Deliverable D4

SCENES European Transport Forecasting Model and Appended Module: Technical Description
SCENES
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Project
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Executive Summary

This Deliverable provides a technical description of the SCENES European Transport Forecasting Model (or simply 'SCENES model'). As such it does not detail the model calibration / validation, or present the results of model forecasts. Rather its role is to set out in some detail the modelling methodology used and the main data inputs.

The SCENES model builds closely on its predecessor, the STREAMS model. The basic STREAMS model structure is retained and the model is enhanced in terms of specification, and extended in terms of geographical coverage. The new model includes eight new countries of central and eastern Europe and the Baltic. Passenger travel between the 'internal' and 'external' countries, i.e., rest of the world is also now included. Thus the model incorporates all passenger travel and freight movements within and between the model's 'internal' countries.

The technical development of the new model built upon the model specification, described in SCENES Deliverable D2. The STREAMS prototype model was used in the 'Forecasts of EU / TEN-T Transport and Emissions: A Pilot Study' project for the Commission. As a result of its use in this Pilot Study, it was clear that there were areas where the model would merit further development. These areas were addressed in the development of the SCENES model. In addition, a comparative study was undertaken between the STREAMS freight model output and the NEAC freight database. The findings were instructive in guiding the development of the SCENES freight model.

The main technical areas of model development are each described in this Deliverable. They amount to a comprehensive re-vamp of the STREAMS model. The main areas of direct work on the model can be very broadly divided between:

- the representation of transport supply, in terms of infrastructure provision and the costs / tariffs of transport services;
- a re-working of the treatment of intra-zonal passenger and freight supply
- basic model inputs in terms of demographic and socio-economic data; and
- the representation of demand both for passengers and freight.

In addition, software changes have been implemented to increase the functionality of the model. The main change is one which allows much greater flexibility in the treatment of individual countries using certain model parameters.

A further new area of work related to the model is the development of an 'Appended Module' which runs 'offline' and in effect recalculates freight origin – destination relationships to reflect the actual routes which might be taken, reflecting the use of logistic chains.

The next relevant SCENES Deliverable pertaining to the model will contain model results. This will detail the new calibration / validation process and report on the new model forecasts. The changes made in going from STREAMS to SCENES will allow a better model to be developed for the Base Year. The lesson learned in forecasting with the STREAMS model will also provide the context for more robust forecast to be made for both passenger and freight, perhaps at a more detailed spatial level than before.

1. Introduction

1.1 Overview

The strategic modelling element of the SCENES project builds closely on the work undertaken by the STREAMS consortium, an earlier 4th Framework Transport RTD Programme research project. The STREAMS project developed a pilot strategic level model for forecasting transport throughout the EU. This model was subsequently applied within the DGVII 'Forecasts of EU / TEN-T Transport and Emissions: A Pilot Study' project, to provide traffic data as input to emissions software. The model was used to assess a range of European transport scenarios in this context.

The STREAMS model can therefore be seen as a successful prototype for the more extensive model developed within SCENES. This new model is broader in terms of its geographical scope, and more detailed in its treatment of the EU countries. In particular, the model is extended to cover countries in Central and Eastern European (CEE) and includes an 'appended module', which incorporates aspects of freight logistics indirectly within the modelling framework. The eight 'new' countries which are now internal to the model are the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Slovenia. The other European countries and the rest of the World remain external to the model (trips to / from but not between external countries are now included).

This deliverable builds upon Deliverable D2 'SCENES European Transport Forecasting Model Specification', which outlined the developments that would be made to the STREAMS model in the course of the SCENES project. It also draws on Deliverable D1 (CEEC Data and Method). Deliverable D1 reported in detail the level and type of transport, socio-economic and economic data available in the CEE countries. The data contained in D1 forms an essential input for all the work concerning the CEE countries within the SCENES project.

Deliverable D4, titled 'Scenes European transport forecasting model and appended module: technical description' therefore provides a detailed description of the enhancements made to the STREAMS model and its extension to the CEE countries.

1.2 Objectives

As was pointed out in D2, the SCENES model follows the same basic structure as the STREAMS model. The main objective of Deliverable D4 is therefore to specify model inputs in some detail rather than repeat the details of the model structure, which are reported in STREAMS Deliverable D8/D10. In addition, the features which are 'new' to the SCENES model are reported here. Deliverable D4 does not seek to report on the model calibration or validation however – this will be covered in Deliverable D7 'SCENES European Transport Forecasting Model Results and Regional Model Results'.

Deliverable D2 in part took the form of a 'taking stock' exercise in the light of experience gained in the development and use of the STREAMS model. This has led to a number of model developments which have been tested on the STREAMS model, and are implemented in SCENES. One example is the use of a broader range of country specific model parameters, which required some major software development. This testing and model development is described here in D4.

1.3 Contents of deliverable

The work involved in re-specifying the STREAMS model for SCENES is concentrated in five main areas:

- expansion and changes to the multi-modal transport networks;
- development of passenger demand model and passenger transport supply specification;
- development of Regional Economic Model (REM) for freight demand;
- improvements to the modal split and assignment elements of the freight transport model; and
- the development and assimilation of freight logistics 'Appended Module'.

Each of these main areas of work are considered in brief below, and they then subsequently form a Chapter of their own in the Deliverable.

1.3.1 Development of multi-modal networks

The three main areas of development here have been the extension of the networks to the CEE countries, the testing of additional road network capacity in the EU countries, and major improvements to the intra-zonal networks (i.e., the connections to the 'dummy' zones representing short distance trips). The purpose of the EU road capacity work is to address the problems of overloading 'hot-spots' identified in particular during the 'Forecasts of EU / TEN-T Transport and Emissions: A Pilot Study' work. Chapter 2 documents the development of the new modal networks.

1.3.2 Development of passenger demand model and passenger transport supply specification

There are several main aspects of the area of work, one of which is the establishment of key zonal demographic and socio-economic data. These disaggregated population groupings are required at the zonal level and cover age and employment status, together with zonal car stock data. Also required are the international tourism trip making characteristics (including external countries) in order to establish international trip rates for use in the model. Some adjustments have been made to the definition of trip types and zonal attractors. On the 'supply' side, value of time data, car operating cost data, rail and coach tariffs, and local public transport tariffs are all required at the country level. Obtaining and / or estimating these data are a significant undertaking. All the existing STREAMS input data of this nature have been superseded by new data in SCENES – firstly since the base year has moved from 1994 to 1995 and secondly since much of the data can be regarded as superior to that used in STREAMS. The improvements to the passenger model are described in Chapter 3.

1.3.3 Development of REM for freight demand, and freight transport supply data

Considerable work has gone into a re-working of the STREAMS REM of the European Union countries. This has incorporated the use of 1995 official input – output (I/O) tables for all EU countries, which have replaced the updated 1985 tables (which covered only part of the EU and were adapted for other countries), used in STREAMS. These tables were however only available at a relatively aggregate number of branches, and thus had to be disaggregated for the purposes of SCENES. The new model is then tested at a 2, 3, and 16 zones level, before disaggregating the model to the full 205 internal zones using processed 'observed' intra-EU freight matrices.

An alternative approach was used for representing freight demand for the new internal CEE countries. Extending the I/O approach to the CEE countries was considered in detail. It was concluded however, that the combination of limited data availability and the lack of country specific I/O data, meant that the range of assumptions which would be required to pursue this approach, would in practice outweigh the benefits gained by the use of such an approach. In order to make best use of existing data therefore, the 'NEAC' demand matrices (NEA, INRETS, IWW, 1999) were used for the relevant countries. The modal split and assignment elements of the SCENES modelling approach are retained however.

The freight demand model is therefore outlined in some detail in Chapter 4, as the development of this aspect of the STREAMS model was not widely reported.

1.3.4 Developments in the freight transport model

There are a number of important improvements to the freight transport model within SCENES, that is to say the modal split and assignment elements. Changes are made to freight flow categorisation, load factors, cost functions, values of time, and the representation of intra-zonal trips. These changes are described in Chapter 5, together with a discussion of the various freight data sources, and past trends in the development of freight transport.

1.3.5 Development and assimilation of freight logistics 'Appended Module'

SCENES Deliverable D2 included a detailed description of this 'Appended Module', which is used in the overall SCENES model running process but is not an integral part. In this Deliverable, the implementation of this Appended Module is described in Chapter 6, in terms of a final description of the module's functionality, its assimilation within the model running process and some indicative test results.

2. Development of multi-modal networks

2.1 Introduction

This chapter will cover the three main areas where the STREAMS model networks have been enhanced and extended for use in the SCENES European Forecasting Model. They are:

- extension of all networks and zoning to the CEE countries and other general network improvements;
- addition of road network capacity in the EU; and
- revised specification of intra-zonal network characteristics.

Each of these is now considered in detail below.

2.2 Extension of networks and zoning to CEE countries

The SCENES networks follow the same basic format as was the case in STREAMS. Regarding the networks and zoning, the STREAMS attributes and definitions are utilised and transferred to SCENES with the corrections and enhancements described in this section. The characteristics are largely the same for the EU area as the major focus has been on the CEEC area.

2.2.1 Zoning system

The SCENES model is an extension of the STREAMS model, which concentrated on the EU countries, and hence had the EU area as internal zones. The STREAMS zoning system followed the NUTS2 system maintained by Eurostat, except for Ireland and Denmark where NUTS3 boundaries were used. Originally, it was thought that the zoning system for the EU area would be the same in SCENES as it was in STREAMS.

However, there has been a change concerning the post-1995 NUTS2 zoning of the EU area. The changes are as follows: there are two additional zones in Germany as Saxony is now divided into three zones, and there are more comprehensive changes in the zoning of the UK, due to local government reorganisation.

The new internal countries of the SCENES model in the CEEC area are Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, and Slovenia. The zoning system for these countries follows Eurostat's 'Statistical Region Codes for the CECs' (NUTS2) definitions. For Poland the situation was exceptional because of the administrative restructuring of the country. The new NUTS2 zoning of Poland became effective 01.01.1999, and the zoning system for the whole SCENES area could be defined only after that.

The role of external zones is to ensure that the traffic leaving or coming to the internal SCENES model area goes in the correct general direction. The non-modelled CEE countries each form one zone having their capitals as centroid, because the capitals are sufficiently far away from the internal modelled area. This means that the division of the countries would not significantly change the direction of the traffic flows. Meanwhile, Russia was divided into two zones: the area around St. Petersburg forms one zone and the rest of the Russia the other.

As a summary, there are now 244 internal zones (205 in the EU area and 39 in the CEEC area), and 21 external zones. A full listing of the zones and centroids are presented in Annex A.

For presentation purposes the projection system was chosen to be the same as in STREAMS, British National Grid.

2.2.2 Model networks

The road, rail and inland waterway networks of the SCENES model are based on IRPUD's (Institute of Spatial Planning, University of Dortmund) so-called 'base networks'. The contents of these base networks are outlined below:

- The IRPUD European road network contains all motorways and national roads as well as additional principal roads in agglomerations and important car ferries. Currently the road network contains 36,807 links and 27,665 nodes;
- The IRPUD European rail network contains all passenger and freight railway lines, and rail ferries for the 38 European countries. In addition, the database contains all railway stations for Germany, Belgium, Italy, Switzerland and the Netherlands. For the remaining countries, only the most important stations are included. Currently the rail network contains 38,354 links and 35,354 nodes; and,
- The IRPUD inland waterway network contains the most important navigable rivers and canals and some 400 inland ports. For central Europe all locks and elevators are included, whereas for eastern and southern Europe only some important locks and elevators are given. Currently the inland waterway network contains 2,868 links and 2,764 nodes.

The main difference between the STREAMS and SCENES networks is that the SCENES future year road, rail, and inland waterway networks include information on the development and likely future extent of the TEN projects. This means that the TEN implementation report is incorporated in the network characteristics[1].

This information on the future characteristics of the TEN links is used in defining the future attributes of the modelled links and the alignment and characteristics of new links.

The length calculation of the links was also enhanced by IRPUD. The SCENES version of the networks has a new length item that contains the real link length with greater accuracy. In STREAMS there was a need for a correction coefficient because there was a problem in representing the real length arising from the projection used. The new link length item overcomes this problem.

2.2.3 Selection of links

The work of link selection was carried out using the whole IRPUD base network. This means that there has been altogether almost 80,000 links to choose from. The network in the EU area is based on the STREAMS model network with additional links in congested areas (see Section 2.3, below). Regarding the extension of the model to the CEEC area, the most important links in each new country have been included. The new links for inclusion are selected on a basis of the 'TINA' report[2], national road numbering / categorisation and rail classifications. For example, concerning the road network, the general principle in the CEEC

[1] This is based on the 'Trans-European Transport Network, Report on the Implementation of the Guidelines, Basic Data on the Networks', Report to the European Parliament, the Council, the Economic and Social Committee, and the Committee of the Regions, on the Implementation of the Guidelines for the Development of the trans-European transport network (Decision 1692/96/EC)). The report is based on information received from the member states.

[2] Transport Infrastructure Needs Assessment, TINA Secretariat, Vienna, June 1998

area has been to include all TINA links, E-roads and the most important national links. The local knowledge of the CEEC partners of the SCENES consortium has also been utilised and they have approved the resulting network.

The available data in the CEEC area is described in deliverable D1. This data is used in the network development and relevant parts of it have been coded into the networks.

2.2.4 UN/ECE E-Road counts

The United Nations – Economic Commission for Europe has published a provisional CD-ROM containing the results of the 1995 Census of Road Traffic on Main International Traffic Arteries in Europe. E-road Census results were developed for the first time in the framework of a geographic information system.

The SCENES road network and the data provided in the CD-ROM were linked with each other using a unique counting-post key field. In other words, each link in the CD-ROM database has a key field, and the same key is coded into the SCENES road network, which enables the updating of the counts later if updated data becomes available. There are altogether 3,410 counting-posts that have been located, coded and utilised in the SCENES model, which indicates a very good coverage from a consistent source.

The information of the CD-ROM can be easily imported into the modelled network. Information on the AADT and share of heavy vehicles as well as number of lanes is available for most of the E-roads, which constitute the majority of the SCENES model links. In places where there is no UN/ECE information available, the IRF (International Road Federation) data or information from national sources is used instead. These two sources were coded into the network by IRPUD already during the STREAMS project.

The most important use of the UN/ECE data is in the definition of the local traffic on the road links and the model result validation. This source will form the benchmark in terms of link flows in the SCENES model.

The border times of the non-EU countries have also been updated. The information on the new border times is from the International Road Transport Union (I.R.U.) Internet site (http://www.iru.org).

2.2.5 Network consolidation

The development of the networks was carried out using the whole IRPUD network as described above. The number of links in the model after the selection process is too much to be applied in practice, due to the limitations in the software dimensions, so there is a need to 'consolidate' the network to a manageable number of links. The Network Tool developed within STREAMS provides the means to overcome this problem.

The principle of the network consolidation is to remove the redundant nodes from the network. If there are two or more consecutive links with no junctions and same link type in the network, those links are added together to form one new link. The attributes of this new 'macro' link are derived from the characteristics of the original 'micro' links automatically. The results of the network consolidation can be illustrated with two examples: the number of modelled road links was reduced from 15,246 links to 4,997 links and the rail links were reduced from 14,218 to 2,087. This simplifies the model into practical dimensions.

2.2.6 Sea, air, and pipeline networks

The networks other that those derived from the IRPUD base networks are based on the STREAMS model. The sea network has been extended in order to connect the new ports that have been included, especially on the coasts of the CEEC countries. The air network is also updated and extended, to increase the coverage of the new internal CEEC area of the SCENES model.

The pipeline network in SCENES is retained as it was in STREAMS.

2.2.7 Enhancements of seaport representation

The representation of seaports in the model has been enhanced in SCENES. There are additional ports and ports' specialisations (by commodity type) have been revised. The seaports modelled within the SCENES model have been selected according to the quantity of goods moved (loaded and unloaded). As was the case in the STREAMS model, the ports are specified in line with the definition of the model flow types, i.e., solid-bulk, semi-bulk (general cargo), liquid bulk, and unitised.

The loaded and unloaded tonnes reported in the 'Journal de la Marine Marchande et du transport Multi-modal' (December 1998) are classified for each port. The amounts are specified according the handling categories: liquid bulk (e.g., crude oil, petroleum products, and liquefied gas), solid bulk (e.g., cereals, carbons, iron ore) and other, which represents containers as well as semi-bulk and Ro-Ro. The data on the amount of container traffic has also been drawn from the 'Journal de la Marine Marchande' and from other sources[3].

For the ports used in SCENES, indicative limits were adapted to define which activities are allowed in each coastal port. These are: 3 millions tons for petroleum products, 3.5 millions tons for semi-bulk, 4 millions tons for solid bulk and 1.5 millions tons for unitised traffic. If there is not a port big enough in a given area to satisfy those limits, in some cases a port is introduced to better reproduce the patterns of freight traffic (even if it is not very relevant, by the above definition). The specialisation of most of the ports has been modified with respect to the STREAMS model in the light of the new added ports.

The seaports are classified into two types: deep-sea shipping ports and coastal shipping ports. The most apparent difference to STREAMS is that almost all ports are considered both as deep-sea and coastal ports. This is due to the observation that for bulk and general cargo, transhipment operations are virtually unused. Deep-sea ports have direct services to and from overseas destination. The only ports that are only for coastal shipping are minor ports and ports of the Baltic Sea. Container transhipment takes place in some ports, and in order to model that, a special connection between coastal and deep-sea ports is designed for those ports where transhipment takes place (at present these are Rotterdam, Gioia Tauro, Algeciras, Felixstowe and Le Havre). A full list of the ports in the SCENES model and the port specialisations are reported in Annex A.

The coding of seaports is also enhanced by introducing a direct connection for liquid and solid bulk goods from the port to the centroid of the zone. The reason for this is that most of bulk goods find their destination in ports and do not therefore have to load the network.

[3] e.g., 'Containerisation International Yearbook 1997' and 'Statistical yearbook of Greece 1996'

2.2.8 Rail shuttle and rolling road services

The modelling of freight transport has been enhanced in SCENES by introducing selected European train services as explicit 'transit lines' with actual routes, total travel times and frequencies (i.e., as 'services'). The supply of shuttle services and rolling road services for containers or swap-bodies in 1995/1996 is reproduced in the network. The term 'shuttle' is defined as an unchanged wagon composition train that runs with a set timetable between two terminals without intermediate stops.

Both for shuttle and rolling road services, data has been collected from companies' timetables regarding services that were offered before the end of 1995[4]. Shuttle services are implemented by coding a set of transit lines. In order to do that the route (link by link), total travel time (closing, availability and journey time) and frequency were needed. Between an origin and destination there might be more than one service. In this case, a single line is utilised with a time that is the average of the single services' times, and a frequency that is equal to the sum of the frequencies of the different services.

There are two different kinds of services: 'shuttle' and 'Y-shuttle'. The former are simple services with one origin and one destination, while the latter are services with one origin and several destinations (the train is broken-up in a terminal somewhere along the route) or *vice versa* (two different trains join in a terminal somewhere along the route). The rail shuttle services which have been specified are presented in Annex A.

Rolling road services are special trains where trucks are loaded onto trains, and the drivers are hosted in passenger wagons. This kind of combined transport service is relevant on some origin-destination pairs (e.g., Germany–Austria, Germany–Czech Republic and Italy–Germany), and therefore a set of transit lines are implemented to represent this. The implementation of the rolling road services as transit lines in the model follows the same rules used for the shuttle services. In this case there are no services similar to 'Y-shuttles' with intermediate stops. The rolling road services are also reported in Annex A.

2.3 Addition of road network capacity in the EU

In the STREAMS model, it was generally felt that there were areas of the model, and in particular the road network which suffered from network overloading. This was a result of the varying density of the zoning system, the use of a 'strategic' road network, and the interaction between the intra-zonal and inter-zonal trips. In some places where the zone sizes were small, a high proportion of the trips travel between zone centroids rather than using the 'dummy' zones – this is because the smaller zones have fewer of these zones connected. Thus there are high concentrations of flow on the 'strategic' network, given that all the more local roads are not present in the network.

