THE CZECH HIGHWAY APPRAISAL SYSTEM

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ABSTRACT

This paper discusses the implementation of a highway appraisal system for the Czech Republic, based on the HDM-4 software tool. Development of the Czech Highway Appraisal System (CHAS) started in October 2001 as part of the "Technical Assistance to programmes of Highway Construction and Reconstruction co-financed by the European Investment Bank". The objectives of the systems were to:

- provide a standardised economic appraisal methodology for road investment in the Czech Republic based on HDM-4
- provide a simplified appraisal methodology for the cost-effective and quick appraisal of schemes when required

The system was developed by Mott MacDonald and the University of Birmingham in close co-operation with the Technical Division of the Roads and Motorways Directorate (RMD) of the Czech Republic.

CHAS was designed to integrate with and complement the existing road planning system in the Czech Republic and in particular with the extensive Road Data Bank (RDB) system maintained by the Roads and Motorways Directorate in Ostrava.

The principal elements of the system are the HDM-4 model and a software interface between the RDB and HDM-4 which significantly simplifies the task of performing appraisals on the Motorway and Class I road network using the extensive data collected by the road authorities. The interface, known as ADAPTOR, enables the user to easily create the required HDM-4 input files, reducing the probability of errors and reducing the time needed to undertake appraisals. In this future, this system could be developed into a full HDM-4 based Pavement System.

The system also includes a Simplified Appraisal Methodology (SAM) which enables the user to conduct economic appraisals with limited scheme data and reasonable default values based on average network data. As HDM-4 does not model bridge rehabilitation projects an interim Bridge Appraisal Model (BAM) was developed.
In parallel to the various CHAS software development activities, a Level 2 calibration of HDM-4 was conducted, including the road deterioration, road user effects, and work effects models (amongst others).

KEY WORDS

HDM-4 / ECONOMICS / APPRAISAL / PAVEMENTS

1 INTRODUCTION

Development of the Czech Highway Appraisal System (CHAS) started in October 2001 as part of an ongoing programme titled “Technical Assistance to programmes of Highway Construction and Reconstruction co-financed by the European Investment Bank”. The objectives of the system were to:

- Provide a standardised economic appraisal methodology for road investment in the Czech Republic based on the Highway Development and Management Model (HDM-4)
- Provide a simplified appraisal methodology for the cost-effective and rapid appraisal of schemes when required.

The system was designed by Mott MacDonald and the University of Birmingham in close co-operation with the Technical Division of the Roads and Motorways Directorate (RMD). CHAS was designed to integrate with and complement the existing road planning system in the Czech Republic and in particular with the sophisticated Road Data Bank (RDB) administered by RMD in Ostrava.

The principal elements of the system (illustrated in Figure 1.1) are the HDM-4 model and a software interface between the RDB and HDM-4. The interface, known as ADAPTOR, enables the user to easily create HDM-4 input files.

CHAS also includes a Simplified Appraisal Methodology (SAM) that enables the user to conduct economic appraisals with limited scheme data and network default values. A separate Bridge Appraisal Model (BAM) is also included in the system.

A Level 2 calibration of HDM-4 was conducted as part of the study. This was completed in December 2001 with recommendations for further research.

CHAS is documented in the following four volumes in both Czech and English:

Volume 1 Appraisal Guide,
Volume 2 Software Users Guide,
Volume 3 Calibration Guide, and
Volume 4 Guidelines for Application.

