 - W3	Y	Y			
T1R3W1 - W3		Y			
T1R4W1 – W3		Y			
T1R5W1 – W3			Y		
T2R1W1 – W3	Y				
T2R2W1 – W3	Y	Y			
T2R3W1 – W3		Y			
T2R4W1 – W3		Y			
T2R5W1 – W3				Y	
T3R1W1 – W2	Y				Y
T3R1W3	Y				
T3R2W1 – W2	Y	Y			Y
T3R2W3	Y	Y			
T3R3W1 – W2		Y			Y
T3R3W3		Y			
T3R4W1 – W2		Y			Y
T3R4W3		Y			
T3R5W1 – W2				Y	Y
T3R5W3				Y	
T4R1W1 – W2	Y				Y
T4R1W3	Y				
T4R2W1 – W2	Y	Y			Y
T4R2W3	Y	Y			
T4R3W1 – W2		Y			Y
T4R3W3		Y			
T4R4W1 – W2		Y			Y
T4R4W3		Y			
T4R5W1 – W2				Y	Y
T4R5W3				Y	

Table G1.9 Assignment of Maintenance and Improvement Standards

The number of alternatives assigned to each section are listed in the screen below. The year that the maintenance and/or improvement standards are applied can be viewed by expanding the assignments in each section in the navigation menu. For example, for section T1R1W1, the maintenance standard Renewal is applied in each year of the 5-year planning period (i.e. 2006 to 2010 inclusive) together with the LTMP alternative the following year.

efine Alternatives		
etails Navigation	T Details	
	Analysis by Section	
tematives	Section Name	Section Number ID Alternatives
aparata	TIBIWI	T1B1W1 6
trategy 2000. Notifie	T181W2	T1B1W2 6
BEN 1	T182w1	T1B2W1 11
erform	T1B2W2	T1B2W2 11
atministran	T1B2W3	T1R2W3 11
2000 Hodano	T183W1	T1B3W1 6
enerate	T1B3W2	T1B3W2 6
eports	T183W3	T1B3W3 6
2000 . Notifie	T1B4W1	T1R4W1 6
2007 : Nellewal	T185W1A	T185W1A 6
	TIB5W2	T185W2 6
V 2006 - Pautina	T185W3	T185W3 6
V 2000 - Renewal	T2B1W1	T2B1W1 6
2000 . Herewar	T2B1W2	T2B1W2 6
	T2B2w/1	T2B2W1 11
CINE DEN_4	12824/2	T2B2W2 11
2006. Houtine	T2B2W3	T2B2W3 11
2009 : Henewai	12834/1	T2B2W3
ZUIU: Long Term Ma	12P3//2	T2P3W1 0
HEN_5	1200/2	T2P3W2 0
ZUU6 : Houtine	TOPAU	T2004)/d
2010 : Kenewal	T2D6//0	T204W1 0
2011 : Long Term Ma	T2D6/(0	T204W2 0
₽ 🚎 11R1W2	TODD///A	1204W0 0
E Base Alternative	I2DD/2	I2h5w1A 6
2006 : Routine	12DD-/2	12h5W2 6
M 2011 : Long Term Ma	12howa	12h0w3 6
₽ M REN_1	T3HTW3	13H1W3 6
2006 : Renewal	T3R2WIA	I 3R2WIA IB
2006 : Routine	T3R2W3A	13B2W3A 11
🔤 🔜 🔜 🔤 🔤 🔤 🔤 🔤 🔤 🔤	T3R3W1	T3R3W1 11
eve 📄 🔛 REN_2	T3R3W3	T3R3W3 6
2006 : Routine		I3B4W1 11
	Copy Section's Alternatives Paste Section's Alternatives Details	
ose		

1.5 Generate Strategy

1.5.1 Perform Run

The destination of the outputs from the analysis are specified in the Run Set-up dialogue. Options are available for the inclusion of the other models. When using asset valuation, the box must be checked in Run Setup.

Run Setup	
Multi-Year Foward Programme Perform run without economic analysis (Inconstrained Programme) Perform run with economic analysis (Constrained Programme - required before budget optimisation) Life Cycle Analysis Base alternative: Base Alternative Run Data Export Detail Exclude annual vehicle data	Model Inclusion Energy Balance Emissions Model acceleration effects Include Accident Costs In Economic Analysis Average accident category cost (in thousands of Indian Rupee): Eatal: Damage: Injury: All accidents: Log File
Exclude vehicle period data Asset valuation Perform run with asset valuation	Write Log file
Run Data Export Directory D:\Greg\HDM-4\Volume 2\Version 2\Final\RunData	Browse
	OK Cancel
To reduce the size of the exported run data omit the V	ehide data

It is normal to exclude annual and period vehicle data as, if these are saved in the output file, run time is much longer and the output file can be very large. This information would normally only be saved if one wanted to check some of the details because the analysis results are suspect. The export directory must be specified in order for the analysis to be carried out.