Table 2.1, below, shows the congestion levels on the 1994 STREAMS road networks. These figures are based on an adjusted flow / capacity ratio, which makes the assumption that 90% of the traffic occurs within the 0600-2200 period (16 hours). They therefore give an indication of the traffic loads on the STREAMS strategic road networks, e.g., 2% of dual carriageway kilometres were seeing loads which are greater than the strict design capacity. These figures are by direction, so the actual road length in the network was approximately 93,000 kilometres. Overall, 4.4% or 8184km of the road network is over-capacity by this definition.

[4] The companies are: Cemat (I), Hupac (CH), Kombiverkehr (D), Ökombi (A), Novatrans (F) and Intercontainers (CH).

Table 2.1: STREAMS 1994 modelled roads km by flow / capacity ratio and type

Test / Road Type	**Flow / Capacity (V/C) Ratio**					
% km	**<.25**	**.25 - .50**	**.50 - .75**	**.75 - 1.00**	**1+**	**Length (km)**
1994 Base						
Toll Motorway	42.2	37.4	15.5	3.7	1.2	**29,590**
Motorway	26.4	28.4	24.6	14.5	6.1	**47,342**
Dual Carriageway	56.3	29.6	9.2	2.8	2.0	**30,125**
Other Road	57.1	21.7	10.8	5.0	5.4	**78,951**
Total	**46.8**	**27.2**	**14.8**	**6.9**	**4.4**	**186,009**

A problem when making a judgement on these figures however is that there is no benchmark against which to measure these, or indeed any other indicators of congestion on the strategic network at the EU level. A strict comparison against observed flow data is also problematic given the length of some of the links, and thus the varying flow conditions encountered. Nevertheless, some of the over-capacity links were overloaded to a significant degree and it was clear that some measures were required to counter this.

There are two main ways to address this problem (i) by adding more network detail and (ii) adding more intra-zonal links to attract trips off the modelled network within the distribution model.

Adding more network detail is relatively straightforward, as the STREAMS network is based in the IRPUD detailed network, which contains all the major road links in the EU. Areas where the flow / capacity ratio appeared too high were easily identified using the Mapinfo Network Tool developed by ME&P as part of the STREAMS project. Overlaying this on the IRPUD base network, links could be selected to provide additional connectivity and capacity. These selections are stored and converted into the model files. A series of tests were undertaken until virtually all the overloading had been re-routed.

Secondly, the intra-zonal networks were selectively expanded. The intra-zonal network comprises links to ‘dummy’ zones at a distance of 0.6km, 1.97k, 4.7km, 10.6km, 23.4km, 54.6km, and 109.9km. The number of these ‘dummy’ zones connected to the centroid depends upon the size of the zone, based on a radius type judgement – so in the case of the smallest zones, the more distant ‘dummy’ zones are not connected. Experiments were undertaken with the STREAMS model, to connect more of the longer distance ‘dummy’ zones to the zone centroids in the networks. Thus at the distribution stage, trips could use the ‘dummy’ zones and so do not appear on the network.

A combination of these measures leads to a significant reduction in these overloading ‘hot-spots’ and loads on the links in general. Table 2.2 below follows the same format as Table 2.1 and shows the revised figures.

Table 2.2: SCENES test network - modelled roads km by flow / capacity ratio and type

Test / Road Type	**Flow / Capacity (V/C) Ratio**					
% km	**<.25**	**.25 - .50**	**.50 - .75**	**.75 - 1.00**	**1+**	**Length (km)**
1994 Base						
Toll Motorway	85.1	12.9	1.4	0.2	0.5	**29,212**
Motorway	52.2	32.2	11.4	2.9	1.3	**52,172**
Dual Carriageway	80.7	13.9	3.4	1.3	0.6	**36,080**
Other Road	71.9	18.0	5.9	1.6	2.5	**120,713**
Total	**70.5**	**19.9**	**6.2**	**1.7**	**1.7**	**238,177**

It can immediately be seen that the proportion of the link lengths by category which suffer from overloading has reduced significantly. The overall proportion is down to 1.7% of the network. The proportion of links appearing with a V/C ratio of less than .25 has increased from 47% to 71%. The overall scope of the network, in terms of road kilometres has increased significantly, by just over a quarter. Most of this increase is taken up by the 'other road' category, since the vast majority of motorway and dual carriageway links were included in the previous 'strategic' network.

These values are the results of initial testing using the previous STREAMS model and will therefore change as the development of the SCENES model progresses. The road network flows in SCENES will be developed with a view to matching the available observed data, particularly the 1995 UN published traffic flow database.

The 24-hour speed – volume / capacity ratio functions developed in STREAMS are retained for SCENES. A more detailed description of the development of these functions than was reported in STREAMS D8/D10 can be found in Annex A.

Figures 2.1 to 2.4, overleaf show the resulting road and rail networks for use in SCENES. These figures also show the zoning system boundaries for SCENES. They are divided into 'south Europe' and 'north Europe' sections for clarity. The road networks shown include the new links for the CEE countries, and the additional road capacity in the EU. For the road networks (Figures 2.1 and 2.2), the colour coding is as follows:

- Purple – tolled motorway
- Blue – motorway
- Red – dual carriageway
- Green – other road

And in the rail networks (Figures 2.3 and 2.4):

- Red – conventional lines
- Blue – high speed lines

Note that the rail network plots presented here also include planned future rail links.

Figure 2.1: SCENES 1995 Road network – Southern section

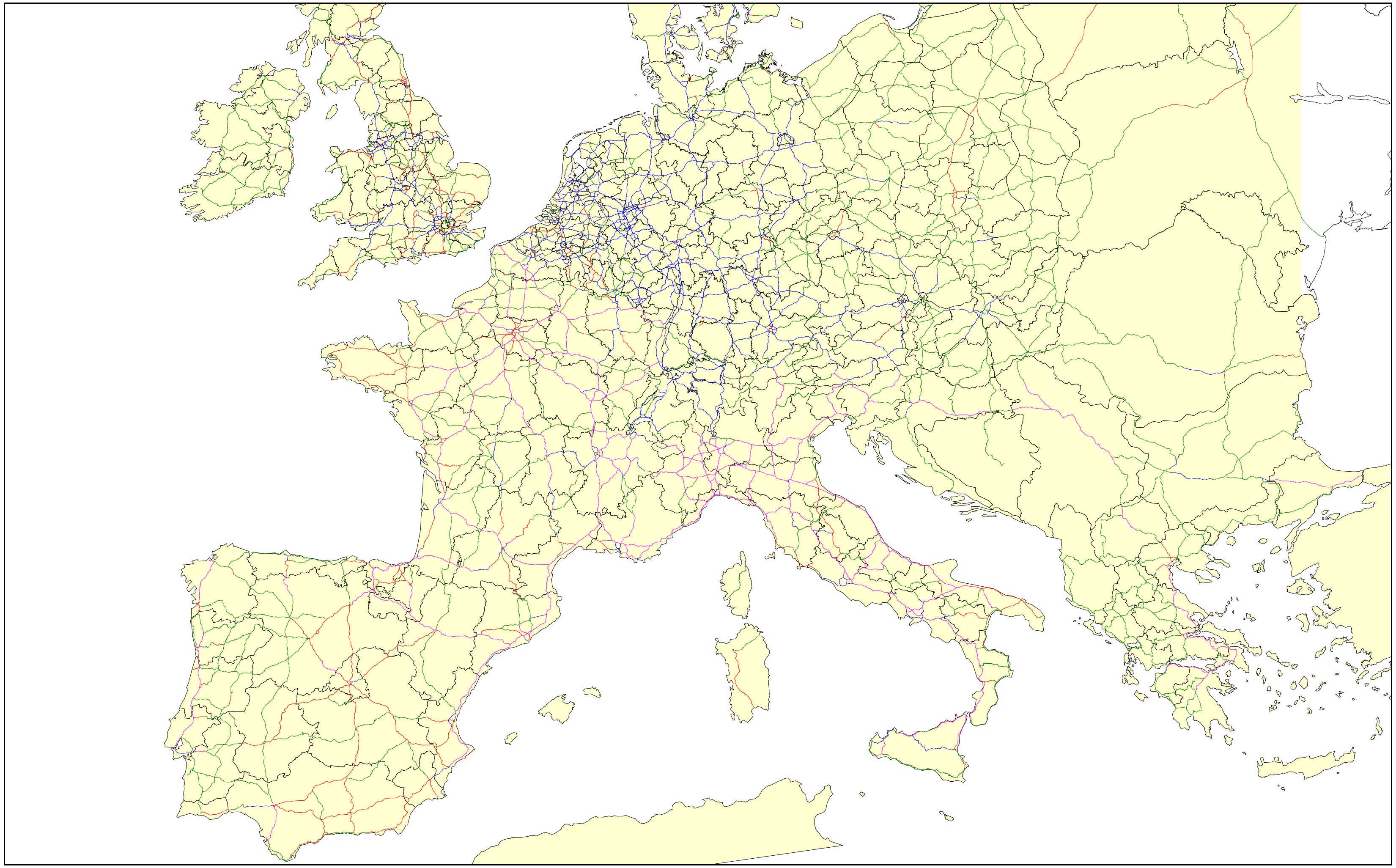


Figure 2.2: SCENES 1995 Road network – Northern section

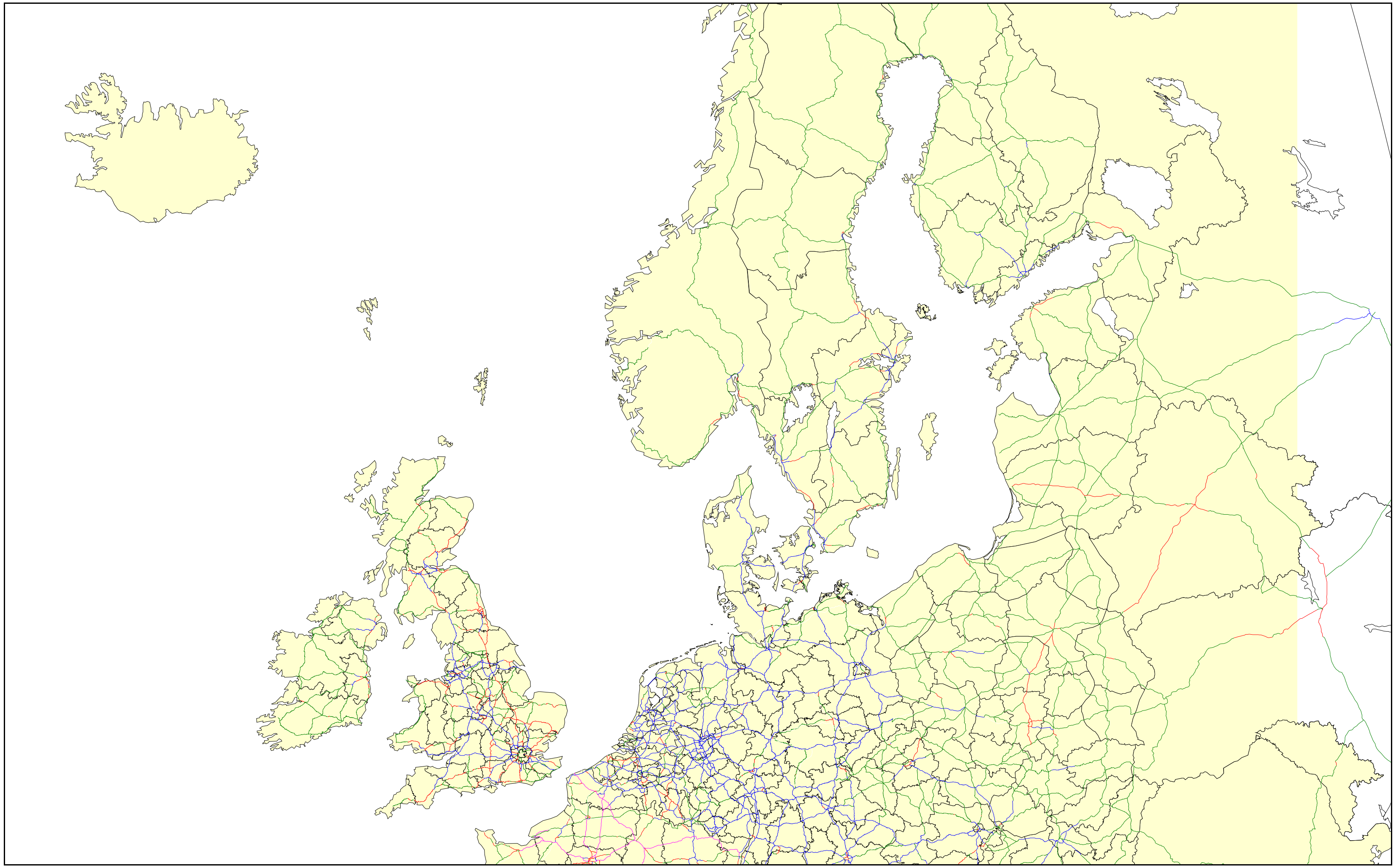


Figure 2.3: SCENES 1995 Rail network – Southern section

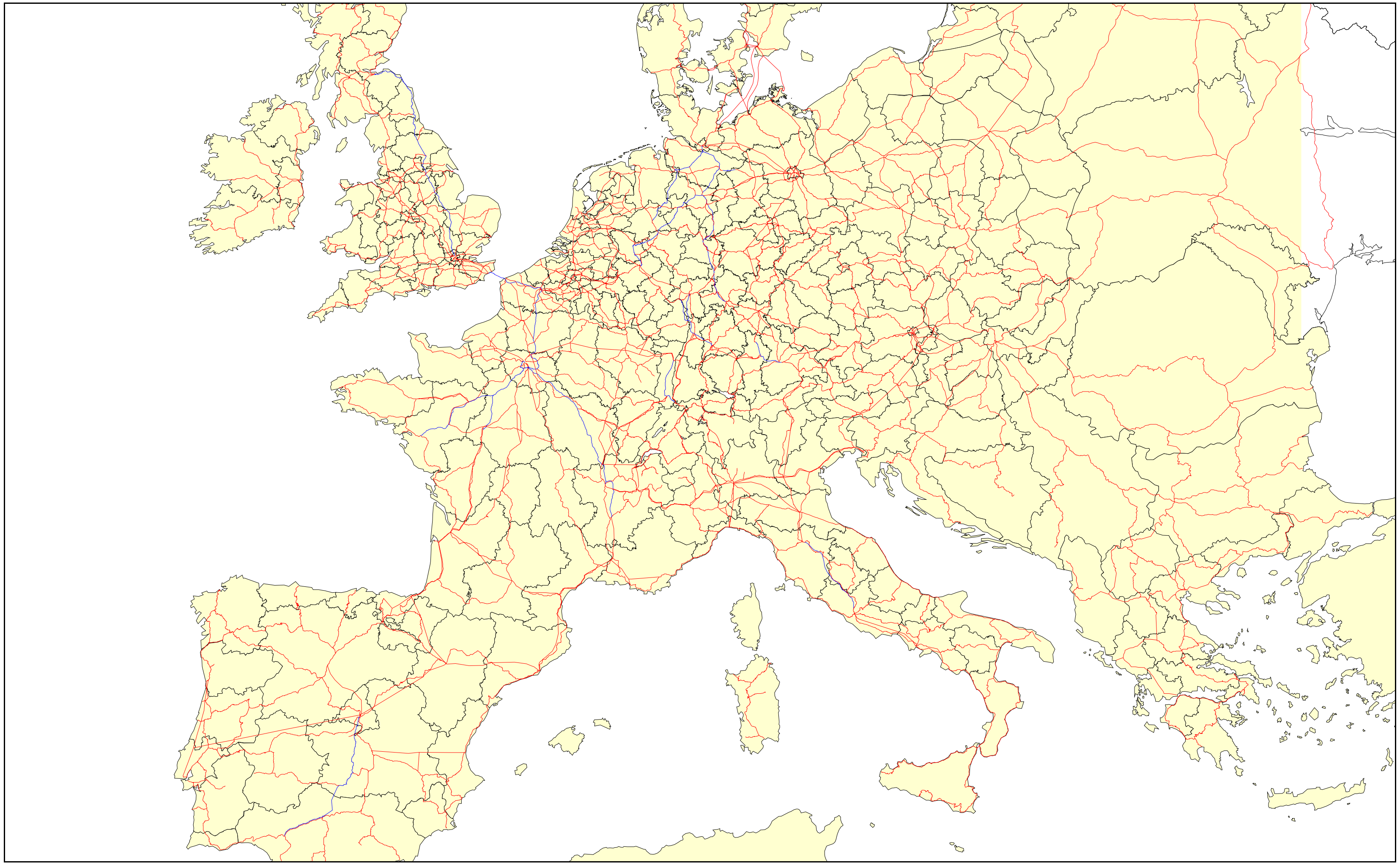
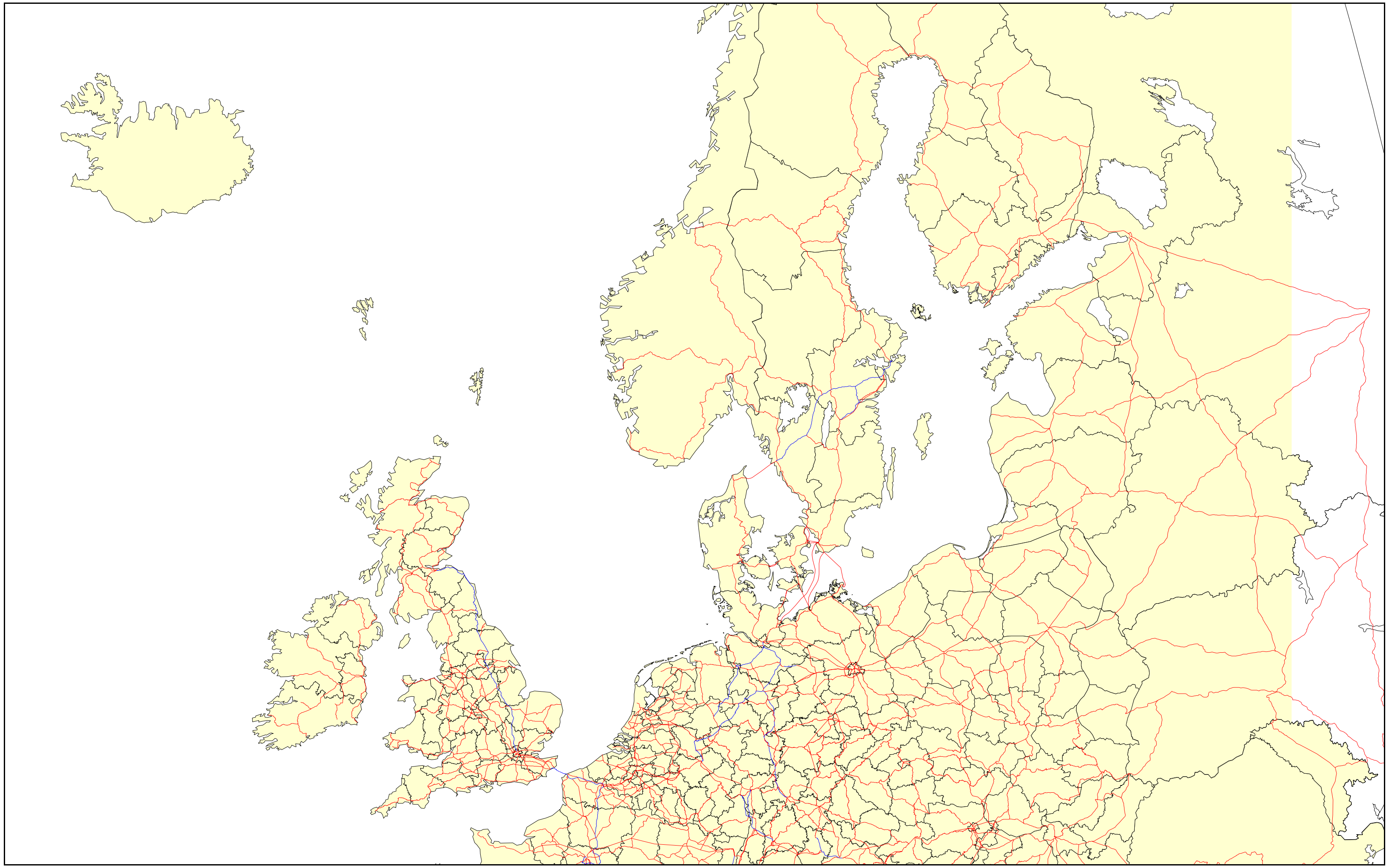


Figure 2.4: SCENES 1995 Rail network – Northern section



2.4 Non-road network capacity issues

It was apparent during the development of STREAMS, that capacity issues for the non-road modes required more detailed consideration, with particular respect to the rail and air modes. The main reason for this emerges when forecasting over a long time horizon, such as 2020. The increase in travel demand in general are great over this time period, so some consideration has therefore to be given to the capacity of these transport systems to cope.