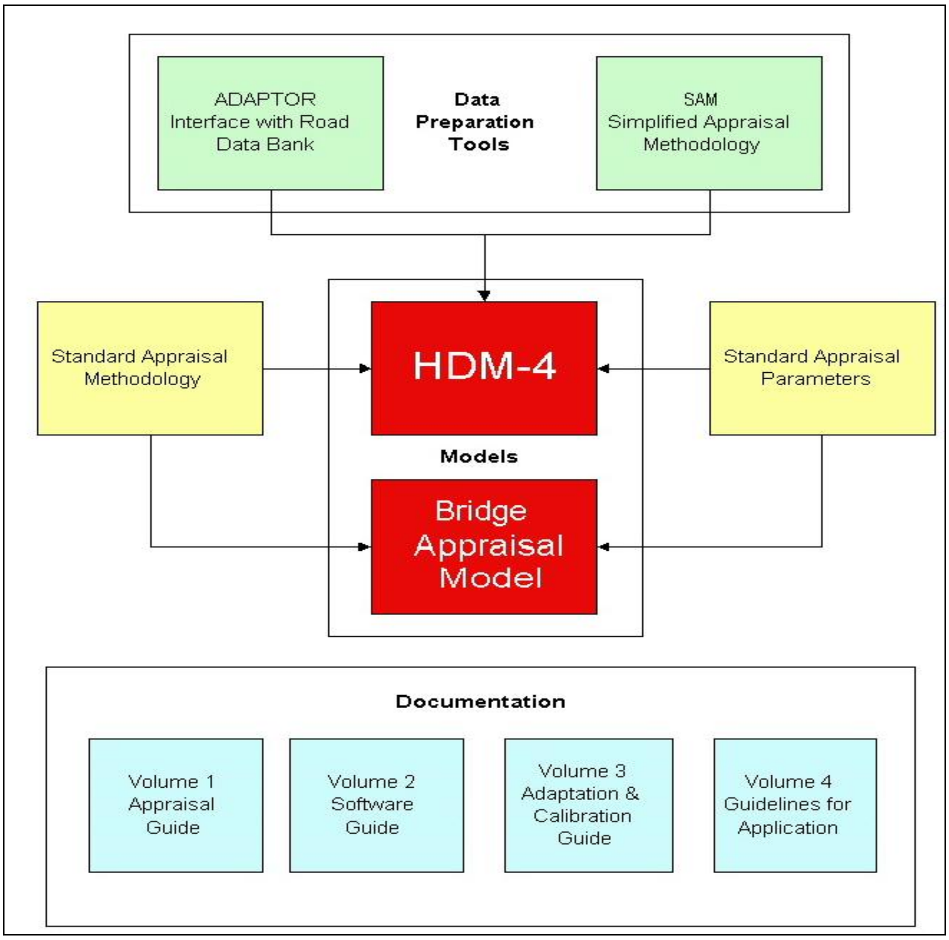

Figure 1-1 The Czech Highway Appraisal System

2 APPRAISAL FRAMEWORK

In CHAS the majority of HDM-4 parameters are pre-defined for the user. These are called 'non scheme-specific parameters' and can be used in all appraisals, as follows:

- Appraisal setup parameters (study duration, discount rate, etc.),
- Traffic growth,
- Road user effect parameters,
- Road deterioration and works effects parameters, and
- Climate parameters.

To conduct an appraisal the user has to define scheme specific data for the road network. This can be done in one of three ways, as follows:

- Using ADAPTOR,
- Using SAM, or
- Directly into HDM-4.

Having created the road network data the user must then set-up an HDM-4 project for the appraisal. CHAS has standardised the methodology for appraising four categories of project, as follows:

- Maintenance,
- Re-construction,
- Widening, and
- New Construction.

A standard procedure for running the project appraisal, assessing the results and presenting the findings is provided in the Appraisal Guide.

3 HDM-4 DATA PREPARATION TOOL (ADAPTOR)

3.1 Background

The purpose of this tool is the preparation of RDB data for use in HDM-4. ADAPTOR has three major software functions, as follows:

- Import of RDB data into ADAPTOR,
- User selection of sections to be analysed in HDM-4, and
- Generation of an export file set for analysis in HDM-4.

3.2 Importing Road RDB Data

ADAPTOR does not extract data directly from the RDB, but instead uses its own internal copy of the RDB data. An 'Import Wizard' is provided to simplify the importing of the latest RDB data into ADAPTOR.

3.3 Selecting Sections for Export to HDM-4

The 'Pre-defined Sections Wizard' is provided to simplify the user selection of road sections for analysis in HDM-4. ADAPTOR interrogates its internal copy of the RDB to determine the availability of data for the user specified subsections. The 'Data Availability' screen (as shown in Figure 3-1), allows the user to review the availability of data for each specified length of road.