Clicking 'Start' executes the run and enables the results of the unconstrained programme analysis to be viewed.

1.5.2 Unconstrained Programme

Having completed the run, the Unconstrained Programme can be viewed by pressing the associated tab.

the Stantomic	renomination choose and	Programme										
Details	Budget Scenario: Unconst	rained Programme	-									
Specify	Life Cucle Analysis - performe	ad at 30.01.2006	_									
Alternatives	Life Cycle Analysis - performe	ed al 30-01-2000							_			
Generate	Road Section	Road class	Length	AADT Pa	avement	Road Works	Year	Liost (m#)	Recurrent Cum. Cost	Capital Cum. Cost	NPV/CAP	-
Strategy	T4R5w1	Secondary or Main	11.00	5039 Bitu	uminous	Widen to 7m	2006	71.23	•	71.23	7.16	
	T4R4W1	Secondary or Main	5.00	5039 Bitu	uminous	Widen to 7m	2006	32.38		103.61	5.77	
Perform Budget	T4R5W2	Secondary or Main	5.80	5039 Bitu	uminous	Widen to 7m	2006	37.56		141.17	5.45	
Optimisation	T4R3W1	Secondary or Main	5.90	5039 Bitt	uminous	Widen to 7m	2006	38.20		179.37	4.37	
	T4R4W2	Secondary or Main	2.00	5039 Bite	uminous	Widen to 7m	2006	12.95		192.32	4.04	-
Generate	T4R5w/3	Secondary or Main	6.40	5039 Bite	uminous	Reconstruct 100	2006	41.44	•	233.76	3.33	
y negotis	T4R3W2	Secondary or Main	3.60	5039 Bitt	uminous	Widen to 7m	2006	23.31		257.07	2.87	
	T4R2W2	Secondary or Main	5.60	5039 Bitt	uminous	Widen to 7m	2006	36.26	-	293.33	2.27	
	T3R5W1	Secondary or Main	48.60	2139 Bitt	uminous	Widen to 7m	2006	314.68	•	608.01	1.86	
	T3R5W2	Secondary or Main	2.00	2139 Bitt	uminous	Widen to 7m	2006	12.95	•	620.96	1.57	
	13R4W1	Secondary or Main	19.00	2139 Bitt	uminous	Widen to /m	2006	123.03		743.99	1.18	
	13R5W3	Secondary or Main	4.40	2139 Bitt	uminous	Heconstruct 100	2006	28.49		//2.48	1.04	
	T2R5WTA	Secondary or Main	36,90	TUUT Bitt	uminous	Reconstruct 100	2006	119.46	•	891.94	0.97	
	12R5W18	Secondary or Main	36.90	1001 Bitt	uminous	Reconstruct 100	2006	119.46	•	1011.40	0.97	
	T2RSWTC	Secondary or Main	36.90	1001 BR	uminous	Heconstruct 100	2006	119.46	-	1130.86	0.97	
	1304W2	Secondary or Main	4.60	2133 BIII	uminous	Widen to 7m	2006	23.73	-	100.65	0.35	
	TIPEVIC	Secondary or Main	46.40	304 Ditt 304 Ditt	uminous	Reconstruct 40	2006	71.40	•	1232.11	0.84	
	T1DB//1D	Secondary or Main	46.40	304 Ditt 304 Ditt	uminous	Reconstruct 40	2006	71.46		1303.07	0.84	
	T 20 20/1	Secondary of Main	27.20	2129 Ditt	uminous	Neconstruct 40	2006	176.12		1570.03	0.04	
	T2PBu/2	Secondary of Main	1.20	1001 Dia	uminous	Percentruct 100	2006	£ 11		1557.20	0.67	
	T2RB1/2	Secondary or Main	5.00	1001 Ditt	uminous	Reconstruct 100	2000	22.20		1509.20	0.92	
	T4B4W/3	Secondary or Main	0.50	5403 Bit	uminous	Rehab 110mm	2007	1.25		1590.99	4 96	
	T4B3W/3	Secondary or Main	6.00	5403 Bit	uminous	Rehab 110mm	2007	14.99		1605.88	2 33	
	T4B2W3	Secondary or Main	13.60	5403 Bib	uminous	30mm Overlau	2007	9.90		1615.78	1.68	
	T3B4W3	Secondary or Main	1.00	2296 Bib	uminous	Behab 110mm	2007	2.50		1618.28	1.30	
	T2B4W1	Secondary or Main	26.00	1073 Bib	uminous	Rehab 110mm	2007	32.49		1650.77	1.25	
	T2B2W2	Secondary or Main	10.40	1073 Bit	uminous	20mm Overlav	2007	4,23		1655.00	1.15	
. 1	T2B2W1	Secondary or Main	48.80	1073 Bitt	uminous	20mm Overlav	2007	12.64		1667.64	1.14	
Save	T2R2W3	Secondary or Main	5.00	1073 Bite	uminous	20mm Overlay	2007	2.59		1670.23	1.14	
	•											I•[
2												

The unconstrained programme shows the alternative for each section that has the highest NPV and is the optimum solution when there is no budget constraint. Key parameters shown include the treatment year, capital cost, cumulative capital costs and NPV/CAP, the latter being the preferred prioritisation indicator for capital budgeting.