One option is to assume that whatever demand there is for these transport modes will be met by the owners and operators of these infrastructures. This was the approach taken in STREAMS, where the forecasts were effectively pure demand for the rail and air modes. A further option is to construct capacity restraint functions for these modes, which would either create capacity 'caps', or a more elaborate method would be to reflect excessive demand over capacity in terms of some other measure, e.g., increased pricing.

Estimating capacity restraint functions for non-road modes is a very difficult area of work however, as there are a wide range of technological and operational factors which influence ultimate capacity. The data which would be required to account for this range of factors in a detailed manner at the European level would also be considerable. The next two sections discuss the approach taken for the rail and air modes respectively.

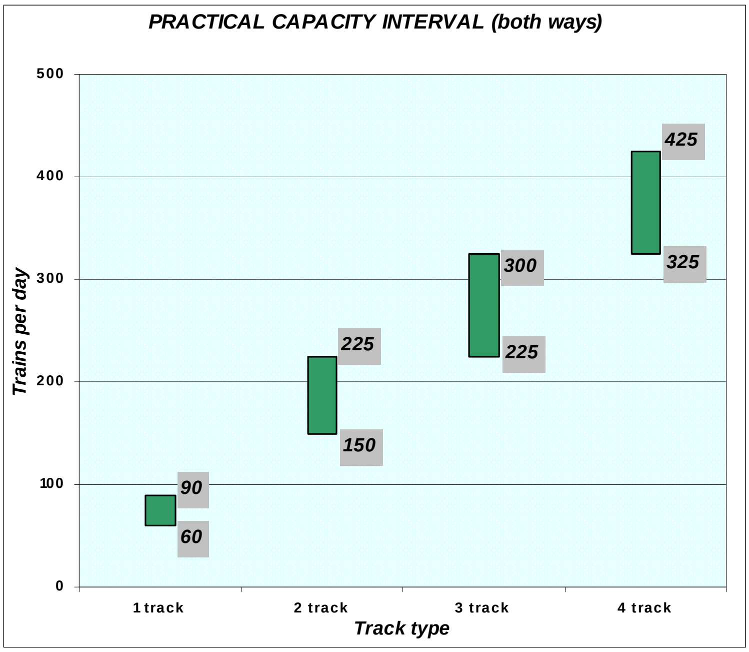
2.4.1 Rail network capacity

Some of the underlying issues regarding the capacity of rail networks were addressed in Annex C in Scenes Deliverable D2. In this section, the implementation issues are outlined. There were two main approaches considered:

- the incorporation of a capacity on each railway link, and the application of capacity restraint functions. In this case, the model reassigns flows in the network until a final balanced situation is obtained; and,
- incorporating a capacity to each railway link, but not applying capacity restrain functions. In this case, the model assigns railway flows in a free flow situation. In the final flow assignment, a comparison between capacity and assigned flows would allow one to obtain certain indicators for the network links. This approach would reveal potential congestion or overloading for the base year calibration and the forecast year.

These two options were considered and the complexities involved in pursuing full capacity – restraint functions were such that the latter option was chosen. It was then established that certain broad capacity ranges for railway links could be established. Consequently, Figure 2.5 below shows the different capacity ranges of railway links by number of tracks. The values which are shown in the Figure are based on estimates by the Batelle Institute. Those figures have been adjusted using data provided by the ECIS work group, and take into account factors such as track infrastructure and superstructure, and traffic composition (mix of passenger and freight trains, train weight and length, traction power, daily distribution etc.).

Figure 2.5: Capacity range of rail links in trains per day (combined direction)



Source: MECSA, based on the information provided by the Batelle Institute and the ECIS work group.

The values shown in the above figure give a useful 'rule of thumb' when considering rail link capacities for the model. After analysing the figures above, the capacity to be assigned to the links by country and by type of rail link (one track, two tracks etc.) can be established. To this end, the information collected in the ECIS Report concerning the 'partial' rail link capacity by certain countries is useful. This 'partial' information confirms the ranges established and provides a good starting point in order to classify the EU countries.

Among the different factors which determine the rail link capacity the 'distance between crossing (and overtaking) stations'[5] is one of the most relevant. It can be assumed that there is a correlation between this variable and the density of the rail network. In this sense the density could be considered as a proxy of the 'distance between crossing station'. Another important factor is the level of technology, which is used in the rail systems for each country. The percentage of single tracks links could be a good way of reflecting the level of use, and hence the technology in place.

Table 2.3 below shows the information collected for these factors by EU country on the basis of which the classification of indicative line capacity by country has been carried out.

[5] *ECIS work group*

Table 2.3: Summary of national railway characteristics

		ECIS 'typical' track capacities (trains / day)				
		1 track	2 track	3 track	Density (1)	% Single Track (2)
Group 1	Germany		196	266	8.55	1
	Belgium	60			9.06	20
Group 2	UK				14.33	24
	Austria	76	193		14.78	45
	Netherlands				14.91	16
	France				17.13	13
	Denmark				18.34	39
	Italy	85	186		18.83	43
Group 3	Portugal		176		32.31	65
	Ireland				36.10	50
	Spain	50	127		41.11	64
	Greece				53.33	100
Group 4	Sweden	55			46.00	71
	Finland	22			57.31	76

(1) Source: EUROSTAT. Units: km^2/km of rail network
(2) Source: SCENES Rail Network (LT)

As it shown in the table above the countries have been classified in four types:

- Group 1**:** High density and good technical level: Germany and Belgium have been included in this group. They are countries with a high density rail network and in which the percentage of the single track links is low;
- Group 2: Medium density and good technical level: Countries like UK, Austria, The Netherlands, France, Denmark and Italy are part of the group. All of them have a medium density rail network which vary from the UK (the highest density within the group) to Italy (the lowest one). Furthermore the percentage of the single track links varies in a wide range although all of them are below 50% of single track;
- Group 3: Low density and medium technical level: Ireland and certain Mediterranean countries could be incorporated in the third group. The countries included in this group have a low density rail network and the percentage of single track links is high (except in Ireland); and,
- Group 4: Low density and medium technical level (Northern Countries). The last group includes the Nordic countries like Finland and Sweden. In these countries the density of the rail network is high as well as the percentage of the single track links.

Considering the classification proposed above and the information provided by the ECIS report concerning the capacity of certain rail links by country (shown in the table above), Table 2.4 below suggests a practical capacity by link type (single, double track etc.) established by country.

Table 2.4: Suggested practical capacity of railway links in trains per day by country by type of track (both ways)

	Country	1 Track	2 Track	3 Track(1)
Group 1	**Germany**	90	200	300
	Belgium	90	200	300
Group 2	**UK**	75	190	280
	Austria	70	180	260
	Netherlands	75	190	280
	France	75	190	280
	Denmark	70	180	260
	Italy	70	180	260
Group 3	**Portugal**	60	150	-
	Ireland	60	150	-
	Spain	60	130	-
	Greece	60	120	-
Group 4	**Sweden**	60	120	-
	Finland	60	120	-

(1) Only for the countries with more than double track rail links

Ideally, these capacities could be implemented in the networks using a 'difficulty' function to represent conditions as they get close to capacity. However, obtaining data relating to the number of tracks by rail link at the European level has not proved possible. The network data collated by IRPUD only differentiates between single and multiple track. This is not enough to sensibly implement a system within the model.

The alternative approach of using these values as 'rules of thumb' or guidelines when examining model output is used. The average train occupancy levels shown below in Table 2.5 are used to translate passengers and tonnes to units of trains for assignment to the model.

Table 2.5: Train & tonne / passenger km movements in EU countries, 1996

		Passenger				**Freight**		
Country	**Railway**	**Train km**	**Pass km**	**Ave. Dist.**	**Pass / train**	**Train Km**	**Tonne km**	**Tonnes / train**
	Company	(10^3)	(10^6)	(km)		(10^3)	(10^6)	
GB	**BR**	372,200	29,216	40.7	78.5	39,500	12,537	317.4
LU	**CFL**	5,843	286	25.5	48.9	1,365	566	414.7
GR	**CH**	16,381	1,568	136.6	95.7	1,728	313	181.1
IE	**CIE**	8,930	1,291	47.6	144.6	4,417	602	136.3
PO	**CP**	29,495	4,809	26.1	163.0	7,704	2,343	304.1
DE	**DB AG**	640,400	60,514	45.4	94.5	216,041	70,523	326.4
DK	**DSB**	51,937	4,784	34.1	92.1	7,490	1,989	265.6
GB	**EPS**	50	18	114.0	360.0			
GB	**Euro-tunnel**	2,492	182	58.0	73.0			
IT	**FS**	256,165	49,700	107.5	194.0	68,890	25,114	364.6
GB	**NIR**	3,553	232	35.8	65.3			
NL	**NS**	108,089	13,977	45.9	129.3	9,705	3,097	319.1
AT	**ÖBB**	88,239	9,628	49.6	109.1	39,813	14,015	352.0
ES	**RENFE**	121,133	15,313	41.9	126.4	39,940	11,489	287.7
SE	**SJ**	61,259	6,219	63.2	101.5	39,086	19,008	486.3
BE	**SNCB/NMBS**	70,281	6,757	46.9	96.1	17,270	8,667	501.9
FR	**SNCF**	307,774	55,319	75.7	179.7	142,806	49,840	349.0
FI	**VR**	24,974	3,184	71.7	127.5	15,998	9,609	600.6

Source – UIC (1995)

2.4.2 Air network capacities

Similar (if not more complex) issues to the coding of rail capacity arise when considering the treatment of capacity in the air supply side. Runway capacity, terminal capacity and air traffic control technology, limits on flying by time of day etc., will all play a role in determining the ultimate capacity of the air network.

Annex B of Deliverable D2 considered this issue in some detail and provided an overview of the trends in the demand for air travel. As with rail, it has not proved feasible to incorporate capacity formally within the air transport networks. However, the model outputs and forecasts by zone can now be placed in the context of the available data obtained relating to airport capacity and airport demand in the base year (ATAG, 1998). This will highlight areas of exceptional growth or otherwise within the model forecasts.

2.5 Revised specification of passenger intra-zonal network characteristics[6]

For the SCENES network, the intra-zonal network representation has been improved with the availability of extensive detailed data from the UK national travel survey. This data is concerned with the typical times taken for journeys of different distances, by different modes and in different settlement types. The details of these journeys are split between in-vehicle time (known as travel speeds) and the time for the entire trip (known as journey speeds). The detailed nature of the data, in terms of identifying the main characteristics of different journeys makes it a good starting point for modelling intra-zonal trips in SCENES. Adjustments can be made to these starting figures to reflect different national characteristics, where these are thought to differ significantly. Given that intra-zonal passenger trips account for around 94% of all passenger trips in the model, it is important to make this part of the model as accurate as possible, in order to ensure that the whole travel picture is realistically represented.

In STREAMS the specification of the actual local networks was fairly basic, although the idea of treating intra-zonal trips in this way was new. As explained above, each zone centroid is linked to a number of 'dummy' zones depending on the zone size. The links to these dummy zones represent trips of different distances, and the characteristics of travel on these links vary. The main determinant of this variation is the zone type, of which there were six in STREAMS representing different urban settlement types or rural areas. This categorisation is as follows:

The descriptions of the zone types are:

Type 1: Large, stand-alone metropolitan centres such as Madrid, London, Brussels, Wien, Athens, and Paris. In these zones the vast majority of the population live in the continuous urban area itself. These all have an urban rail or metro system. The metropolitan population is at least 2 million.

Type 2: Metropolitan areas plus hinterlands, such as Rhone-Alps (Lyon), Cataluña (Barcelona), Lazio (Roma), and Vatsverige (Goteborg). In these zones outside the large metropolitan area there is a substantial surrounding region which contains a significant non-metropolitan population.

Type 3: High density urbanised areas such as West Yorkshire, Pais Vasco and Central Germany where there are a collection of medium to large cities adjacent to one another within which the majority of the population reside.

[6] A new specification for the treatment of freight intrazonal traffic is detailed in Section 5.2.4.

Type 4: High density dispersed areas such as the south of England outside London and parts of the Benelux countries. Here although the population density is reasonably high, there is not a major city but rather a set of small to medium sized cities close together. These would not have major flows by rail within the zone, but might have rail to neighbouring zones.

Type 5: Medium density regions such as those areas in France, Northern Germany where there are well dispersed small to medium sized cities.

Type 6: Low density regions such as in Finland, Northern Sweden, West of Ireland where there are few large towns and the majority of the population live in small towns or rural areas.

This classification is carried forward into SCENES, with the CEE countries' zones now also being classified in this way.

As far as the distribution element of the model is concerned, these 'dummy' zones are no different from conventional zones. Trips are therefore assigned to the dummy zones based on the disutility of travel and their attractiveness, as with any other zone. Constraints are applied in the base year to ensure that the correct number of trips are assigned at each of the distances – these values can be derived from observed NTS data from several countries. The influence of this constraint is carried forward in the form of a residual disutility to the forecast years.

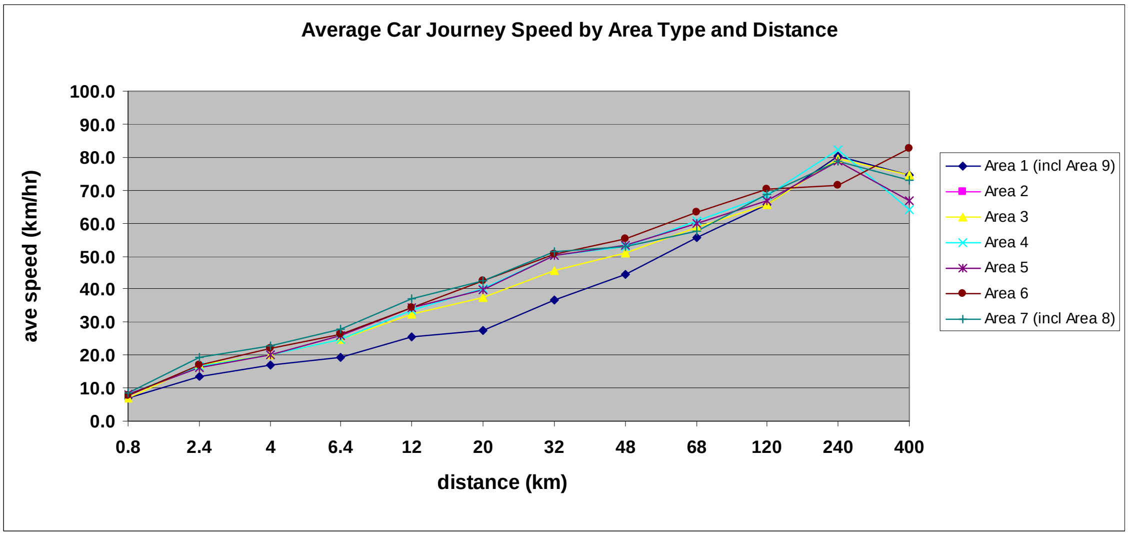
In STREAMS the coded intra-zonal network speeds by mode varied by the six settlement types. Capacity restraint is not applied in the intra-zonal networks. The availability of significant urban rail systems also varied by zone type. The coding of varying terminal costs and times was also used to represent the different supply conditions faced by the traveller (e.g., bus waiting times etc.). Importantly, though, the coded speed on the links did not vary with the distance travelled. Also, much of this formulation was based on fairly limited observed data. This set-up was used principally to ensure that the modal split patterns were in line with observed data for the different settlement types.

For SCENES, more detailed UK national travel survey data was obtained. This is shown in the following three figures, which give the average journey speed by distance and settlement type, for car, bus and rail respectively. The nine area types which are referred to in the key are as follows:

> Area 1 – Inner London, Area 2 – Outer London, Area 3 – Metropolitan Area, Area 4 – Urban big (>250k), Area 5 – Urban large (100-250k), Area 6 - Urban medium (25-100k), Area 7 - Urban small (<25k), Area 8 – rural, Area 9 – central London

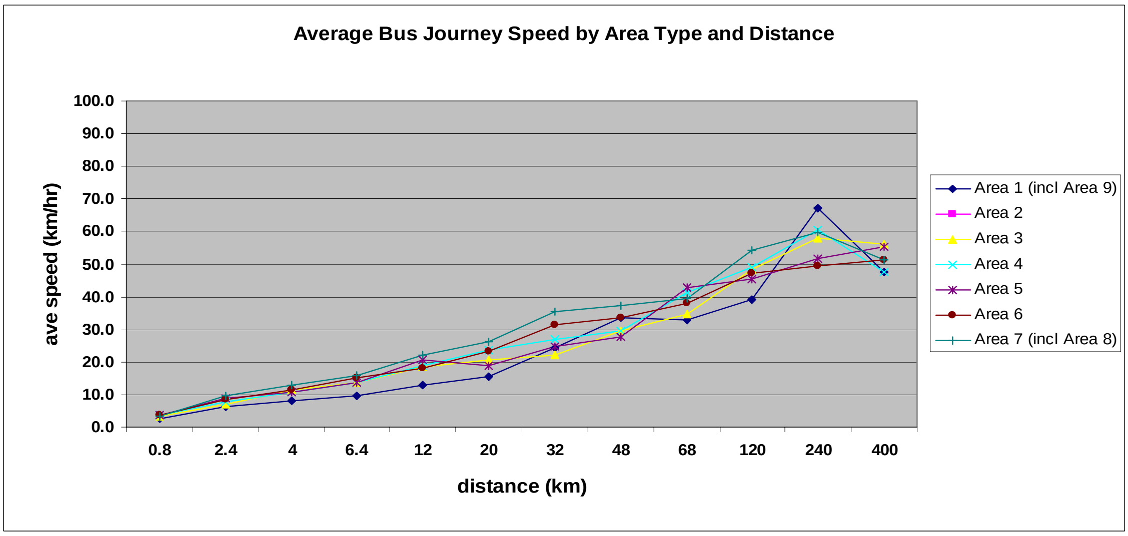
The main relationships between speed, journey distance, and settlement type found in the observed data (and shown in the following three figures) are therefore incorporated in the SCENES model set up for intrazonal trips.