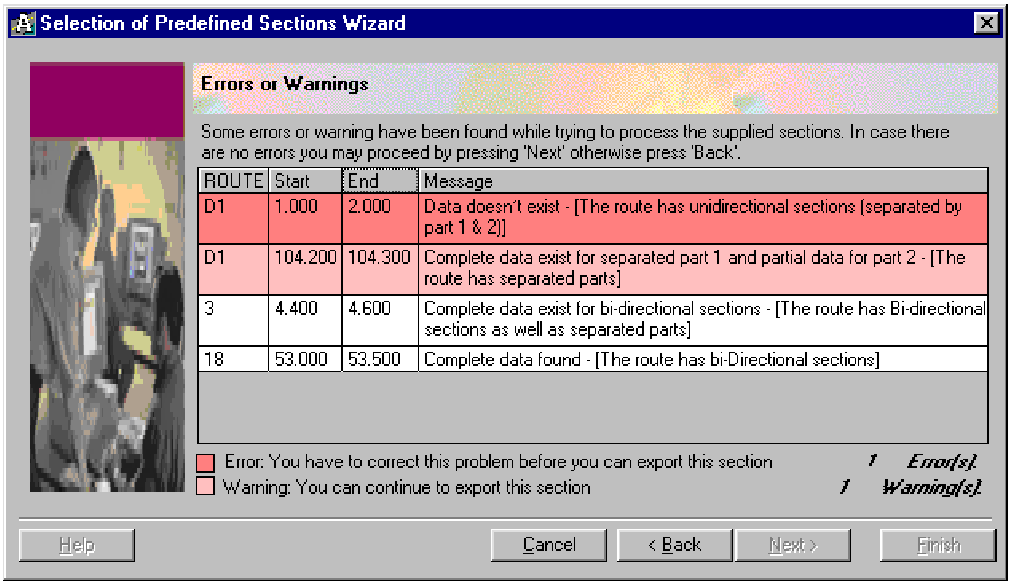

Figure 3-1 The Data Availability Screen

Having reviewed data availability, the 'Review Selected Sections' screen shows the RDB sections that correspond to the specified lengths of road. The results are displayed in the form of a tree-control as shown in Figure 3-2. The user may review the resultant RDB sections, and make minor adjustments to the 'final selection set'.

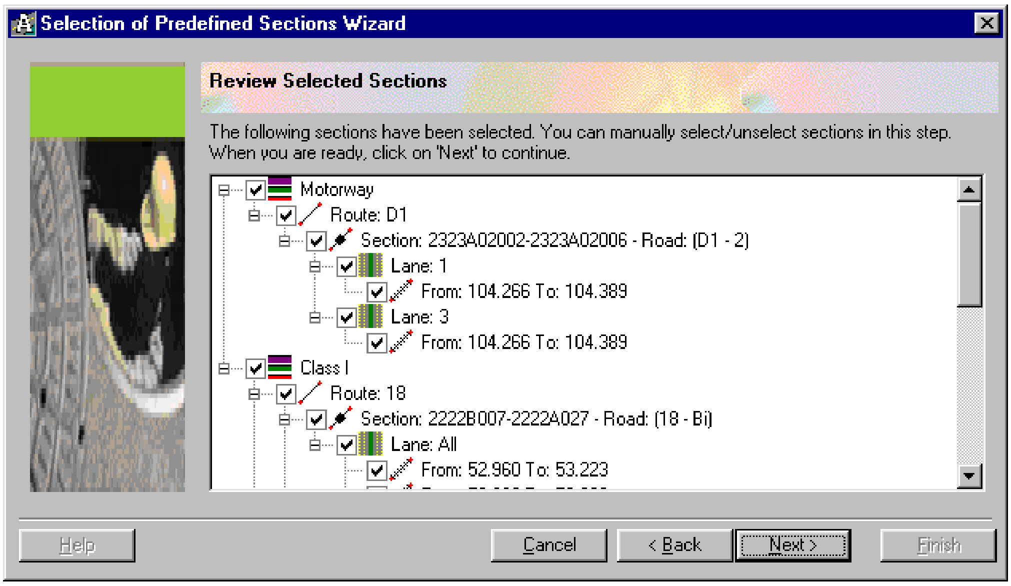

Figure 3-2 The Review Selected Sections Screen

3.4 Exporting Selected Sections to HDM-4

Having selected the RDB sections to be analysed in HDM-4, the next step in the export process is the creation of an export file-set in the format required by HDM-4. The 'HDM-4 Export Wizard' is provided to guide the user through this process. HDM-4 has very particular input data input requirements. A sophisticated piece of software is needed to convert the source RDB data into the format required by HDM-4. Several steps are involved:

- creation of homogeneous sections,
- derivation of appropriate values for the many 'missing' data items
- conversion of RDB data into HDM-4 units, and
- creation of export files in the exact format expected by HDM-4

The HDM-4 Export Wizard has been developed in an attempt to hide as much of this inherent complexity from the user as possible. The result is a powerful tool which significantly simplifies the task of creating HDM-4 import files.