In this screen the following two options can also be selected:

- Select sections for Manual assignment (shown in the bottom left of the screen). This
 allows works which have an NPV of zero or greater to be selected as committed works
 and the budget reserved for their treatment. Where budget optimisation is performed the
 total value of the works for these sections is removed from the available budget prior to
 performing budget optimisation.
- Selecting **Display recurrent works** (shown in the bottom right of the screen) shows the treatments and associated costs for all recurrent works in addition to the capital works.

It is useful at this point to scroll through the active screen and note the capital budget distribution by year, as this will be important for assessing investment needs and for budget

optimisation purposes. The total budget needed to the five year plan (i.e. the cumulative capital cost at the end of year 5 (2010)) is 2242 million. This figure can then be used to examine various budget constraint scenarios in the budget optimisation procedure.

1.6 Perform Budget Optimisation

1.6.1 Define Budget

The budget scenarios that are to be investigated need to be defined. For this case study, the analysis considers budget constraints only for the 5 years of the planning period. For years 6 to 20 an unconstrained budget is assigned.



Three budget constraint scenarios have been created in this case study; high, medium and low. The high scenario budget level was obtained by taking the unconstrained five year total (approx 2250 million) and splitting this total evenly between the five years – a more balanced 'unconstrained' solution. The medium budget was set at 75% of high and the low budget at 50% of high. An unconstrained budget was assigned for the remaining part of the analysis period.

Budget Scenario	Details - Hi	gh				×
Name: Hi	igh					
Description:						
Budget Details					1	
Start of year	End of year	Capital Bu	dget -	≜ _"	isert period	
2	2		450 000000	Ap	pend period	
3	3		450.000000			
4	4		450.000000			
5	5		450.000000		late period	
6	20	99	99999.000000	- <u> </u>	elete periou	
The capital but millions of India	dget is expres: in Rupee	^{ed in} Σ[1	.00022e+007			
				_	Canaal	1
					Lancel	
unique name to id	dentify the Bu	dget Scenario				-

1.6.2 Optimised Programme

Having set up the budget scenarios, then the user needs to click on Perform Budget Optimisation to produce the Optimised Programmes for each defined scenario.