Figure 2.6a: Observed car journey speeds by area type and distance



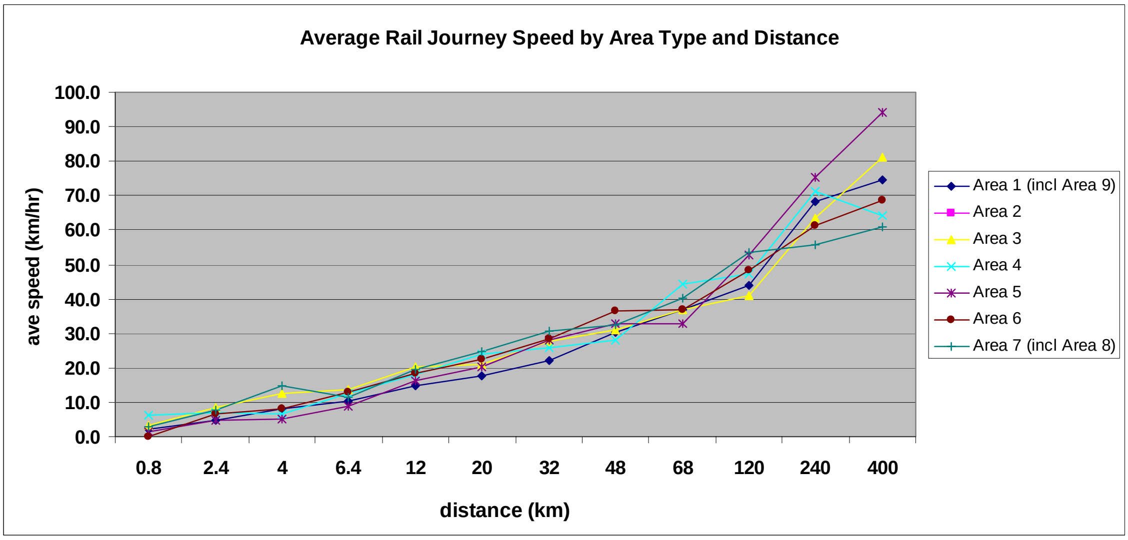
Looking at trips made by car, the average journey speed clearly increases with the length of the trip. The average speed at any given distance also increases as the settlement size declines, although this effect is perhaps not as pronounced as might be expected, with the exception of the Area 1 / Area 9 combination, where the speeds are significantly lower.

Figure 2.6b: Observed bus journey speeds by area type and distance



It can immediately be seen that bus journey speeds are much lower than car journey speeds. A similar pattern emerges in terms of the speeds between the area types.

Figure 2.6c: Observed rail journey speeds by area type and distance



Surprisingly, looking at rail journey speeds, they are not on the whole faster than the bus speeds. Only over the longer distances does rail overtake bus in terms of average journey speeds. This may reflect the longer access / egress time in terms of access to railway stations.

This observed data is also available in the form of average travel speeds (in-vehicle time only). Using both sets of data as a base, it is possible to re-configure the data in line with the SCENES dummy zones (or distance band) distances. It is also possible to make some assumptions about the correspondence between the UK 'area type' definitions and the SCENES zoning classification.

This results in the first instance in a set of in-vehicle speeds, by mode, by distance band for each of the zone types. This speed is coded directly onto the intra-zonal links in the network – each link represents a trip within a certain 'distance band' in a certain zone type. Terminal times (which represent walk / wait / park times) are then used to adjust (i.e., to reduce) the in-vehicle time to the overall journey time. Again values are obtained by mode, by distance band and by zone type. These values are coded into a separate file. In this way the true characteristics of the journeys by mode, distance and zone type are encapsulated in the model structure.

Figures 2.7a and 2.7b below show the resulting journey speeds for the car and bus modes. For rail, as this mode applies to only three zone types, the travel and journey speeds are shown for extra clarity in Figure 2.7c. This demonstrates the difference between considering in-vehicle speeds only and whole journey speeds.

The charts follow the same general pattern as the observed, with speeds increasing as the urban size reduces. It is perhaps surprising that the average speeds of public transport trips do not reduce as the zone types become less urban in nature. This reflects the conditions encountered by the travellers in the NTS – rather than reflecting availability. It does not therefore reflect 'average' conditions for all travellers. It is important though to input these characteristics into the supply side of the model. Other model parameters are used in the model calibration process to represent the varying availability and attractiveness of the modes between the different zone types. This is required in order to model the modal split by zone type and indeed country correctly.

Figure 2.7a: Intra-zonal journey speeds by Zone Type and distance band - Car

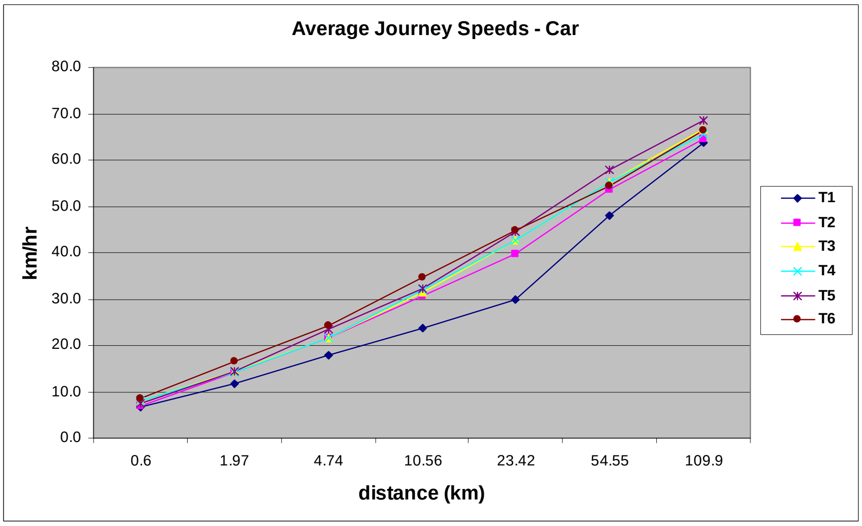


Figure 2.7b: Intra-zonal journey speeds by Zone Type and distance band - Bus

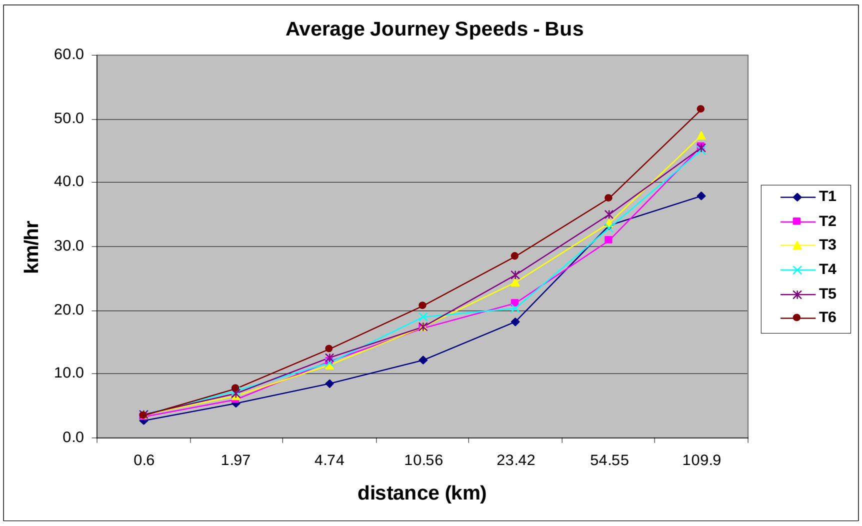
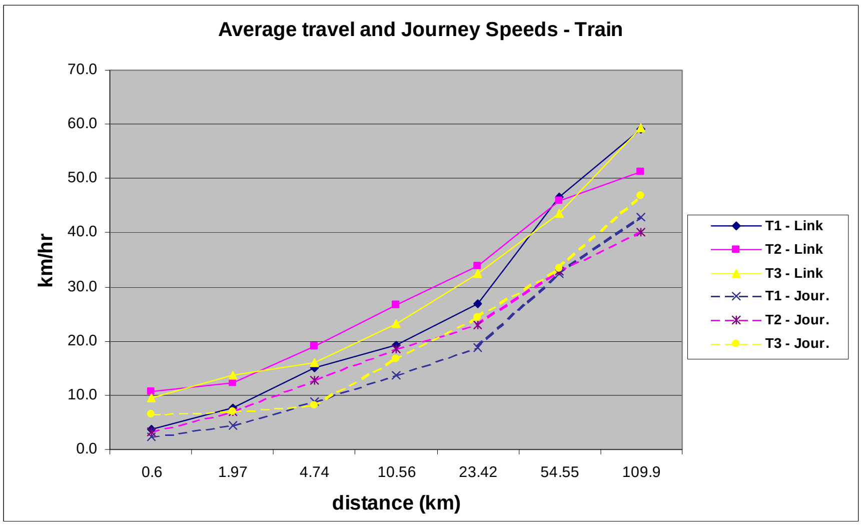


Figure 2.7c: Intra-zonal travel and journey speeds by Zone Type and distance band - Train



The following tables show the terminal costs and times which have been derived to act in tandem with the link (or travel) speeds, in order to obtain the correct overall journey time. Table 2.6, details the terminal costs and times for car trips.

Table 2.6: Intra-zonal terminal times (minutes) - Car

	Zone Type					
Km	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
0.6	0.6	0.7	0.3	0.2	0.4	0.4
1.97	1.0	0.6	0.4	0.4	0.5	0.5
4.74	1.1	0.6	0.6	0.9	0.5	0.6
10.56	1.8	0.6	0.6	0.6	0.7	0.6
23.42	1.8	1.2	1.1	1.2	1.2	1.2
54.55	3.6	1.8	1.8	1.2	1.3	2.4
109.9	3.3	3.0	3.0	3.4	2.4	4.2

In all cases, the terminal times for car are small (under five minutes for all). They increase slightly as the distance increases for all zone types, perhaps indicating that longer and thus less frequent journeys have less certainty in tems of parking at the destination end, although the effect is modest. Table 2.7 Shows the same data for the bus mode.

Table 2.7: Intra-zonal terminal times (minutes) - Bus

	Zone Type					
Km	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
0.6	5.7	4.2	3.3	3.0	2.7	3.0
1.97	8.1	7.8	4.8	4.8	4.5	4.2
4.74	10.8	6.0	5.7	6.0	4.2	4.2
10.56	15.0	7.2	6.6	6.0	6.0	4.8
23.42	16.8	10.8	8.7	15.6	7.8	6.0
54.55	12.0	22.2	9.9	12.6	10.2	10.8
109.9	21.0	21.0	10.8	14.4	22.8	13.8

It is interesting that bus terminal times decrease as the size of the urban settlement decreases, in virtually all cases. This may refelct that where services are less frequent, passengers are required to know bus times, rather than simply turning up and waiting, as would be the case on the majority of occassions in urban areas. In all cases, these values are greater than those of car however, since they incorporate walk and wait times. Finally, Table 2.8 Gives the equivalent values for rail trips.

Table 2.8: Intra-zonal terminal times (minutes) - Train

	Zone Type					
Km	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
0.6	6.0	7.8	1.8	-	-	-
1.97	12.0	7.2	8.4	-	-	-
4.74	13.2	7.2	16.8	-	-	-
10.56	13.2	10.5	10.8	-	-	-
23.42	22.2	19.8	14.4	-	-	-
54.55	30.6	28.2	22.8	-	-	-
109.9	42.0	35.4	30.0	-	-	-

Looking at the rail mode, terminal times are generally greater than equivalent bus times, perhaps reflecting the lower frequency overall. The longer distance trips with the higher values probably reflect wait times when changing between trains.

These speeds and terminal times therefore form the basis of the supply characteristics of the intra-zonal network. Other model parameters, such as mode specific constants are used to calibrate the model, but these values will be fixed as model inputs.

3. Developments in the passenger model

3.1 Introduction

The structure of the passenger model remains fundamentally the same as that used in STREAMS, with a number of enhancements. The overall model comprises two main 'modules' linked by an interface, known loosely as the 'land-use model' and the 'transport model'. These two modules comprise firstly, trip generation and distribution, and secondly, modal split and assignment. Each component, and the overall system works in an iterative fashion. In this sense, the model has a fairly traditional structure. The only 'feedback' between the transport and land-use models is that the transport costs and times (translated into 'disutility' feeds the distribution model therefore affecting destination choice, and length of trip. It has no effect however on the generation or suppression of the number of trips.

Chapter 3 documents the developments to the STREAMS passenger model, both in terms of the revised data which is used in the EU countries, and also the entirely new data which is required for the CEE countries. The inputs break down into the following broad areas:

- Zonal demographic / socio-economic data, and car stock data;
- Refinement of trip type definitions and zonal 'attractors';
- International tourism trips;
- Value of time data by country;
- Car operating costs by country;
- Rail and inter-urban coach tariff data by country; and,
- Local public transport tariffs by country.

Each of these is considered in the following sections.

3.2 Establishment of new base year demographic / socio-economic data

As with STREAMS, the SCENES model requires a detailed zonal level segmentation of the population. There are two segmentations, based firstly on age and employment status (five groups), and secondly on household composition and car ownership (four groups), giving twenty population groups for each zone. The first segmentation is input directly to the model and the second is estimated within the model structure (using 'observed' data as a starting point). The required groups are:

- persons under 15 years old (P1);
- persons aged 15-64, employed full time (P2);
- persons aged 15-64, employed part time (P3);
- persons aged 15-64, not in employment (P4); and,
- persons aged 65 and over (P5).

The majority of these data, relating to 1995, were obtained for the EU directly from Eurostat. Some problems were encountered however, where the NUTS2 classification had changed to reflect new local government boundaries. Some estimates were required for these zones based on the previous years' data. Car stock data was available by zone from the same source.

Population by age group at the zonal level was obtained for the CEE countries based on material reported in SCENES Deliverable D1 (CEEC Data and Method). The split of working age population between 'employed' and 'not in employment' was estimated based on labour force, labour force participation, and unemployment data for each of the eight countries. In some cases, this data was available from the D1 material, in others it was obtained from statistical yearbooks, or national statistical websites. The real difficulty here is in obtaining these data at the zonal level and for a year in the region of 1995. The split between part and full time employment is really only available at the national level, and only for some countries, from OECD sources. Estimates are made for counties where no data was found, based on figures in countries with similar characteristics.

The number of cars per zone can be obtained from the SCENES Internet Database for each of the CEE countries. In some cases these figures relate to later years, and have been factored back to 1995 using assumed rates of growth. These figures can be thought of as being reliable however. Table 3.1 below shows a summary of the demographic data by country. The complete zonal data can be found in Annex B.

Table 3.1: Summary of SCENES 1995 model input demographic / socio-economic data

Country	P1 (<15)	P2 (FT emp.)	P3 (PT emp.)	P4 (not emp.)	P5 (>65)	Total
Austria	1,415.60	3,125.63	503.87	1,783.10	1,211.60	8,039.80
Belgium	1,826.70	3,255.63	513.47	2,938.50	1,596.20	10,130.50
Germany	13,294.10	29,673.64	5,783.76	20,245.80	12,495.90	81,493.20
Denmark	900.90	2,023.27	556.23	936.70	798.60	5,215.70
Spain	6,306.70	10,571.76	849.04	14,152.50	5,755.00	37,635.00
Finland	972.10	1,760.71	233.39	1,412.20	720.20	5,098.60
France	11,386.00	18,501.18	3,428.72	16,021.90	8,682.30	58,020.10
Greece	1,785.40	3,515.51	176.29	3,360.90	1,604.60	10,442.70
Ireland	887.10	1,080.53	148.07	1,067.50	411.50	3,594.70
Italy	8,620.60	18,393.42	1,248.88	19,605.10	9,400.70	57,268.70
Luxembourg	74.60	148.27	12.73	114.60	56.40	406.60
Netherlands	2,893.80	4,326.77	2,483.93	3,886.00	2,047.70	15,638.20
Portugal	1,668.50	3,730.05	297.35	2,347.80	1,371.30	9,415.00
Sweden	1,662.70	3,048.76	1,015.04	1,550.40	1,539.40	8,816.30
UK	11,360.20	19,550.89	6,414.44	12,651.01	9,214.56	58,500.40
EU15	**65,055.00**	**122,706.02**	**23,665.21**	**102,074.01**	**56,905.96**	**369,715.50**
Czech Rep	1,893.26	4,799.70	311.80	1,944.31	1,372.28	10,321.34
Estonia	288.83	557.02	44.33	370.83	201.43	1,462.43
Hungary	1,806.00	3,247.77	189.02	3,902.21	846.00	9,991.00
Lithuania	787.69	1,522.44	121.16	817.73	460.49	3,709.50
Latvia	495.19	968.89	77.11	602.28	348.54	2,492.00
Poland	8,446.12	13,845.77	1,641.67	9,303.95	5,401.84	38,639.34
Slovenia	346.72	712.71	37.51	736.46	157.60	1,991.00
Slovak Rep.	1,130.79	2,034.44	132.16	1,469.72	603.89	5,371.00
Study Total	**80,249.59**	**150,394.75**	**26,219.98**	**121,221.49**	**66,298.02**	**443,693.12**

Note that the populations in the above table exclude non-continental European populations for some countries such as Spain (Canary Islands) and Portugal (Azores, Madiera).

Table 3.2 below, shows a summary of the car stock, population and thus cars / 1000 rate for each of the SCENES internal countries. The full input data set at the zonal level can again be found in Annex B.

Table 3.2: Summary of SCENES 1995 model input – car stock data

EU Country	Cars (10^6)	Pop. (10^3)	Cars / 1000	CEE Country	Cars (10^6)	Pop. (10^3)	Cars / 1000
Austria	3.589	8040	446	**Czech Rep.**	3.008	10321	291
Belgium	4.273	10131	422	**Estonia**	.383	1462	262
Germany	40.384	81493	496	**Hungary**	2.277	9991	228
Denmark	1.674	5216	321	**Lithuania**	.717	3709	193
Spain	13.586	37635	361	**Latvia**	.331	2492	133
Finland	1.900	5099	373	**Poland**	7.509	38639	194
France	24.538	58020	423	**Slovenia**	.699	1991	351
Greece	2.205	10443	211	**Slovak Rep.**	1.108	5371	206
Ireland	.989	3595	275				
Italy	30.150	57269	526				
Luxembourg	.229	407	563				
Netherlands	5.632	15232	370				
Portugal	3.751	9415	398				
Sweden	4.191	8816	475				
UK	21.462	58500	367				

There are a number of discrepancies between the cars / 1000 persons data shown in Table 3.2 above, when compared with the DGTREN EU Transport in Figures Statistical Pocket Book (January 2000 edition) for EU countries. For the CEE countries the car stock figures agree with the Pocket Book. The discrepancies are now considered in turn.

For France, the DGTREN figure is 478 cars / 1000 compared with 423 cars / 1000 persons above. The DGTREN car stock figure is 27.8 million, compared to 24.5 million in the zonal data received from Eurostat. The SCENES Internet Database reports that there were 28.5 million in 1998.

The figures for Portugal are also out of line. The statistical pocket book reports 258 cars / 1000 for 1995 compared to 398 cars / 1000 derived above. In this case, the car stock reported in the pocket book is 2.6 million which seems very low when compared with the figure of 3.7 million, received from Eurostat (this value is also reported in the SCENES Internet Database).

The other main difference is seen for Sweden. The car stock figure in the pocket book is 3.6 million, which compares with a figure of 4.2 million obtained from Eurostat. The SCENES Internet Database reports figures from SIKA / SCB (the Swedish statistical office) of 3.8 million for 1998/99, so here the Eurostat figures look out of line.

In the absence of any definitive explanation, the figures which were received directly from Eurostat for 1995 at the zonal level are used as model inputs.

3.3 Refinement of trip type definitions and zonal 'attractors'

There have been some detailed changes to the definition of trip types for the SCENES model. These changes affect international tourism trips in particular. International charter holiday trips have been merged with international holiday trips, and a new category of international business trips (incorporating at least one overnight stay) has been added. This latter group will form a new flow in the transport model. New trip rates are required for this re-definition (based on tourism data), and these are discussed in Section 3.4 below. A trip rate is required for each of these purposes, for each of the twenty population groups detailed above.

Zonal attractors are used in the distribution model, in combination with travel disutilities, to establish the matrix of passenger trips for each of the travel purposes. Different attractors are used for different trip types as measures of a destination's attractiveness for that particular type of trip.

The full revised list of trip types and attractors is therefore as follows:

- commuting and business – short (approximately < 40km), total national employment split to zonal level using GVA;
- shopping, personal business, and education – short, full-time employed persons by residence;
- visiting friends and relatives, entertainment and day trip – short, total population;
- visiting friends and relatives, entertainment and day trip – long (approximately > 40km), total population;
- day trip, shopping, personal business, and education – long, , full-time employed persons by residence;
- business and commuting – long, GVA;
- domestic holiday – long, country level tourism arrivals split to zonal level using total bed-spaces;
- international business (1+ overnight stay), GVA; and,
- international holiday, country level tourism arrivals split to zonal level using total bed-spaces.