The first step in the generation of the export file–set is called 'Segmentation'. The basic unit of analysis in HDM-4 is the homogeneous section: a length of road for which all attributes (e.g. pavement width, traffic, condition, etc.) are constant for its entire length. All RDB sections must be converted into homogeneous sections before being analysed in HDM-4. In common with most road databases, the RDB does not store all its data as a single set of unified homogeneous sections. Instead, separate sets of homogeneous sections are stored for the different categories of road data. The chainages of these different categories of homogeneous sections are not synchronised.

The segmentation routine in the Export Wizard generates a single set of homogeneous sections by analysing the various categories of data simultaneously, and identifying road lengths (segments) for which all road characteristics are constant. This is sometimes referred to as the ‘lowest common denominator’ approach.

The segmentation process usually results in a large number of relatively small segments. As the raw segment set is usually too large for use in analysis an aggregation function is provided to reduce the size of the export file. The aggregation process reduces the number of sections in the export file by combining segments with similar characteristics. Two phases of aggregation are employed: ‘Automatic’ and ‘Manual’. During ‘Automatic Aggregation’, ADAPTOR identifies adjacent segments which satisfy the system’s aggregation rules. During the subsequent ‘Manual Aggregation’ the user may over-ride the aggregation recommendations resulting from the automatic phase.

The next stage in the export process is the derivation of values for the many data items required by HDM-4 for each road section, but which are not present in the RDB data-set. In order to produce an HDM-4 compliant data set, sensible values must be obtained for these ‘missing’ parameters. The mechanism implemented for the derivation of values for the missing data-items is the ‘look-up table’.

The look-up table is effectively a list of ‘representative sections’ that reflect the range of different road types found on the RMD network. For each representative section values are defined both for those data items that exist in the RDB, and for those data items required by HDM-4 but not in the RDB. During the look-up process, ADAPTOR determines the representative section (in the look-up table) which most closely corresponds to each RDB section, and uses this to derive values for the missing data-items. The result is a set of RDB sections, with values specified for all the parameters required by HDM-4. Once the user has reviewed the derived values and is satisfied, and final export file-set is generated. This can then be imported into HDM-4 for subsequent analysis.

4 SIMPLIFIED APPRAISAL METHODOLOGY (SAM)

SAM is a pro-forma (in EXCEL spreadsheet format) for collecting the minimum amount of data required to conduct an HDM-4 appraisal. The pro-forma is based on a set of key HDM-4 input parameters including visual condition, traffic counts, and pavement strength, plus the use of default characteristics and aggregate data. Use of the pro-forma ensures that all the key data is obtained. Upon completion of the SAM sheets, the user then transfers the collected data manually to HDM-4. SAM is used for the rapid screening of RMD projects.

5 CZECH BRIDGE APPRAISAL MODEL (BAM)

HDM-4 does not support the economic appraisal of bridge rehabilitation and replacement schemes. The CHAS Bridge Appraisal Model (BAM) provides a simplified framework for the economic appraisal of bridge rehabilitations and replacements. The model calculates the whole life cycle agency costs for the project case (involving bridge rehabilitation), and for the base case (with no rehabilitation and eventual failure and replacement of the structure). The model also calculates the additional road user costs resulting from traffic diversions due to restrictions to use. The economic impact on agency and road user costs is calculated. The model is implemented as an EXCEL spreadsheet with17 input parameters. It is envisaged that the BAM approach will form the basis for the proposed bridge appraisal methodology in HDM-4 Version 2.1.

6 CALIBRATION OF HDM-4 TO CZECH CONDITIONS

6.1 Background

The initial calibration of CHAS consisted of a Level 1 and a partial Level 2 calibration. Recommendations were made for future Level 3 calibrations in areas where data availability was poor. A procedure for the future updating of the calibration data-set was also provided. The calibration focused on the most important parameters as measured by impact sensitivity. The following sections describe the calibration of each of the main sub-models and data sets within HDM-4.