Define	Define Budget Optimised Pro	gramme										
Details	Budget Scenario: High		•									
Specify	Optimisation of alternatives - p	performed at 30-01-20	06									
Generate	Road Section	Road class	Length	MT AADT	Pavement	Road Works	Year	Cost (m#)	Recurrent Cum. Cost	Capital Cum. Cost	NPV/CAP	
Strategy	T4R5W2	Secondary or Main	5.80	5039	Bituminous	Widen to 7m	2006	37.56	-	37.56	5.45	
	T4R4W2	Secondary or Main	2.00	5039	Bituminous	Widen to 7m	2006	12.95		50.51	4.04	
Perform	T4R5W3	Secondary or Main	6.40	5039	Bituminous	Reconstruct 100	2006	41.44	1.1	91.95	3.33	
Optimisation	T3R5W1	Secondary or Main	48.60	2139	Bituminous	Reconstruct 100	2006	157.34		249.29	2.68	
-	T4R2W2	Secondary or Main	5.60	5039	Bituminous	Widen to 7m	2006	36.26	÷ .	285.55	2.27	
Generate	T3R5W2	Secondary or Main	2.00	2139	Bituminous	Widen to 7m	2006	12.95		298.50	1.57	
negons	T3R5W3	Secondary or Main	4.40	2139	Bituminous	Reconstruct 100	2006	28.49		326.99	1.04	
	T2R5W1A	Secondary or Main	36.90	1001	Bituminous	Reconstruct 100	2006	119.46	1.1	446.45	0.97	
	T4R4W1	Secondary or Main	5.00	5403	Bituminous	Widen to 7m	2007	32.38	•	478.83	5.98	
	T4R4W/3	Secondary or Main	0.50	5403	Bituminous	Rehab 110mm	2007	1.25	•	480.08	4.96	
	14H3W1	Secondary or Main	5.90	5403	Bituminous	Widen to /m	2007	38.20		518.28	4.56	
	13H4W1	Secondary or Main	19.00	2296	Bituminous	Hehab 110mm	2007	23.74		542.02	4.07	
	14H3W2	Secondary or Main	3.60	5403	Bituminous	Widen to /m	2007	23.31	•	565.33	2.95	
	13H4W2	Secondary or Main	4.60	2296	Bituminous	Rehab 110mm	2007	9.03	•	574.36	2.56	
	14H3W3	Secondary or Main	5.00	5403	Bituminous	Hehab I Tumm	2007	14.99		589.35	2.33	
	T402W3	Secondary or Main	1.00	3403	Distantinous	John Ovenay	2007	3.30		033.20	1.00	
	1304W3	Secondary or Main	1.00	1070	Dituminous	Deheb 110mm	2007	2.00	•	601.75	1.00	
	T2D3V/2	Secondary or Main	20.00	1073	Dituminous	20mm Oundau	2007	32.43	•	604.24 C00.47	1.20	
	T2R2w2	Secondary or Main	49.90	1073	Bituminous	20mm Overlay	2007	4.20		651.11	1.13	
	T2B2W3	Secondary or Main	5.00	1073	Bituminous	20mm Overlau	2007	2.59		653.70	1.14	
	T1B2W1	Secondary or Main	51.00	412	Bituminous	20mm Overlau	2007	13.26		ae aaa	1 13	
	T1B2w2	Secondary or Main	11.00	412	Bituminous	20mm Overlay	2007	4 48		671.44	1.11	
	T1B2W3	Secondary or Main	25.00	412	Bituminous	20mm Overlav	2007	12.95		684.39	1.10	
	T3R2W38	Secondary or Main	46.70	2296	Bituminous	30mm Overlav	2007	34.00		718.39	1.08	
	T3R2W3A	Secondary or Main	46.70	2296	Bituminous	30mm Overlav	2007	34.00		752.39	1.08	
	T1R5W1A	Secondary or Main	46.40	412	Bituminous	Reconstruct 40	2007	71.46		823.85	0.90	
	T1R5W1B	Secondary or Main	46.40	412	Bituminous	Reconstruct 40	2007	71.46		895.31	0.90	
1	T4R1W3	Secondary or Main	13.00	5795	Bituminous	30mm Overlay	2008	9.46	-	904.77	2.15	
Save	T1R5W1C	Secondary or Main	46.40	442	Bituminous	Reconstruct 40	2008	71.46	-	976.23	1.00	
	1											•
~												En l

As can be seen in the above screen, the cumulative capital costs for each year in the high budget scenario (450 million/year) is not exceeded.

1.7 Generate Reports

Having run the analysis it is now possible to **Generate Reports** and perform a similar check of key reports to ensure the data inputs and modeling are as expected. These should be examined and verified as any subsequent results are dependent on the performance of individual sections, with results aggregated to represent the network.

For Programme and Startegy analysis case studies a wider selection of reports are available, and examples of a selection of useful reports for the particular case study are given below. The following screen shows the list of reports available in the Programme and Strategy Analysis folder.



The Roughness: Average for Road Network by Budget Scenario graph presents the average roughness weighted by length for each scenario.



Others are tabular and these can be exported and used for further analysis or summary outside HDM-4 (e.g. in Excel).

The report Work Programme Optimised by Section was exported and the analysis results summarised to show the total cost and length of different categories of works over the five years.





These graphs show that, as the budget level is reduced, the proportions spent on maintenance and improvement works remain broadly the same.

1.8 Asset Valuation Analysis

The asset valuation reports currently available in HDM-4 show annual asset value by section for each section alternative generated. There is no summary reporting showing the total asset value for the network. To obtain this information the relevant data from the output file (rundata.mdb) must be extracted.

Figure G1.1 shows the change in the asset value of the total analysis network over the 5-year planning period.



Figure G1.1 Asset Valuation for the Budget Scenarios

Table G1.10 compares the increase in asset value with the total expenditure over the five year period.

Budget Level	Increase in Asset Value (Rs million)	Total Expenditure (Rs million)	Increase in Asset Value as % of Expenditure		
High	1,416	2,064	69%		
Medium	1,154	1,671	69%		
Low	566	1,112	51%		

Table G1.10Comparison Of Increase in Asset Value and Expenditure

The increase in asset value is less than expenditure. The asset as initially defined in the road network includes components for bridges, road furniture etc. which depreciate over time while no work is applied to these items by HDM-4 to enhance their asset value. At the same time as maintenance and improvement is applied to different sections, the other sections are also depreciating.

The results of the optimisation, presented earlier, showed around 70% of expenditure was for improvement works (reconstruction and widening). It is this component that increases the asset value. Maintenance works are simply keeping pace with depreciation of the pavement, given an adequate budget. With a low budget, depreciation is more than maintenance expenditure.

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