The 'short' and 'long' denominations are necessary to obtain the correct spread of trips by purpose over different distances.

The Gross Value Added data were obtained from the SCENES Internet Databank. In virtually all cases, the data was available at the zonal level. The data for the UK had to be obtained for the UK Office of National Statistics, due to the reorganisation of the NUTS2 zoning system. For the EU, the total employment data used came from the Eurostat figures obtained for the project. For the CEE countries, the employment data used came from the figures which were reported in Table 3.1, above.

Zonal bed-space data were also obtained from the SCENES Internet Databank – this was supplemented by data from national statistical websites where such data were available. Some gaps in the data are still apparent though – assumptions had to be made for the Czech and Slovak Republics for example. International tourism arrivals data comes from World Tourism Organisation (WTO) sources. This is elaborated upon below.

3.4 International tourism trips

Obtaining good data relating to international trips is particularly important for a model of the scale of SCENES. The key definitional issue here is that this section refers to tourism trips – which are defined as any international trip (of any purpose) away from the normal country of residence, which involves at least one overnight stay (WTO definition). This aspect of the model is important for two main reasons – obtaining international trip rates by purpose (leisure / business), and creating a matrix of observed international travel data for the model to 'match' in the base year.

Regarding the first point, this is particularly relevant given that the evidence suggests that the nature of international travel varies greatly by country, much more so than for other types of trips. For example holiday taking patterns vary between generally 'stay at home' southern countries and 'sun-seeking' northern European countries, so it is not possible to assume a near uniform pattern of behaviour across all countries. The addition of the CEE states adds further to the requirement to have country specific trip making characteristics based on observed data.

On the second point, the model requires an 'observed' matrix of international trips to act as a 'fixing point' in the base year calibration. This is required because of the variety of non-transport factors which influence international travel patterns such as weather and cultural association. The model creates a matrix of residual disutilities which it uses to match the observed matrix in the base, and carries this influence forward into the forecast year runs. This process can operate on partial matrix data but clearly the more cells of the observed matrix are filled, the more satisfactory the resulting matrix will be.

The principal source of tourism data is the World Tourism Organisation. Through their various publications and via there (by subscription) website, a good start can be made on assembling an observed data set. There are many inconsistencies however, and some countries count same day visitors as well as tourism trips which makes the data useless in this context. Also the scope of SCENES is greater then STREAMS in that passenger trips to the external zones are now included, so there are many more cells in the matrix. Where possible, gaps in the data are filled using data from national sources, although again there can be consistency problems.

A good starting point is the total world tourism arrivals and departure by country. These are shown in Table 3.3 below. These figures are the total number of person trips per year to / from each country.

Table 3.3: Total world arrivals and departures by country, 1995 WTO / OECD figures

Country	Total World Tourism Arrivals	Total World Tourism Departures
Austria	17,173,000	12,688,000
Belgium	5,560,000	10,494,203
Germany	14,847,000	73,443,000
Denmark	1,614,000	4,846,874
Spain	39,324,000	12,644,000
Finland	1,779,000	3,318,449
France	60,110,000	20,211,000
Greece	10,712,000	1,835,338
Ireland	4,821,000	3,177,220
Italy	31,052,000	15,989,000
Luxembourg	767,000	3,074,406
Netherlands	6,574,000	19,047,000
Portugal	9,706,000	2,523,475
Sweden	2,310,000	6,631,415
UK	24,008,000	43,109,411
Czech Republic	16,500,000	1,465,474
Estonia	530,000	599,105
Hungary	20,690,000	3,385,579
Lithuania	211,000	1,438,073
Latvia	200,000	693,510
Poland	19,200,000	6,278,937
Slovenia	732,000	847,692
Slovak Republic	903,000	1,208,169
Study Area Total	289,323,000	248,949,330

Source: WTO

It is clear from this table that the pattern of international travel is highly asymmetric. The grey shading indicates whether a country is a net receiver or provider of tourism trips. France remains the World's largest tourism destination, whilst Germany is by far the largest provider or out-going international tourism trips. Other major net receivers are Spain, Greece, Portugal, and Czech Republic, Hungary and Poland amongst the CEE countries. Overall it can be seen that the countries in the study area are net recipients of tourism trips from the rest of the World, when considered in total.

Looking at trip rates firstly, the objective is to divide the overall international tourism trips per person per country into business and leisure trips, given their markedly different characteristics. The problem here is that there are no data sources which can be used directly and consistently to produce this data.

One source which was used in part in STREAMS, was the Eurobarometer Number 48 which reports a survey of Europeans and their holiday taking habits, which was undertaken by INRA (Europe) as part of a series of public opinion surveys. A copy of the full report was obtained for SCENES, which offered a great deal more than the Executive Summary report which was available to STREAMS. This survey provides some indication of the main trends in terms of the amount of international and domestic holiday taking by EU country, and their favoured destinations. This survey can therefore be used as a basis for obtaining trip rates for both domestic and international holidays.

Some further limited data was obtained from various websites regarding the extensive surveys undertaken by the European Travel Monitor (ETM). This organisation undertake very comprehensive surveys of European travel behaviour, but to purchase the reports in full is prohibitively expensive. Some results are available through 3rd parties and summary reports however. Again the problem of consistency arises between the ETM figures and the WTO figures.

The general approach is as follows. The proportion of the population who took a 'holidays' in the surveyed year (by origin country) can be taken directly from the Eurobarometer. The survey also provides some details of the proportions of persons taking 2nd, 3rd etc. holidays per year. Therefore the total number of surveyed person holidays per country is established, and is classified by the duration of the holiday. For holiday trips of four nights or more only, for each origin country, the destination in terms of 'own country', 'other EU', 'other European' and 'rest of World' can be obtained. This categorisation is not available for holiday trips of less than 4 nights – for this, an assumption is made that the vast majority of these trips are taken as 'own country' holidays. The nature of the survey also meant that the reporting of 'short' holidays is likely to have been underestimated. These figures were grossed up in line with limited country specific data (notably from Italy).

At this point a figure for the total number of international long and short stay holidays taken per country, as well as similar figures for domestic holidays is obtained. An initial estimate of international business trips can be by subtracting the holiday trips from the WTO total trips for each country. From the ETM data, the overall proportions of European international trips by purpose are known to be 12% - short holidays, 55% - long holidays, 19% business trips and 13% visiting friends and relatives trips (the latter category is contained within 'holiday' trips for SCENES). The data derived for the model is therefore compared to the ETM proportions. An adjustment is then made to the model values to bring the number of trips by purpose at the EU level in line with the ETM proportions (the ETM figure for total travel is greater then the WTO, but includes Europe as a whole, and relates to 1997). A final adjustment is then made to match the WTO total figures for international travel. This procedure is repeated in an iterative manner (since the figure for international business travel depends upon the total number of trips and vice versa) until a stable result is achieved. Other country specific adjustments are made where the trip rates obtained look incorrect.

Table 3.4 below shows the final set of estimated trips rates obtained by purpose for the EU countries. These rates are trips / person / annum. Note that the figures in the table exclude the return element of the trip.

Table 3.4: EU International tourism and domestic holiday trip rates (1995)

	Total domestic holidays	Total international holidays	International business	Total international trip rates	All international trips
Austria	0.7292	0.8609	0.7221	1.5830	12,688,000
Belgium	0.5770	0.8292	0.2098	1.0390	10,494,203
Germany	0.5538	0.7441	0.1588	0.9029	73,443,000
Denmark	1.6174	0.8532	0.0795	0.9327	4,846,874
Spain	1.0605	0.2008	0.1356	0.3363	12,644,000
Finland	2.7730	0.4700	0.1834	0.6534	3,318,449
France	0.9940	0.2956	0.0542	0.3498	20,211,000
Greece	0.9361	0.1254	0.0509	0.1763	1,835,338
Ireland	0.4353	0.5529	0.3346	0.8875	3,177,220
Italy	0.8253	0.2367	0.0431	0.2798	15,989,000
Luxembourg	0.3692	2.1373	5.5487	7.6860	3,074,406
Netherlands	1.5626	1.1070	0.1346	1.2416	19,047,000
Portugal	0.6395	0.1789	0.0906	0.2695	2,523,475
Sweden	1.7540	0.6951	0.0632	0.7583	6,631,415
UK	0.9743	0.6359	0.1036	0.7395	43,109,411
Total	**337,206,317**	**185,235,018**	**47,797,773**		**233,032,791**

The main trends regarding holiday taking habits can be seen in the table. For some European countries such as France, Spain and Italy, the trip rates for international holidays are low. In contrast high rates are recorded for Germany, Austria, the Netherlands and Belgium. The total number of trips made from each country matches the WTO 1995 totals. When forecasting with the model, trend estimates of international tourism trip rates will be developed exogenously and input. Organisations such as the WTO publish estimates of future levels of international tourism travel.

For the CEE countries, there is no survey data of the type of the Eurobarometer. The WTO total departures by country have been used and split by purpose based on the average values for the EU. The trip rates for domestic holidays have been assumed at three quarters of the EU average, except for Poland and Hungary where data were obtained. The trips rates used for the CEE countries are therefore shown in Table 3.5 below.

Table 3.5: CEE Country international tourism and domestic holiday trip rates (1995)

	Total domestic holidays	Total international holidays	International business	Total international trip rates	All international trips
Czech Rep.	0.6865	0.1138	0.0282	0.1420	1,465,474
Estonia	0.6865	0.3283	0.0814	0.4098	599,105
Hungary	0.8000	0.2666	0.0661	0.3328	3,385,579
Lithuania	0.6865	0.3108	0.0771	0.3879	1,438,073
Latvia	0.6865	0.2241	0.0556	0.2796	693,510
Poland	1.7200	0.1302	0.0323	0.1625	6,278,937
Slovenia	0.6865	0.3411	0.0846	0.4258	847,692
Slovak Rep.	0.6865	0.1801	0.0447	0.2248	1,208,169
Total	**91,991,984**	**12,753,108**	**3,163,431**		**15,916,539**

The trip rates for international holiday / business, and domestic holidays are used in combination with two matrices of infinite disutilities. These matrices effectively disallow (for each country) domestic and international trips respectively for each trip type.

In addition, the trip rates per person have to be adapted to reflect the trip making characteristics of the 20 population segments referred to previously in this chapter. This is done using proportions obtained from the UK NTS, from which the trip rates for 'long holidays' are available for the 20 population groups. These trip rates are used as proportions to attribute the holiday trips for each country to the 20 segments, using the total number of holidays as an overall control. The same technique is used for international business trips (using 'long business trips'), except that trips of this type are only attributed to the 'employed' population groups.

Splitting the holiday and international business trips between the population segments in this way has the effect that more trips are made by the employed and 'car available' groups. The number of these trips being made will therefore increase when the model is used for forecasting, since the level of car availability will increase – this acting as a proxy for increased wealth in this case.

Regarding a matrix of observed international tourism data, the full matrix is reported in Annex B. This matrix is based on WTO data supplemented by national tourism statistics where available. Although there are still many gaps in the data, the level of tourism travel between the main countries is now well established.

3.5 Country specific 'Value of time' data

It was note in Section 1.2 that an important element of the SCENES development work is the implementation of software changes which allow the use of a wider range of country specific parameters in the model. In STREAMS, many elements of the model were defined explicitly at the country such as public transport tariffs and car operating costs. However, the 'ability to pay' for transport services was implemented using a Europe wide value of time in combination with other indirect measures. These indirect measures came partly from the car availability by zone, and also using terminal costs, times and disutilities. This rather indirect approach could be sustained in STREAMS although it was inconvenient in practice. It was clear that changes to the structure would be required for SCENES particularly in the light of the inclusion of the CEE countries.

As a result of this, in SCENES, modifications to the software now allow a wide range of model inputs to be specified for aggregations of zones (i.e., countries), rather then at a 'whole model' level. These input parameters are for example values of time, mode specific constants and weightings on time / cost / distance in the modal disutility functions. Many of these factors could be termed 'calibration parameters' – i.e., they are adjusted within the model calibration process and not based on hard data.

However, values of time need to be specified externally by country, by trip purpose and by person type, from various economic data. This is required in order to have a value of time for use with each of the SCENES population groups (socio-economic and demographic), and each of the broad trip purposes (e.g., business and leisure), for each country on the model. Of course, data of this nature is not readily available and a process of estimating values based on the limited available data is therefore required. The development of these values are now discussed below.

Values of time are a reflection of ability to pay more to travel more quickly in the models and therefore reflect income, as well as the purpose of the journey. The starting point in the process of developing these values is the UK Family Expenditure Survey (1992 Edition). Here the average weekly expenditure is available for a wide range of socio-economic and demographic disaggregations of the population.

From this data, average per-person expenditures can be calculated for four of the five population groups, full-time employed, part-time employed, economically inactive / unemployed, and the retired. This expenditure data is treated as a proxy for income. For the purposes of the model, the income for children is assumed as an average of the three working age group incomes.

The next step is to disaggregate these 'income' values obtained for each of the five population groups to the four car availability categories. The guide here was the Sample of Anonymised Records (SARS) from the 1991 UK Census – from this, it is possible to obtain the number of persons in the twenty population groups (5 person types times 4 car availability / household composition groups). Looking at these figures, it is clear that the 2+ adults / 1 car, household group is the most populous in each of the five person types groups. It is then assumed that this group reflects 'average' earnings, and that groups with greater car availability (1 adult, 1+car and 2+ adults / 2+ cars) will have higher earnings and vice versa for the lower car availability group (0 cars). This is implemented using earnings factors for the other groups, and retaining the 2+ adult / 1 car group as the average at 1.0.

These deliberations are illustrated in Table 3.6 below. The columns in the table are as follows. Columns 1 and 2 are the five demographic / socio-economic population groups and the average 'income' for each, established using the method described above. Column 3 shows the car availability / household structure groups for each of the five population groups, and Column 4 gives the number of persons in each of these 20 groups from the SARS data. The assumed income ratios are then contained in Column 5 – indicating a greater income for the groups with a higher car availability. The incomes implied by these ratios are given in Column 6 and Column 7 is a 'test' to see how these ratios perform in terms of retaining the overall average income for each of the five starting groups. Columns 8, 9 and 10 are simply transformations of the Column 6 income values through time and between currencies.

Table 3.6: SCENES UK based Values of Time

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Demog. / socio-econ. category	**Average Weekly Exp.**	**H/hold – Car availability category**	**SARS persons (no.)**	**Income ratios**	**New Ave. Weekly Exp.**	***Ratio Check***	**New Ave. Yearly Exp.**	**Ave Exp. Per hour (£), 1992**	**Ave Exp. Per hour (ECU), 1992**
Children	*151.19*	All pers. / 0 car	23,871	0.5	**75.6**	*16.90*	3931	**2.05**	2.78
		2+ adult / 1 car	45,634	1	**151.2**	*64.62*	7862	**4.09**	5.55
		1 adults / 1+ car	4,559	1.3	**196.5**	*8.39*	10220	**5.32**	7.22
		2+ adults / 2+ car	32,700	1.3	**196.5**	*60.20*	10220	**5.32**	7.22
			106,764			*150.12*			
FT-Emp	*200.86*	All pers. / 0 car	22,394	0.45	**90.4**	*11.11*	4700	**2.45**	3.32
		2+ adult / 1 car	71,928	1	**200.9**	*79.28*	10445	**5.44**	7.37
		1 adults / 1+ car	11,471	1.15	**231.0**	*14.54*	12011	**6.26**	8.48
		2+ adults / 2+ car	76,443	1.15	**231.0**	*96.89*	12011	**6.26**	8.48
			182,236			*201.82*			
PT-Emp	*125.57*	All pers. / 0 car	5,596	0.45	**56.5**	*8.34*	2938	**1.53**	2.07
		2+ adult / 1 car	16,845	1	**125.6**	*55.76*	6530	**3.40**	4.61
		1 adults / 1+ car	1,257	1.2	**150.7**	*4.99*	7835	**4.08**	5.53
		2+ adults / 2+ car	14,235	1.2	**150.7**	*56.55*	7835	**4.08**	5.53
			37,933			*125.64*			
Inactive /	*76.21*	All pers. / 0 car	35,346	0.45	**34.3**	*11.25*	1783	**0.93**	1.26
Unemp.		2+ adult / 1 car	42,082	1	**76.2**	*29.76*	3963	**2.06**	2.80
		1 adults / 1+ car	4,317	1.65	**125.8**	*5.04*	6539	**3.41**	4.62
		2+ adults / 2+ car	26,009	1.65	**125.8**	*30.35*	6539	**3.41**	4.62
			107,754			*76.40*			
Retired	*88.23*	All pers. / 0 car	42,737	0.7	**61.8**	*33.01*	3211	**1.67**	2.27
		2+ adult / 1 car	26,453	1	**88.2**	*29.19*	4588	**2.39**	3.24
		1 adults / 1+ car	5,197	2.2	**194.1**	*12.62*	10093	**5.26**	7.13
		2+ adults / 2+ car	5,559	2.2	**194.1**	*13.50*	10093	**5.26**	7.13
			79,946			*88.32*			

The next step in implementing the values of time is to translate these 'factor' based values to reflect the transportable 'trades' which go on to form the 'transport flow' groups in the transport model. The transport flows incorporate combinations of purpose, person type, and car availability. The trip rates which are used in the trip generation phase are used as weighting factors to establish a weighted average value of time for each trade, since these trades are aggregations across the groups. The values are factored to 1995 earnings at this point. Trades are the aggregations used in the distribution model, so the value of time is not used explicitly at this point. The composition of the trades are explained fully in STREAMS Deliverable D8 / D10, Table 3.1.

A further weighted average across trades is necessary to obtain values of time for the transport flow groups. The next issue regards the proportion of income which is appropriate to use as a value of time depending on the journey purpose. In STREAMS, it was assumed using evidence from a World Bank paper (Gwilliam, 1997) that 100% of the income value should be used for short commuting trips and long distance visiting friends and relatives, and holiday trips. A value of 30% was used for the remaining leisure trips, and 200% for longer distance business and leisure trips, reflecting the greater importance of time for these journeys.

At this point, there are a set of UK values of time for the different trip purposes suitable for use in the modal split and assignment phases. The next step is to adjust these values to reflect the different EU and CEE countries. A global adjustment is made all transport flows, for each country, in line with average income data for each of the EU countries. These values were obtained from Eurostat, with the exception of Austria, Finland, and Sweden. For these countries, adjustments based on GDP / head of population were made. No income data were available for the CEE countries. Instead straight GDP / head (local currency) data obtained from Deliverable D1 were used and translated into 1995 ECU. The relativity between this figure and the UK GDP / head was used to factor the values of time. Tables 3.7 and 3.8 below summarise this data. Table 3.7 shows the UK average incomes and values of time by trip purpose. Table 3.8 then details the adjustments factors used to translate these values for other EU and CEE countries.