6.2 Road User Effects

6.2.1 Vehicle Operating Costs (VOC)

The starting point in deciding how many vehicles to model for the CHAS was the RMD classification used for traffic counting. This classification is the basis on which traffic data is stored in the Road Data Bank. RMD classifies the vehicle fleet into 8 main categories, with an additional four sub-categories for vehicles with towed trailers. A number of representative vehicles are identified for each vehicle class to allow for the large variations in vehicle characteristics within each class. Cars have been modelled in more detail as they account for some 80 per cent of traffic on main roads. Eight representative vehicles are used for cars. This includes a category for old cars to reflect the large number of old Czech cars still registered. Figure 5-1 sets out the CHAS vehicle classification system.

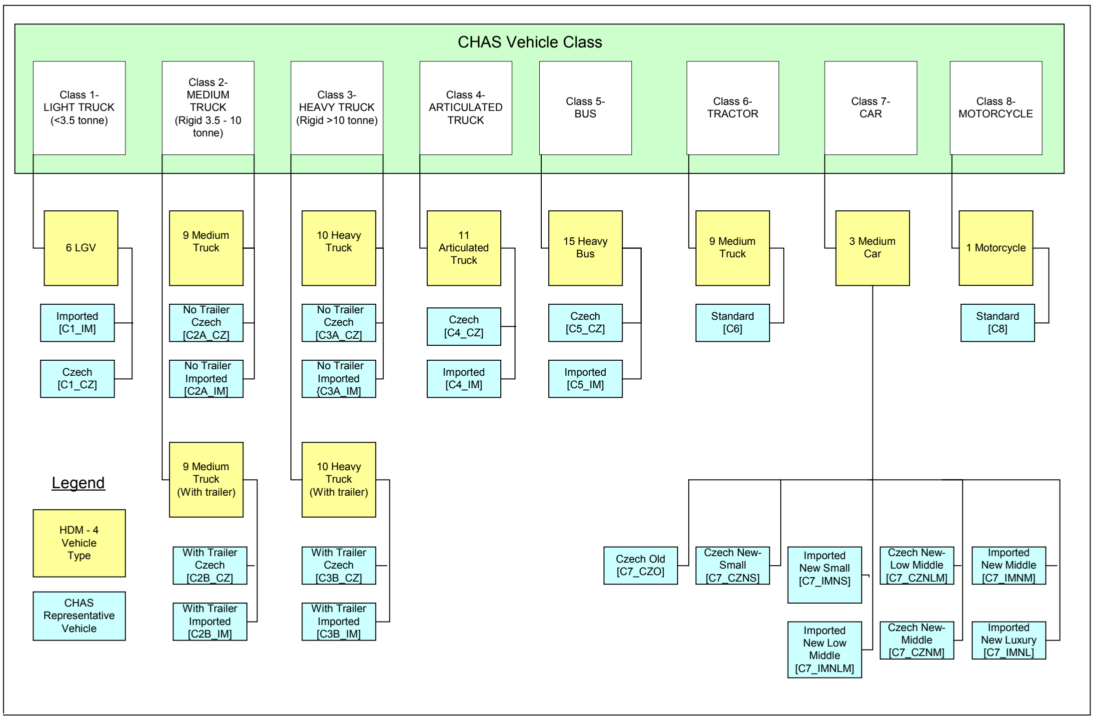

Figure 6-1 Vehicle classification

CHAS incorporates a standard vehicle fleet to be used for all appraisals. In the standard fleet one HDM-4 vehicle type is used for each CHAS vehicle class, resulting in ten standard vehicles. Each of the standard vehicle classes consist of the weighted average vehicle costs and operating characteristics of the representative vehicles in that class. It is possible to model representative vehicles individually for special studies.

Standard pro-formas were prepared for the collection of input data. A global validation of the data against fares and tariffs was conducted. However, it was not possible to undertake a detailed calibration of the VOC resource consumption models. This was recommended for a future Level 3 Study.

Unit VOC's predicted by HDM-4 are set out in Table 5-1. The table shows the sensitivity of VOC to roughness, all other factors being constant.