Table 3.7: UK derived values of time by trip purpose (1995, ECU)

Transport flows	**UK average income In ECU/hour 1995**	**UK value of time in ECU/hour 1995**
11 - commuting & business, short – 0 car	2.98	**2.98**
12 - commuting & business, short – pt car	6.61	**6.61**
13 - commuting & business, short – f car	7.96	**7.96**
14 - child – personal business, education, shopping, short all car	5.55	**1.67**
15 - personal business education, vfr, short – 0 car	2.03	**0.61**
16 - personal business education, vfr, short – pt car	5.67	**1.70**
17 - personal business education, vfr, short – f car	6.68	**2.00**
18 - vfr, day trip, long – 0 car	2.19	**2.19**
19 - vfr, day trip, long – pt & f car	4.23	**4.23**
20 - commuting & business, long – all car	6.84	**13.67**
21 - international business	6.84	**13.67**
22 - international holiday, 0 car	2.19	**2.19**
23 - international holiday, pt & f car	4.23	**4.23**
24 - domestic holiday, 0 car	2.19	**2.19**
25 - domestic holiday, pt & f car	4.23	**4.23**

Note – ‘vfr’, visiting friends and relatives

Table 3.8: EU and CEE country value of time adjustments

Country	**VOT adjustment factor**	**Country**	**VOT adjustment factor**
Austria	1.1061	**Czech Rep**	0.2883
Belgium	1.3028	**Estonia**	0.1580
Germany	1.4045	**Hungary**	0.2023
Denmark	1.4072	**Latvia**	0.0950
Spain	0.7802	**Lithuania**	0.1161
Finland	1.3173	**Poland**	0.1825
France	1.2451	**Slovakia**	0.1842
Greece	0.6544	**Slovenia**	0.5070
Ireland	0.9263		
Italy	0.7661		
Luxembourg	2.3150		
Netherlands	1.1747		
Portugal	0.5899		
Sweden	1.3838		
UK	1.0000		

Table 3.8 therefore demonstrates that incomes are higher than the UK in most EU countries. This is reflected in a higher value of time. Conversely incomes in the CEE countries are seen to be very low compared to the EU. Of course, when viewed in the context of the cheaper transport costs in the CEE countries, the disparity is not so great.

Finally, the inverse of the values of time are implemented in the model, as SCENES functions in terms of generalised time rather than generalised cost. This has been shown to provide a more stable framework for forecasting the growth in travel demand, as is discussed below.

When determining the future rate of growth of travel demand the most important element is the travel disutility. The travel disutility combines into a single value: the monetary costs, travel times and quality of service of each of the modes available for travel between a zone pair. The combination is built up initially from the characteristics of the links of the network for each mode. The travel disutility is then passed up in a consistent fashion through a hierarchy of nested logit models of discrete choice. This uses a log-sum formula at each level, to calculate the composite travel disutility of the set of choices available at that level.

One issue of importance concerns the units in which this travel disutility is denominated. A typical form in which it may be defined is as a simple linear function of the travel cost c_{ijk} and travel time t_{ijk} that is incurred in travelling from the origin zone i to the destination zone j on the mode k. Thus the travel disutility may be written as

$$u_{ijk} = \alpha_{0k} + \alpha_1 c_{ijk} + \alpha_2 t_{ijk} \qquad (3.1)$$

where the parameters play the following roles

- α_{0k} denotes the alternative specific constant for the mode k which represents the intrinsic attractiveness of the service offered by this mode
- α_1 denotes the marginal utility of money to the traveller
- α_2 denotes the marginal utility of time to the traveller

In many studies one or other of the parameters α_1 and α_2 is set to unity by dividing the whole of equation (3.1) by the selected parameter. This modifies both the units in which the travel disutility is measured and the meaning of the resulting parameter ratios. For example, in the case of division by the marginal utility of time parameter α_2, the resulting travel disutility is measured in units of generalised time, whereas if the division is by the marginal utility of money term α_1, the disutility will be measured in units of generalised monetary cost.

The use of generalised time units can lead to major improvements in the ability of a simple model structure to forecast the evolution of passenger travel demand through time as will be explained now. The equation (3.1) can be rewritten in units of generalised time as

$$u'_{ijk} = \alpha'_{0k} + \alpha'_1 c_{ijk} + t_{ijk} \qquad (3.2)$$

where the parameter

$$\alpha'_1 = \alpha_1 / \alpha_2$$

is the inverse of the monetary value of a unit time saving.

If it is assumed that the importance of a given amount of money to an individual decreases approximately in proportion to size of the disposable income of the individual, then as real incomes increase in future years *t* the magnitude of the marginal utility of money, parameter α_{1t}, will decrease correspondingly. In this way the growth in personal disposable income automatically leads to a corresponding reduction in the travel disutility when the latter is expressed in units of generalised time as in equation (3.2).

3.6 Specification of car operating costs

The car operating costs used in the model are specified as the costs perceived by the user. For non-work trips, this equates to the direct 'out of pocket' expenses, i.e., fuel costs only. For trips in business time, the full running costs, including depreciation etc. are regarded as perceived.

The functions which provide the car operating costs are based on those published by the UK Government (HEN2, DETR, 1997). These functions are speed based and give a higher cost at low speeds reflecting the effects of stop-start motoring. Similarly, the greater fuel consumption resulting from travelling at high speed is also reflected in a higher cost. There is an additional function for the non-fuel elements of business car use.

The functional forms are as follows:

Fuel Cost = Length . (LngthPar + Speed^2 . ParB) + time . TimePar

Non-Fuel Cost = LngthPar + TimePar/Speed^2

LngthPar, TimePar, and, ParB are parameters which are extracted from HEN2 as shown in Table 3.9, below.

Table 3.9: Car operating cost parameters (1994 prices)

Vehicle category	A – Lnghtpar (p / km)	B – TimePar (p / hour)	C – ParB (p / (hour^2.km))
Non-working car, fuel	1.981	68.28	.0001439
Non-working car, non-fuel	-	-	-
Working car, fuel	1.686	58.12	.0001225
Working car, non-fuel	4.801	62.34	-

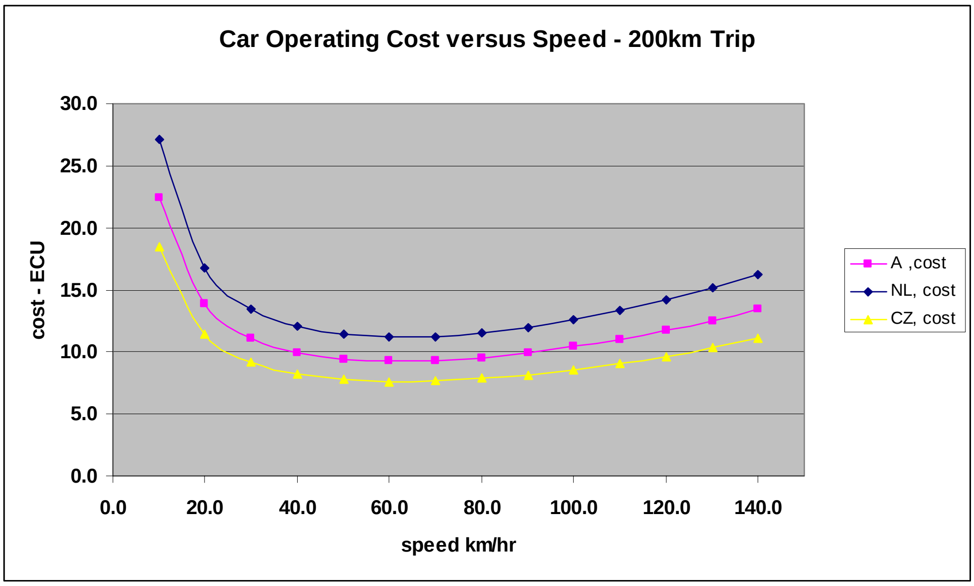
The functions are converted to 1995 values and then into Ecu for the UK. Petrol and diesel prices were obtained for all EU countries from the AA, and CEE countries from Deliverable D1. The proportion of diesel cars in each of the national fleets was obtained from the DGTREN TIF Pocketbook. In this way, it was possible to obtain fuel price relative to the UK, which it is assumed is a reasonable reflection of motoring costs in general between the countries. For the non-fuel element of business car travel, behavioural costs per hour in ECU were obtained for business car use from EUNET Deliverable D12 (Table 4.2). These values are used to factor the original UK functions for the non-fuel costs for each of the EU countries. For the CEE countries, an assumption based on Deliverable D1 data was made that the non-fuel elements are 55% of the EU average.

A function for working and non-working car costs is then developed for each country in the model. For those countries with toll roads, an additional component is built in to reflect costs on these links – this toll data was also obtained from the AA.

Figure 3.1, below shows examples of car operating cost in ECU for three countries (Austria, Netherlands and Czech Republic) and illustrates how the cost changes with average speed. The example shown is for a 200km trip. The lowest cost for a 200km trip is found between around 50 and 70kph. It can be seen that the cost varies by country, although the pattern of cost over different speeds is the same for all countries.

As a guide, the costs in terms of ecu / km for Austria range for around 0.11 ecu / km to 0.05 ECU/ km. The total costs for 'working car' are around 2 to 3 times the non-working car values. The value of tolls is in the range of .02 ecu / km for Greece to .17ecu / km for Austria.

Figure 3.1: Examples of car operating costs functions – non working car, 1995



3.7 Specification of rail, inter-urban coach and local public transport tariffs

3.7.1 Rail tariff functions

New tariff functions have been developed for rail and coach tariffs for SCENES. Of course, additional functions were required for the new countries, but the opportunity was also taken to revise the cost functions for the EU where more or better data had become available. In general, when viewed in terms of ecu/km, it was discovered in STREAMS that rail tariffs decline with distance. A linear tariff function was therefore not suitable.

Initial formulations of the rail tariffs used a simple quadratic form on a set of tariffs and distances obtained for each country. However, the use of a quadratic form created problems in the tariffs over very long distances. The inclusion of a negative quadratic term to represent the reduction of tariffs (ecu / km) with distance generated negative tariffs over very long distances. An alternative approach therefore had to be found which circumvented this problem. The approach used was based on the 'Solver' function within Excel, which minimises the sum of the squares of the differences between observed and modelled values, based on a user-defined functional form.

The functional form used in the model is split into two parts (which are input in 2 separate model files):

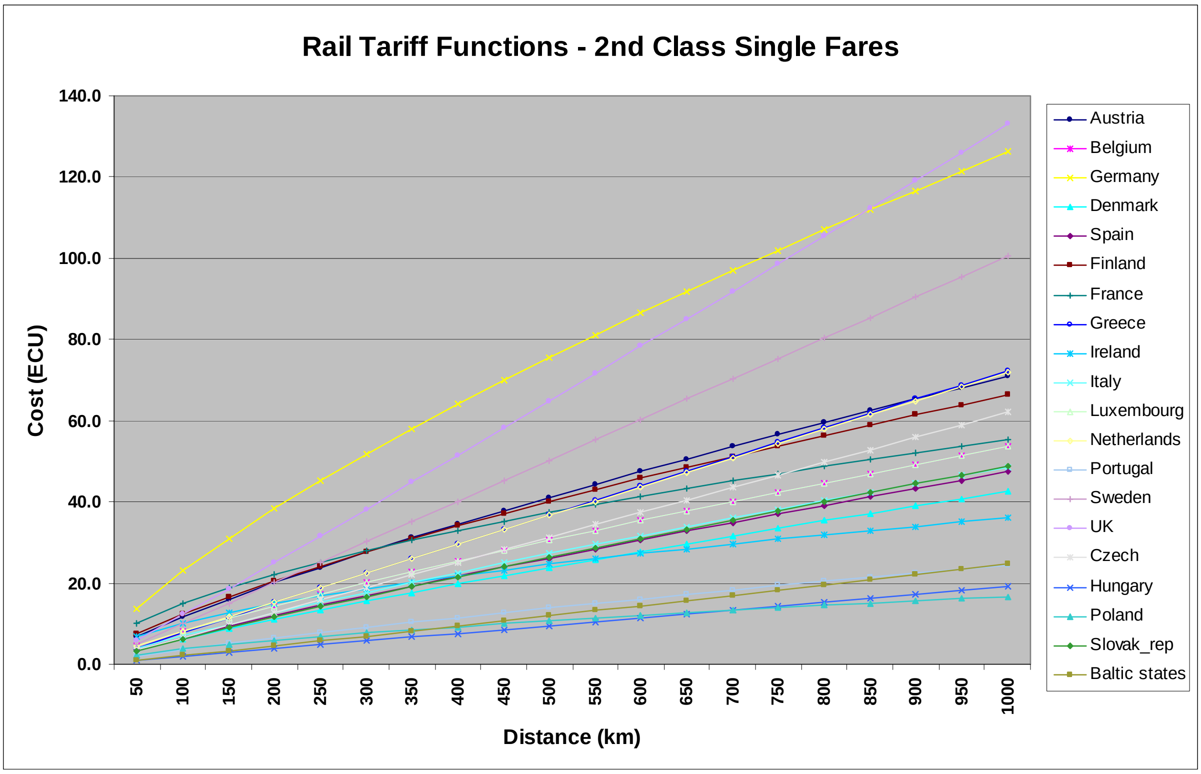
- Cost = Length . LngthPar
- Cost = Length . DistPar . (Length $^{-\text{ExpDist}}$)

The parameters LngthPar, DistPar and ExpDist are all estimated using the Solver function. An improvement over the STREAMS set-up is that in STREAMS, the second of the above elements was limited to an EU average value. With the software changes already referred to in previous sections, it is now possible to implement this part of the function on a country specific basis.

A 'basket' of typical fares was obtained for all the EU and CEE countries. Of course, there are now a very wide range of ticket types with varying costs and restrictions in place in most European countries. This makes the process of obtaining 'typical' fare data more difficult again. The fares which were selected attempt to represent 'average' ticket prices faced by travellers. This data was not easily available for all countries however since national railway websites do not always provide suitable fare information. The sources used were national rail websites, more general travel information websites, and Deliverable D1 for the CEE countries. Unfortunately, obtaining fares for 1995 directly was not possible. Present day tariff data was therefore used and converted back to 1995 using simple assumptions regarding the changes in tariffs. These values are then converted from national currencies to ECU.

For illustrative purposes, Figure 3.2 below shows the tariff functions for second class single rail travel for the SCENES countries.

Figure 3.2: SCENES EU and CEEC passenger rail tariff functions (1995 ECU)



The difference in rail tariffs throughout the study area can clearly be seen, with the UK, Germany and Sweden coming out as the most expensive countries. By contrast, rail travel in the CEE countries is seen to be very cheap indeed, relative to travel in the EU. There are a large group of countries between these extremes where rail travel is similarly priced.

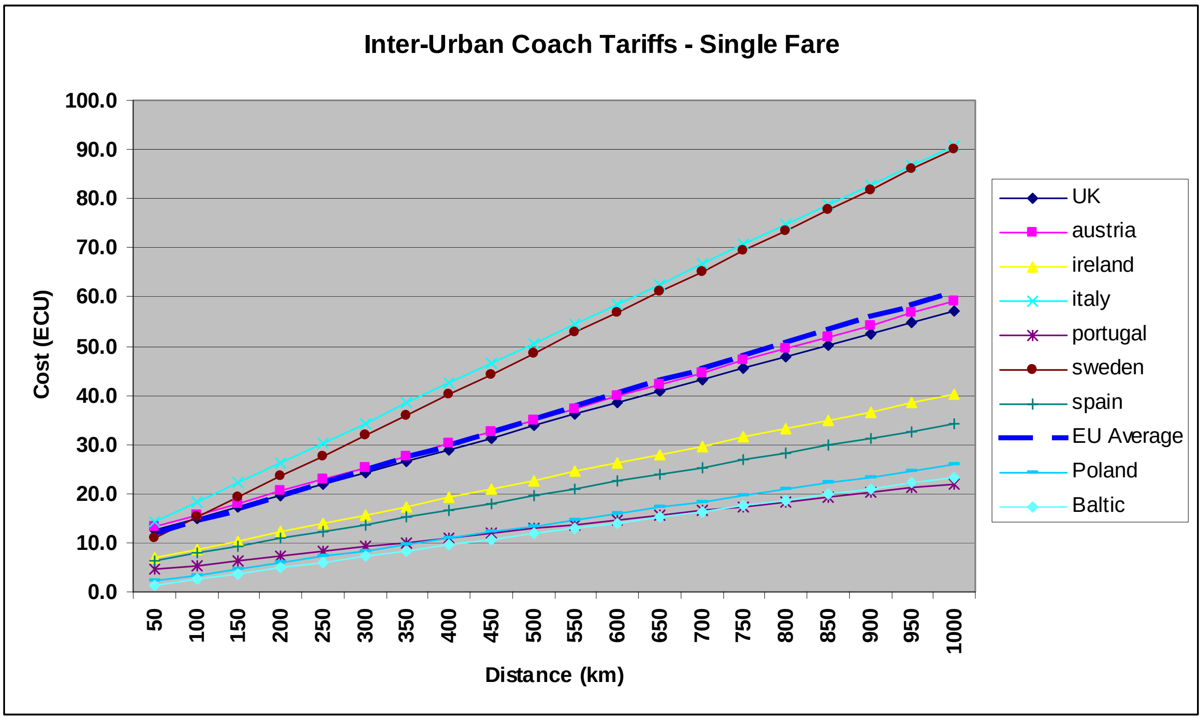
A similar set of functions were developed for first class rail (which it is assumed is used for business travel) and also second and first class high speed rail. The countries deemed to have a 'high-speed' rail network are those with dedicated high-speed lines of the TGV type. In 1995, these were France, Germany, Italy, Sweden and Spain. High-speed rail tariff functions for the UK were also determined for Eurostar services.

3.7.2 Coach tariff functions

New long distance (i.e., inter urban) coach tariffs were developed for SCENES. Again a 'basket' of fares were obtained from national Internet sources for UK, Spain, Ireland, Italy, Austria, Sweden, and Portugal. Data for the other EU countries were more difficult to find. For these countries, an EU 'average' based on a large sample of Eurolines international fares was established. CEEC inter-urban coach tariff data was obtained for Poland and Estonia. Poland is assumed representative of the central European countries, and the Estonian tariffs are assumed typical of the Baltic states.

Coach fares proved to have a simpler general structure, the evidence of declining ecu / km over distance was not so strong. Simple linear regression functions proved a good fit for most countries. Figure 3.3 below shows the coach tariff functions obtained for the different countries and groups of countires.

Figure 3.3: SCENES EU and CEEC passenger coach tariff functions (1995 ECU)



The costs in the figure show a wide range, with Italy and Sweden proving the most expensive on this occasion. Portuguese fares appear to be in line with Polish and Estonian fares which is surprising. The UK and Austria's fares are very close to the EU average.

3.8 Local public transport tariff functions

Ultimately, local public transport tariffs could be coded into the model for each and every zone. This would however, be an onerous undertaking, in terms of collecting and processing data. In fact, the myriad of fare types operated in different cities and regions makes specification of tariffs based on observed fare data very difficult indeed. Time limiting of tickets, flat fares, different peak and off peak fares, ‘carnet’ style ticketing and the use of unlimited ‘travel-cards’ would make specifying tariff functions very difficult. In STREAMS a flat rate ECU / kilometre fare was used for all countries, but in SCENES, an attempt is made to better reflect the different fare levels by country, all be it in a fairly crude way.

The alternative approach to coding elaborate ticketing systems is to use data relating to revenue and passenger ridership by country / urban area. If the number of passenger trips is known, together with the total revenue and passenger kilometres travelled, a rate in local currency per passenger trip and therefore by passenger kilometre travelled can easily be determined. Obtaining this sort of revenue and ridership data across all European countries is however problematic. The best source of this type of data is the ‘Janes Urban Transport Systems’ publication. This is prohibitively expensive to buy however.

Some figures from the Janes publication are however quoted in the ‘Citizens’ Network’ European Commission Green Paper. Here cost recovery rates are given for a capital or major city in each of the EU countries, i.e., the proportion of public transport operating costs which are covered by passenger fares. For Belgium, Germany, Spain, France, Ireland, and Sweden, similar figures relating to a sample secondary cities were obtained from a source quoting Janes Urban Transport Systems, 1996/97, so it was possible to obtain a more ‘average’ figure for these countries.

The approach taken for the EU countries is to use comprehensive data which was obtained for the operation of the UK local bus fleet as a basis. The coloured panel below illustrates the approach.

UK Local Buses 1995/96 [1]		
Passenger receipts (inc. subsidy)		£2,407,000,000
Subsidy		£435,000,000
'Fare-box Revenue'		**£1,972,000,000**
Passenger journeys		4,383,000,000
Local bus passenger km per year		403
Passenger trips / year		62
Average distance (km)		6.50
Average fare per journey		£0.45
Fare per km (£)		£0.069
Fare per km (ECU)		**0.082**
Operating cost per vehicle km		£0.89
Total vehicle km		2,649,000,000
Total		**£2,357,610,000**
UK Cost Recovery		**83.64%**
Full UK cost per person km (ECU)		**0.098**
Country	**% cost recovery** [2]	**Fare per passenger km**
Belgium	**36.0%**	**0.035**
Denmark	**52.0%**	**0.051**
Germany	**39.5%**	**0.039**
Greece	**27.0%**	**0.027**
Spain	**66.5%**	**0.065**
France	**46.3%**	**0.046**
Ireland	**89.5%**	**0.088**
Italy	**10.0%**	**0.010**
Luxembourg	**18.0%**	**0.018**
Netherlands	**25.0%**	**0.025**
Portugal	**62.0%**	**0.061**
Austria	**40.0%**	**0.039**
Finland	**44.0%**	**0.043**
Sweden	**51.0%**	**0.050**

Source: [1] Transport Statistics GB, 1996, [2]'Citizens Network – Fulfilling the potential of public transport in Europe' – EC Green Paper, 1996

Using the UK data, it is possible to obtain a full cost (i.e., without subsidy) per passenger kilometre. The cost recovery proportions per country can then be used to estimate a fare / person kilometre for each country. A check was made against similar revenue data which was obtained for Ireland. The result obtained was very close to the value reached using the above approach. Clearly, however, as this approach relies on an assumption that operating costs are broadly similar in all countries, better data would allow a refinement of the figures. This approach does however at least reflect the different subsidy regimes in EU states and therefore the different costs likely to be faced by the traveller.

The ECU / km fare for each country is used in conjunction with an estimated minimum fare (e.g., 0.25 ECU) which would operate over the shorter distances, to avoid unrealistically cheap travel.

Looking at the CEE countries, comprehensive revenue / ridership / operating costs data were available for a number of cities in Poland. The average of these cities gives a rate of 0.02 ECU / km for 1995. This value is initially used as the standard for the CEE and Baltic countries. If more data for other countries becomes available, then more country specific data could be included in the model. Some figures were obtained for Estonia – they inferred a very high average trip distance by public transport (over 20km), and a therefore a very low revenue rate in terms of ECU / km. They are not therefore currently used as inputs in the model.

3.9 Air passenger tariffs

The development of air passenger tariff functions is now also a very complex issue. The proliferation of airlines and services, together with the very wide range of fares which can be paid for the same flight means that the development of functions based on actual fares paid is not a tenable way forward. In STREAMS, the cost functions were based on a study in the Single Market Review series (Cranfield University, 1997). These functions were relatively limited in scope however.

For SCENES, a method based on revenues by airline is used. From IATA (International Air Transport Association) it is possible to obtain revenue per passenger-km, by individual airlines, for both scheduled and chartered services. These data cover a range of years, so some trend analysis is also possible, which is of use for forecasting.

These revenue (or yield) based functions should provide a much more realistic ‘average’ of the range of fares paid by scheduled and charter travellers.

4. Developments in the freight demand model

4.1 Introduction

This chapter reports on the improvements that have been made to the STREAMS freight model, within the SCENES project. The work is split into two main areas: (i) development of the regional economic model (REM), and (ii), improvements to the freight transport (modal split and assignment) model.

Firstly, Section 4.2, below details the re-specification of the regional economic model.

4.2 SCENES Regional Economic Model specification

4.2.1 Overview

The base data are the EUROSTAT 1995 Input-Output (I/O) tables for each EU15 country. The data requires some modification to generate the input for the SCENES model. This includes expansion of the tables to 44-sector level and the allocation of national totals to individual zones based on the Gross Value Added (GVA) and other socio-economic data per zone.

For each of the 15 EU countries, the relevant 25-sector 1995 input output table (IOT) has been expanded to 44-sector level. The national tables were then tested by running them, first, in a simple two zone model (one internal and one external zone). They were then run in a three zone model (one internal zone and two external zones, one covering the rest of the EU and the other covering the rest of the world).

The third step in the process was to combine the fifteen countries into a single model. A seventeen zone model was produced with zones one to fifteen representing each of the EU member states. Zone sixteen, an external zone, represented the rest of the world. An additional seventeenth zone also had to be created. This was required because an imbalance existed in the intra-EU trade data contained in the original IOTs. Zone seventeen was created to soak up any excess or deficit of intra-EU imports and exports in any factor. This is a modelling device that is designed to cope with the noises in the EU trade data.

The IOT data on which the model was based does not, however, provide any information about the pattern of intra-EU trade. For each country, information is only provided about imports from and exports to the rest of the EU as a whole (i.e., not on a country by country basis). The pattern of trade between zones therefore had to be determined using a modelling process and the information on intra-EU trade (‘observed’ trade matrices), discussed in Annex C. The (adjusted) import and export totals for intra-EU trade, taken from each country’s IOT, were combined with ‘observed’ trade data using a matrix expansion procedure to produce a zone to zone pattern of trades that was consistent with the overall totals for the fifteen EU countries.

The final step in developing the regional economic model is to disaggregate the model from fifteen to two hundred and five internal EU zones. The data for each country had to be divided up between its constituent zones. To achieve the required zonal disaggregation two sources of information were used. These were, first, the ‘observed’ intra-EU freight matrices and, second, a set of GVA and socio-economic data that was originally used to carry out a similar procedure in the STREAMS project. This gives a full disaggregation of country level production data to the level of SCENES zones for the base year 1995.

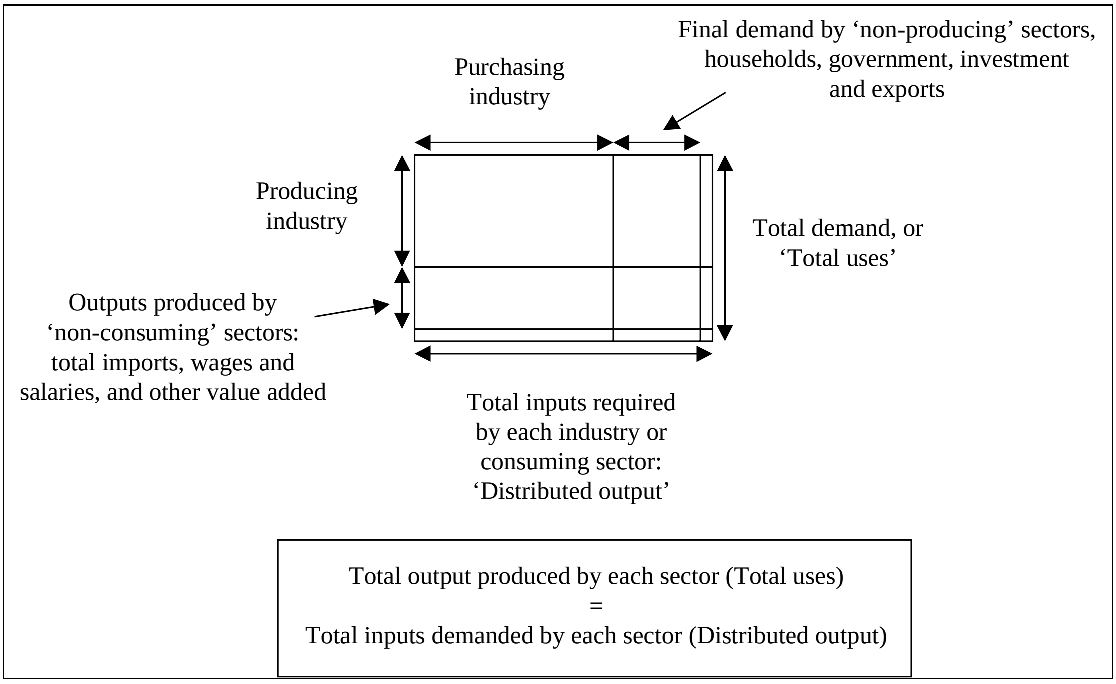
The calibration of the spatial distribution model then starts on the basis of such zonal data.

4.2.2 The input-output approach

The REM produces information about the pattern of trade in commodities between regions within the modelled area (the internal zones) and to and from regions in the rest of the world (represented as external zones). The model structure is based upon a spatial adaptation of the Leontief input-output framework. This provides a consistent mechanism for representing the economic linkages between different sectors of an economy and between different economies.

An input-output table describes the flow of goods and services between the different sectors of an economy over a given period of time. These flows are usually expressed in terms of monetary values. The fundamental idea is that production, or output, in one sector of the economy draws on inputs from a range of other economic sectors. Production in each of these sectors, in turn, demands inputs from other sectors and so on. The resulting complex pattern of inter-dependencies can be represented in matrix form as an input-output table. Figure 4.1 shows the format of the 'Domestic production' table from a typical set of input-output tables.

Figure 4.1: Composition of a typical input-output table covering domestic production



Each row in the upper section of the table corresponds to a particular industrial sector. The same sectors are also listed in the table columns. Reading along any given row shows what part of a sector's output is used as a production input by each of the other industrial sectors in the economy, plus what the sector uses of its own output. In addition to this 'intermediate demand' by other producing sectors, the output of a sector may also be demanded by 'non-producing' parts of the economy. This 'final demand' includes that by households, government, that used for investment together with goods and services that are exported. The row sum, comprising intermediate and final demand, is the total output produced by a given sector, termed 'Total uses'.

The sum of each row, Total uses, is equal in value to the sum of each column, termed 'Distributed output'. For any given column, reading down the rows in the upper part of the table shows the inputs required from different industrial sectors. The lower part of the table shows the inputs required from 'non-consuming' sectors of the economy. These include the labour and capital inputs to production plus imported goods. More detailed information on imports is usually provided in a separate table.

In SCENES, the REM has been constructed based upon individual input-output tables for each of the 15 EU Member States. The following sections go on to describe the data manipulations that were necessary to construct the REM on this basis.

4.2.3 Specification of 1995 Input-Output tables (IOT)

The starting point for the process was the 25 sector input-output tables, for the year 1995, obtained from EUROSTAT in May 1999. A set of tables was obtained for each of the 15 EU Member States. Each set had a similar structure, comprising four tables, one each for domestic production; imports of goods and services from the EU15; imports of goods and services from third countries and total imports of goods and services. All data were for 1995 and were presented in units of millions of ECU.

4.2.3.1 Equivalence of EUROSTAT sectors and SCENES REM factors

The EUROSTAT data were presented at the level of 25 aggregate sectors. (It should be noted that the previous 1985 I/O data, which were updated with national accounts data to 1994 for use in the STREAMS project, were grouped into 33 sectors). For SCENES, it was proposed to use 44 sectors.

Table 4.1, below, shows the correspondence between the 44 sectors used in SCENES and 25 sector aggregation contained in the EUROSTAT tables.

Table 4.1: Correspondence between Eurostat 25 and 44 sector I/O aggregations

	44 sector aggregation (used in SCENES REM)		**25 sector aggregation (contained in EUROSTAT IOTs)**
1	Agriculture, forestry and fishery products	1	Agriculture, forestry and fishery products
2 3 4 5	Coal, coke and lignite Extraction of crude petroleum and gas Manufactured fuel Other fuels	2	Fuel and power products
6 7	Ferrous and non-ferrous ores Metals	3	Ferrous and non-ferrous ores and metals
8 9 10	Cement and building materials Glass and ceramic materials Other non-metallic mineral products	4	Non-Metallic mineral products
11 12	Basic chemicals Fertilisers and chemical products	5	Chemical products
13	Metal products except machinery	6	Metal products except machinery
14	Agricultural and industrial machinery	7	Agricultural and industrial machinery
15	Electrical products	8 9	Office and data processing machines Electrical goods
16	Transport equipment	10	Transport equipment
17 18	Food, beverages and tobacco – consumer Food, beverages and tobacco – conditioned	11	Food, beverages and tobacco
19	Textiles, clothing, leather and footwear	12	Textiles, clothing, leather and footwear
20 21	Paper pulp Printing products	13	Paper and printing products
22	Other manufactured products	15	Other manufactured products
23	Other chemical products	14	Rubber and plastic products
24	Building and civil engineering works	16	Building and construction
25 26	Recovery and repair services Wholesale and retail trade	17	Recovery, repair services, wholesale and retail
27	Lodging and catering services	18	Lodging and catering services
28 29 30	Railway transport services Road transport services Inland waterways services	19	Inland transport services
31 32	Maritime and coastal transport services Air transport services	20	Maritime and air transport services
33	Auxiliary transport services	21	Auxiliary transport services
34	Communications	22	Communication services
35	Credit and insurance	23	Services of credit and insurance institutions
36 37 38 39 40	Business services provided to enterprises Renting of immovable goods Market services of education and research Market services of health Market services n.e.c	24	Other market services
41 42 43 44	General public services Non-Market services of education and research Non-Market services of health Non-Market services n.e.c	25	Non-Market services

4.2.3.2 Expanding from 25 to 44 sectors

In order to develop the SCENES REM based on 44 sectors it was necessary to expand the 1995 25 sector IOTs to 44 sector level. A number of additional IOTs were obtained from EUROSTAT at 59 sector level. These tables were expressed in national currency units and related to the year 1985. Tables were available in this form for Denmark, Germany, Spain, France and Italy, Ireland and the Netherlands. The tables for Ireland and the Netherlands were not used. In the case of the Irish table, this was because the sectoral aggregation was different from that used in the other country tables. In the Dutch case, there were anomalies in the table relating to the oil extraction sector.

For the countries Denmark, Germany, Spain, France and Italy, the 59 sector tables were used to expand the 25 sector tables to 44 sector level. For the countries Belgium, the Netherlands, Luxembourg, Austria, Sweden, Finland, Greece and Portugal, the same basic procedure was used though with the 59 sector table from one of the five preceding countries being used. Table 4.2 shows the 'donor' country tables that were used in each case. Finally, for the UK and Ireland, the expansion was based on the 1990 UK 123 sector IOT. The various expansion procedures used are summarised below.

Table 4.2: 'Donor' countries for expansion of other countries' IOT

'Donor' country	**Country**
Denmark (59 sector, 1985 IOT)	Netherlands Belgium Luxembourg Finland Sweden
Germany (59 sector, 1985 IOT)	Austria
Spain (59 sector, 1985 IOT)	Greece Portugal
France (59 sector, 1985 IOT)	-
Italy (59 sector, 1985 IOT)	-
United Kingdom (123 sector, 1990 IOT)	Ireland

4.2.3.3 Expansion of IOTs for Denmark, Germany, Spain, France and Italy

The expansion of the 25 sector tables to 44 sector level, using the 59 sector tables, was carried out in a set of spreadsheets. The broad steps, carried out for each country, are described below.

1. The basic data from the EUROSTAT 59 sector 1985 IOT formed the starting point. Specifically, three tables were used: Domestic production at producers' prices (net of all VAT); Imports from EC member countries at producers' prices (net of all VAT) and Imports from third countries at producers' prices (net of all VAT).

2. The 59 sectors were aggregated into the 44 sectors required for the SCENES REM. Table 4.3 shows the correspondence between the 59 and 44 sector aggregations. Note that in the case of chemical products it was necessary to expand the single sector from the 59 sector table into two sectors, basic chemicals and fertilisers and other chemical products, to complete the 44 sector table. The expansion was based on the equivalent split in the domestic production table of the UK 1990 123 sector IOT. The end result of this process was a 44 sector IOT for 1985, expressed in national currency units.

3. Using the 44 sector IOT, factors were calculated that could be applied to the row and column totals of a 25 sector IOT to expand them to 44 sector level. These factors were calculated for the domestic production table and the two tables of imports. The factors were then applied to the 25 sector 1995 IOT of the country concerned. The end result was the production of row and column totals at 44 sector level, expressed in millions of ecu, for the year 1995. These totals could be aggregated to match the totals at 25 sector level, contained in the original 25 sector 1995 EUROSTAT IOTs.

4. The row and column totals calculated in step 3 were then used in a matrix expansion procedure. Briefly, the row and column totals from each of the three IOT matrices (domestic production, EU Imports and Non-EU imports) were combined with 'seed matrices'. The seed matrices used were the 1985 44 sector tables, produced in step 2. The end result of this procedure was a nearly complete 44 sector IOT, expressed in millions of ecu, for the year 1995. These tables were not yet fully complete because, at that stage, the matrix row totals did not equal the column totals.

5. To complete the tables, the column totals (Distributed output) were set equal to the row totals (Total uses). Total value added was used as the residual to make the whole table balance. For each sector, Total value added, was split between labour and other value added according to the proportions that existed in each country's 44 sector table (calculated in step 2). The end result was a competed 44 sector IOT, expressed in millions of ecu, for the year 1995.

6. The final step was to calculate the technical coefficients for the newly produced 44 sector table. For each sector these coefficients represent the quantity of the output of sector i absorbed by sector j, per unit of the total output of sector j. These coefficients were used in the construction of the REM.

4.2.3.4 Expansion of IOTs for Belgium, the Netherlands, Luxembourg, Austria, Sweden, Finland, Greece and Portugal

In the case of those countries for which 59 sector 1985 IOTs were not available, the same basic procedure was used but with the 59 sector IOT for 1985 used was taken from the relevant 'donor' country, as listed in Table 4.2, above.

Table 4.3: Correspondence between 59 and 44 sector aggregations

	59 sector aggregation (contained in EUROSTAT 1985 IOTs)		**44 sector aggregation (used in SCENES REM)**
1	Agriculture, forestry and fishery products	1	Agriculture, forestry and fishery products
2 3 4	Coal and coke briquettes Lignite and lignite briquettes Products of coking	2	Coal, coke and lignite
5	Crude petroleum	3	Extraction of crude petroleum and gas (1)
6	Refined petroleum products	4	Manufactured fuel (1)
7	Natural gas	3	Extraction of crude petroleum and gas (2)
8 9	Water (collection, purification, distribution) Electric power	5 5	Other fuels (1) Other fuels (2)
10	Manufactured gases	4	Manufactured fuel (2)
11	Steam, hot water, compressed air	5	Other fuels (3)
12	Nuclear fuels	4	Manufactured fuel (3)
13	Iron ore and ECSC iron and steel products	6	Ferrous and non-ferrous ores
14 15	Non-ECSC iron and steel products Non-Ferrous metal ores; Non-Ferrous metals	7	Metals
16	Cement, lime and plaster	8	Cement and building materials
17 18	Glass Earthenware and ceramic products	9	Glass and ceramic materials
19	Other minerals and derived products (non-metal)	10	Other non-metallic mineral products
20	Chemical products	11 12	Basic chemicals Fertilisers and chemical products
21	Metal products	13	Metal products except machinery
22	Agricultural and industrial machinery	14	Agricultural and industrial machinery
23 24	Office machines, etc. Electrical goods	15	Electrical products
25 26	Motor vehicles and engines Other transport equipment	16	Transport equipment
27 28	Meat and meat products Milk and dairy products	18	Food, beverages and tobacco – conditioned
29 30 31	Other food products Beverages Tobacco products	17	Food, beverages and tobacco – consumer
32 33	Textiles and clothing Leathers, leather and skin goods, footwear	19	Textiles, clothing, leather and footwear
34	Timber and wooden furniture	22	Other manufactured products (1)
35	Pulp, paper, board	20	Paper pulp
36	Paper goods, products of printing	21	Printing products
37	Rubber and plastic products	23	Other chemical products
38	Other manufacturing products	22	Other manufactured products (2)
39	Building and civil engineering works	24	Building and civil engineering works
40	Recovery and repair services	25	Recovery and repair services
41	Wholesale and retail trade	26	Wholesale and retail trade
42	Lodging and catering services	27	Lodging and catering services
43	Railway transport services	28	Railway transport services
44	Road transport services	29	Road transport services
45	Inland waterways services	30	Inland waterways services
46	Maritime and coastal transport services	31	Maritime and coastal transport services
47	Air transport services	32	Air transport services
48	Auxiliary transport services	33	Auxiliary transport services
49	Communications	34	Communications
50	Credit and insurance	35	Credit and insurance
51	Business services provided to enterprises	36	Business services provided to enterprises
52	Renting of immovable goods	37	Renting of immovable goods
53	Market services of education and research	38	Market services of education and research
54	Market services of health	39	Market services of health
55	Market services n.e.c	40	Market services n.e.c
56	General public services	41	General public services
57	Non-Market services of education and research	42	Non-Market services of education and research
58	Non-Market services of health	43	Non-Market services of health
59	Non-Market services n.e.c	44	Non-Market services n.e.c

For all thirteen countries for which the expansion of their 25 sector table was based on a 59 sector table, a comparison was made between the structure of their 1995 25 sector IOT and a 1985 25 sector IOT, calculated from the underlying 59 sector table. The purpose of this comparison was to check that the structure of the 1985 table was not too different from that of the 1995 table. It was most important to make this check when a 1985 table from a different country was being used.