Table 6-1 Unit Vehicle Operating Costs for 2001 (CZK per km)

IRI	1 Light Truck	2a Med. Truck	2b Med. Truck (with trailer)	3a Heavy Truck	3b Heavy Truck (with trailer)	4 Artic. Truck	5 Bus	6 Tractor	7 Car	8 Motor cycle
2	6.49	19.18	21.83	15.64	18.54	25.76	18.71	9.11	4.97	3.59
3	6.53	19.24	21.94	15.71	18.65	25.95	18.85	9.14	5.00	3.60
4	6.71	19.64	22.48	16.12	19.26	27.06	19.91	9.34	5.10	3.68
5	6.91	20.24	23.23	16.56	19.91	28.03	21.13	9.57	5.23	3.80
6	7.13	21.17	24.32	17.01	20.61	28.94	22.47	9.83	5.42	3.96
7	7.41	22.51	25.80	17.54	21.41	30.16	23.92	10.13	5.71	4.13
8	7.77	24.19	27.63	18.30	22.44	31.66	25.51	10.48	6.09	4.34
9	8.18	26.1	29.70	19.24	23.66	33.33	27.20	10.90	6.53	4.57
10	8.62	28.15	31.92	20.31	24.99	35.10	28.94	11.36	7.02	4.82
11	9.09	30.28	34.22	21.46	26.39	36.94	30.69	11.85	7.53	5.07
12	9.57	32.45	36.57	22.66	27.83	38.17	32.44	12.36	8.06	5.33

Source: HDM-4 Note: IRI = International Roughness Index

6.2.2 Travel Time Costs (TTC)

The average wage approach was used to estimate TTC's in CHAS. Recommendations were made for a Level 3 Stated Preference study. In line with the previous approach in the Czech Republic values of time of other EU members are taken into account as the majority of road schemes are funded by the EU to benefit all EU members. Costs with and without EU members are provided so that the user can assess the sensitivity of the appraisal to this effect. Table 5-2 summarises the unit costs for 2001.

Table 6-2 Travel Time Costs for 2001 (CZK)

Item	Car	Bus
Work time cost per Czech occupant	83.6	66.9
Non-work time cost per Czech occupant	16.7	13.4
Work time cost per EU occupant	882.4	705.9
Non-work time cost per EU occupant	176.5	141.2
Average cost per Czech	30.1	24.1
Average cost per EU occupant	317.7	254.1
Average cost all nationalities	87.6	70.1
Average occupancy	2.66	10
Average cost per vehicle (all nationalities)	233.0	2808.3

6.2.3 Accident Costs

Unit accident costs were derived by the Transport Research Institute (CDV) Brno for fatal, serious injury and minor injury accidents, and are set out in Table 5-3. Accident rates are published annually by the RMD and have been included in CHAS.

Table 6-3 2001 Accident Costs (CZK)

Accident Category	Cost per Accident 2001
Fatal	6,700,000
Serious Injury	2,200,000
Minor Injury	200,000
Average accident	871,000

6.3 The Traffic Relationships

6.3.1 Background

HDM-4 contains a number of traffic-related models. The input parameters for these models are not located in one module in the HDM-4 user interface, but instead in a number of locations. The following sections describe the approach adopted to the adaptation and calibration of the various models for CHAS.

6.3.2 Prediction of Total Annual Traffic Volumes

The procedure used by RMD for traffic counting and the creation and projection of AADT's was maintained for CHAS. The system of traffic data collection is common to all the different planning systems and is centrally controlled and organised by RMD. This ensures continuity of data across all the systems.

6.3.3 Vehicle Damage (Axle Loading)

Axle load data is not regularly collected on the road network in the Czech Republic. However, recent studies indicate that over-loading is not a problem. This view is shared by RMD. The assessment of Equivalent Standard Axle Loads was therefore based on existing axle load legislation and assumptions regarding average loading,

6.3.4 CHAS Speed Flow Categories

Eight speed flow curves are provided in CHAS. Seven inter-urban and one urban standard are provided ranging from a narrow two lane road to a four lane motorway. These are based on existing research in the Czech Republic and experience in other similar countries.

6.3.5 Hourly Distribution of Traffic Volume (Flow Patterns)

The derivation of the hourly distribution of the Czech Republic was based on an analysis of Automatic Traffic Counter (ATC) data for 1999. Two standard patterns for inter-urban and urban roads were identified from the analysis. Five flow periods were used in each traffic flow pattern, representing the five distinct periods of the day identified from the analysis of the ATC data.

6.4 ROAD DETERIORATION AND WORKS EFFECTS (RDWE)

6.4.1 Background

The adaptation and calibration of the RDWE model was divided into three tasks, as follows:

- Adaptation of data inputs,
- Maintenance and improvement policy and standards, and
- Calibration of deterioration profiles.

The first two tasks were concerned with adapting existing RMD data for use in HDM-4 and the last with calibrating the HDM-4 predictions to fit Czech conditions.

6.4.2 Adaptation of Data Input

A major part of the remit for developing CHAS was to avoid changes to RMD's road data collection process. A review of the current process showed that sufficient data was collected to run HDM-4. Existing data was adapted for entry into HDM-4 by mapping RMD pavement and defect types onto the HDM-4 hierarchy.

6.4.3 Maintenance Standards

Three generic maintenance standards are provided in the CHAS Workspace*,* as follows:

- CHAS 1 Bitumen Maintenance Standard,
- CHAS 2 Composite Maintenance Standard, and
- CHAS 3 Concrete Maintenance Standard.

Each standard contains a set of routine and periodic work items. These standards are intended to provide the user with default standards to apply for Base Case and Project Case routine and periodic maintenance. The composite maintenance standard is an interim solution pending the release of HDM-4 Version 2.1.

6.4.4 Road Deterioration

A review of road deterioration curves was undertaken using engineering judgement, and a recommendation made for a Level 3 study based on a empirical analysis of time series data held in the RDB.

6.5 Climate Parameters

The HDM-4 Climate zones defined for the Czech Republic were based on topography, as precipitation, temperature and winter conditions are closely correlated to elevation. Three zones were selected as follows:

- Moderate (0-500m),
- Average (500-850m), and
- Severe (>850m).

6.6 Economic Appraisal Parameters

A number of economic parameters have to be set by the user when creating an HDM-4 study. The Czech Government did not have guidelines in 2002 for setting these parameters, which should be consistent across projects and sectors. Nor does the European Union or European Investment Bank. Recommendations were based on international experience and discussions with the relevant authorities. The principal values are:

- Analysis period is 20 years from the first year of construction, (inclusive),
- The discount rate is 8 per cent,
- Analysis Start Year is the first year of construction,
- Base Year for Costs is current year,
- All costs are expressed in current year values,
- Salvage values are included according to a given formula, and

- All costs input as economic values according to Guide.

6.7 Updates And Recommended Level 3 Studies

The CHAS calibration data-set needs to be regularly updated and reviewed so that it reflects changes in costs, technologies and other parameters. These exercises are divided into three categories for CHAS, as follows:

- Annual updates,
- Periodic updates, and
- Level 3 studies.

The annual updates should be made in January of each year. As a guideline it is recommended that periodic updates should be made every five years at the maximum. However, this is not a rigid rule and when significant changes have occurred to affect a certain parameter (such as the introduction of a new road surfacing technology or a new fuel) then the review must be brought forward.

7 IMPLEMENTATION OF CHAS

It is intended that all HDM-4 appraisals conducted by consultants on behalf of RMD should use the CHAS Workspace and follow the RMD guidelines for appraisal. In this way, commonality and consistency of results should be maximised.

One of the inherent problems of evaluating studies conducted using HDM-4 is determining the validity of the results. This problem arises from the considerable number of input parameters used by HDM-4 (approximately 500 different data items are used by HDM-4 for each analysis). It is very easy, whether deliberately or accidentally, to alter some of these parameters, and thereby significantly affect the results.

A procedure was designed to ensure that studies are conducted with the CHAS set of calibrated parameters and according to the standard appraisal techniques as set out in the CHAS Manual.

The calibration process took much longer than envisaged at the start of the study. It was concluded that considerably more resources are needed to achieve a Level 2 calibration than the HDM-4 documentation suggests.

The ADAPTOR tool provides a powerful means of exploiting the considerable amount of valuable network data stored in the RDB. It is envisaged that the ADAPTOR-RDB combination, could eventually be developed into a full HDM-4 based Pavement System.

Finalisation of the system has been delayed, mainly due to problems of institutional capacity in RMD. However, a follow-up phase to the project was initiated in 2003 to support and further develop the system. It is envisaged that the system will become institutionalised within the planning system of the Czech Republic by 2004.