4.2.3.5 Expansion of IOTs for the United Kingdom and Ireland

In the case of the United Kingdom, a 59 sector IOT for 1985 was not available. Instead, a 123 sector 1990 IOT was used as the basis for expansion of the 25 sector 1995 UK table. The same table was also used to expand the 25 sector 1995 Irish table. The full table of correspondence between the 123 and 25 sector aggregations is not reproduced here, for brevity.

The first step in this process was aggregation of the 123 sector UK table to 44 sector level, for 1990. This table was then used in a similar way to that in which the 44 sector 1985 tables, described above, were used for the other countries. The end result was the production of 44 sector IOTs for the UK and Ireland, expressed in millions of ecu, for the year 1995. Technical coefficients were calculated, as described above.

4.2.4 Population and economic data

In order to disaggregate national totals to the zonal level, population data and GVA data were requested from the EUROSTAT Data Shop.

4.2.4.1 National and zonal population data

For the REM, only the total population per zone is required and no age or employment breakdown is needed. These data were received from EUROSTAT's REGIO database and some adjustments were required in order to produce data in the NUTS2 format, for the same reasons as were discussed previously. The NUTS2 data is input for each modelled internal zone to in units of thousands of persons.

The national population data are necessary for the calculation of the private consumption per capita for 1995 for the internal countries. This is input for each country (not by zone) and factor.

4.2.4.2 Gross Value Added data

To disaggregate the national totals to the zonal level, the GVA per zone is required. The GVA at market prices for each NUTS2 zone was received from EUROSTAT's REGIO database. The data are available for the 17 branches of the RR17 NACE-CLIO classification for each zone. The branch names for the NACE-CLIO branches are given in Table 4.4 below. However, the data are far from complete. For some countries the GVA for a year preceding 1995 is available, but for other countries no data are held by EUROSTAT.

In the absence of these data, GVA at factor prices could be used but EUROSTAT have indicated that these are similarly lacking in coverage to the market prices data. Some data were gathered for the STREAMS project from the SCENARIOS website and other sources which may be useful. Failing this, employment data or population data could be used to achieve the zonal split.

Table 4.4: Nomenclature of RR17 NACE-CLIO branches

RR17 Code	RR17 Label
B01	Agriculture, forestry and fishery products
B06	Fuel and power products
B13	Ferrous and non-ferrous ores and metals, other than radioactive
B15	Non-metallic minerals and mineral products
B17	Chemical products
B24	Metal products, machinery, equipment and electrical goods
B28	Transport equipment
B36	Food, beverages, tobacco
B42	Textiles and clothing, leather and footwear
B47	Paper and printing products
B50	Products of various industries
B53	Building and construction
B58	Recovery, repair, trade, lodging and catering services
B60	Transport and communication services
B69	Services of credit and insurance institutions
B74	Other market services
B86	Non-market services

4.2.4.2 Import/export data

For trade with third countries, the national totals are split using TREX data.

4.2.5 Model input data

The main inputs to the model files for the REM are:

- inter-industry technical coefficients by country and factor
- total domestic production by zone by factor
- public consumption, investment and change in stocks by zone by factor
- private consumption per capita by country and factor
- imports from third countries, by third country and factor
- exports from third countries, by third country and factor

Each of these is dealt with in turn in the following sections.

1. Technical coefficients

The technical coefficients relate to intermediate demand and represent the inter-linkages between the factors. For example, the final demand coefficient will demand a certain quantity of steel. The technical coefficients then dictate that the required inputs for steel include a certain quantity of energy, raw materials, financial services, and labour.

The technical coefficients are input by country and factor. For each country, each of 28 factors has a value for the input required from all 28 factors and the value added.

2. Total domestic production

The data from EUROSTAT has separated out the domestic production from the imports of each factor for each country. The total national domestic production is split by the zonal GVA for the industrial branches to provide zonal figures.

3. Public consumption, investment and change in stocks

These three items are taken together to represent consumption other than private consumption. However, the method of presentation for the 1995 I/O tables is different from those used in the STREAMS project. The classifications for 1995 include Collective consumption of government, gross fixed capital formation, and change in stocks. The national totals are split, again using the GVA data.

4. Private consumption per capita

This represents the final consumption by households. The national populations are used to produce the consumption per capita. These values are then input by country by factor.

5. Imports from third countries

Imports from the EU15 are differentiated from those from third countries. The imports by third country and by factor are input as constraints.

6. Exports to third countries

Exports to the EU15 are not differentiated from those to third countries. The exports by third country and by factor are input.

4.3 REM: Model testing

4.3.1 Overview

The SCENES REM is based upon a spatial adaptation of the Leontief input-output framework, providing a consistent mechanism for representing the economic linkages between different sectors of an economy and between different economies. The REM has been constructed based upon individual input-output tables for each of the 15 EU Member States. The preceding sections described the data assembly and manipulation that was necessary to begin construction of the REM. This section now goes on to cover further development and testing of the REM.

The REM was developed in a number of stages:

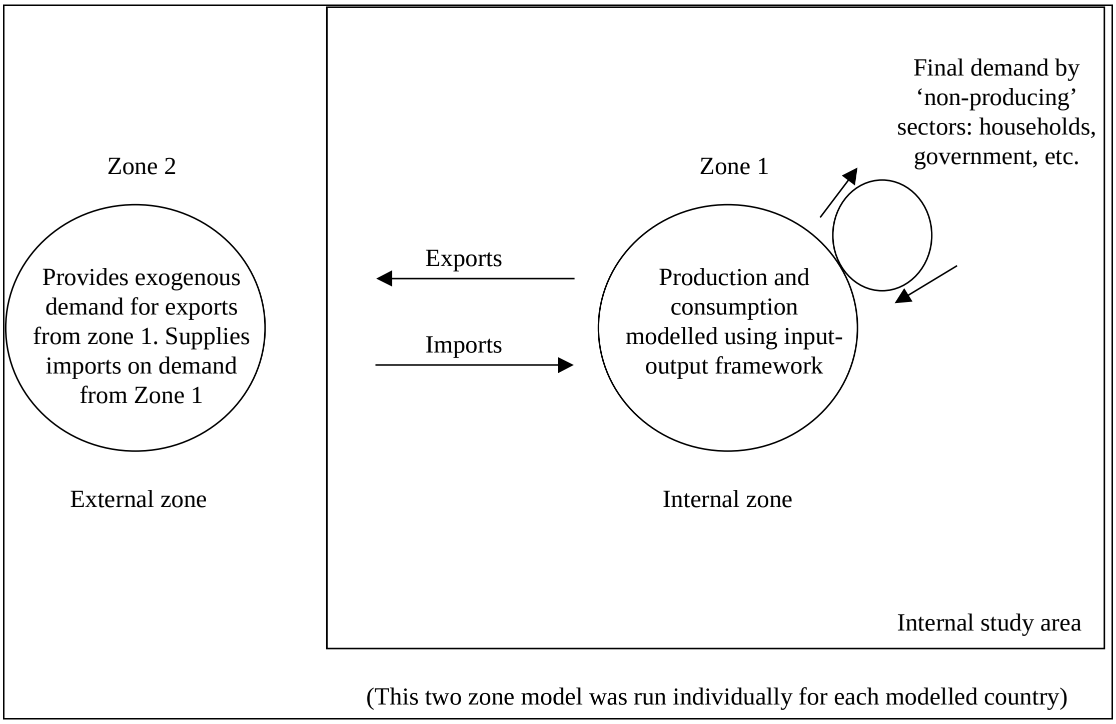
1. First, a simple model was constructed comprising just two zones. A model of this type was run individually for each of the 15 EU Member States.
2. The next step was to expand the simple model to three zones. Models of this type were again run individually for each of the 15 EU Member States.
3. The third step was to combine the 15 individual country models, developed in step 2, into a single model. The new model comprised 17 zones.
4. The final step in the development of the REM *(to date)* was to disaggregate the internal zones within the model to match the number of zones in the full SCENES model of western Europe. The data for each of the 15 countries therefore had to be disaggregated to the level of its constituent zones. In total, the model comprises 205 internal zones.

Each of these stages is discussed in the following sections.

4.3.2 The two zone model

The two zone model consisted of one internal zone and one external zone, with the latter generating imports for – and consuming exports of – the internal zone. A model of this type was run for each of the 15 Member States. The first step in the construction of the REM, this process also served to confirm that each country's input-output table and the technical coefficients thus derived would behave in a 'normal' manner when run within the modelling software. Figure 4.2 provides a schematic representation of the model structure.

Figure 4.2: Schematic representation of simple two zone model



4.3.3 The three zone model

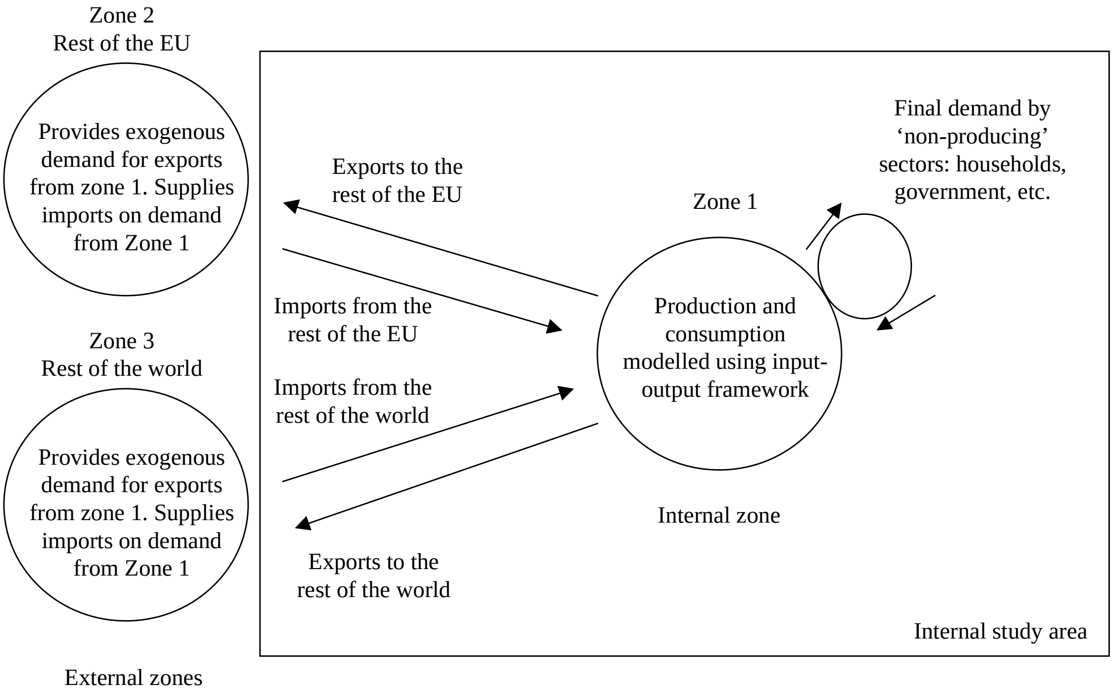
The three zone model consisted of one internal zone and two external zones representing, respectively, the rest of the EU and the rest of the world. A model of this type was, again, run for each of the 15 EU countries. Figure 4.3 (overleaf) provides a schematic representation of the three zone model.

4.3.4 The combined seventeen zone model

Following development and testing of the basic two and three zone models for each of the 15 EU countries, the next step was the combining of the fifteen countries into a single model comprising sixteen (in fact seventeen) zones. In the combined model, zones 1 to 15 represented each of the 15 EU countries. Zone 16, an external zone, represented the rest of the world. An additional zone, zone 17 also had to be created.

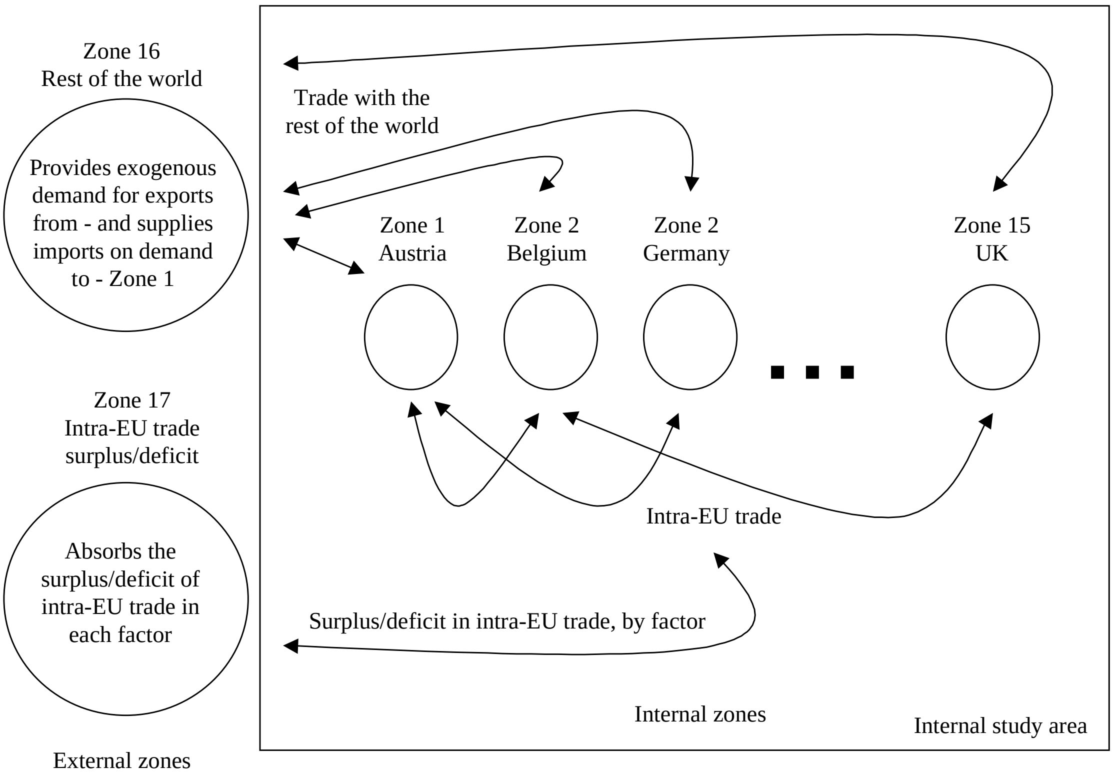
Combining all of the individual country models into a single model created several technical difficulties. The most important of these related to the data that the IOTs contained about each country's exports to and imports from the rest of the EU. First, the input-output data provided no information about the pattern of trade between EU countries. Each country's IOT identifies exports and imports to and from the rest of the EU, by sector but does not detail the destination or origin country of that trade. Second an imbalance existed, in aggregate, in the intra-EU trade data contained in the IOTs. In theory, for each sector, the sum of all the EU 15 exports to the rest of the EU should be equal to the sum of all the EU15 imports from the rest of the EU. In practice the totals did not balance. Zone 17 was therefore created to soak up any excess or deficit of total intra-EU imports and exports of a sector. Figure 4.4 provides a schematic representation of the structure of the combined seventeen zone model.

Figure 4.3: Schematic representation of simple three zone model



(This three zone model was run individually for each modelled country)

Figure 4.4: Schematic representation of combined seventeen zone model



(This seventeen zone model combines all of the individual models for each of the 15 EU Member States)

4.3.5 Production constraints

- For factors 201 to 244 (i.e., imports from EU countries) total production in each internal zone (1 to 15) is constrained to a specified level (the totals were obtained through using 'DERFR' – see below).
- For factors 1 to 44 and factors 251 to 294 (imports from the rest of the world) production in zone 17 (the additional external zone used to account for the mismatch in intra-EU trade) is constrained to zero.
- For factors 1 to 44 and factors 201 to 244 (imports from the EU) production in zone 16 (the rest of the world) is constrained to zero.
- For factors 201 to 244 production in zone 17 (the intra-EU trade balancing zone) is set as the excess of total imports from EU countries over total exports to EU countries (or zero, where exports exceed imports).
- Production of factors 251 to 294 is constrained to zero in zones 1 to 15.
- Production of factors 1 to 44 in zones 1 to 15 is fixed as Total Uses from each county's IOT.

4.3.6 Changes in zonal characteristics

The following figures are input for zones 1 to 15 as exogenous consumption:

- Final uses less exports (domestic final demand) of factors 1 to 44
- Final uses (domestic final demand plus exports) of factors 201 to 244 (EU imports)
- Final uses (domestic final demand plus exports) of factors 251 to 294 (ROW imports)
- For zones 1 to 15, summed together, total exports of factors 1 to 44 to the rest of the world (zone 16) are input as exogenous consumption.
- For zones 1 to 15, summed together, the excess of EU internal exports (that is, where total exports from EU countries to EU countries are greater than total imports to EU countries from EU countries) are input as exogenous consumption in zone 17.

This data therefore tells the model about total demand for production plus imports of factors 1 to 44 in each zone. The model does not know, however, (i) how much is produced in each zone nor (ii) what the pattern of trade (intra EU imports and exports) is between zones.

The first of these problems (i) is handled by the production constraints above. Thus the model has been told what the maximum production of each factor plus imports is in each country (zones 1 to 15). The pattern of (intra EU) trade between zones, problem (ii) above, is determined by using a program called DERFR. The procedure is explained below.

A matrix of 'Exogenous trading disutilities' is used in the production of a matrix of 'Trade disutilities and costs'. This matrix contains a set of trade disutility values for all factors (1 to 44, 201 to 244 and 251 to 294) and all trades (from each zone to every other zone). These disutilities were set up to:

- allow consumption of factors 1 to 44 in their zone of production but not in other zones, and
- allow consumption of factors 201 to 244 and 251 to 294 in zones other than their zone of production but not in their zone of production (which actually appears to be redundant for factors 251 to 294 since these can only be produced in zone 16 in any case).

A key input here is an 'observed' value matrix, that is derived from product matrices. Two main tasks were undertaken to prepare this file. First, the intra-EU trade matrices, had to be converted into a useable form. This would provide the seed matrix for a 'FRATAR' estimation. Second, the individual country EU import and export totals by factor needed to be prepared for use as the row and column totals in the FRATAR process.

To produce the required row and column totals, the necessary data were calculated. Total imports of all factors (201 to 244) were summed over zones 1 to 15 to calculate total imports from and exports to EU countries. This same procedure had been carried out earlier in the course of defining imports and exports to zone 17. Imports and exports were then scaled, using individual scaling factors for each of the 1 to 44 factors, so that total imports equalled total exports and so that the totals equalled the import and export data from the IOTs less the calculated imports and exports to zone 17. That is:

Total imports (IOT) – Total imports to zone 17 = Total adjusted imports = Total adjusted exports = Total exports (IOT) – Total exports to zone 17.

The resultant adjusted (matching) totals of imports and exports would then be used as row and column totals in the FRATAR process.

At the same time, the necessary seed matrices for the FRATAR process were developed. The steps were:

(i) The 1995 and 1996 observed matrices were compared. For all records that were non-zero in 1995 the 1995 values were used. Where there were gaps in the 1995 data, the 1996 figures were used.

(ii) The model zone numbers were worked out using a look up table and all the records of the matrix were assembled.

(iii) A pivot table was also used on the data to obtain a total trade matrix. This total product matrix was used as a seed matrix for the service factors 24-44.

As the model is run, the production constraints are monitored until they are met. Once this 17 zone model was running satisfactorily, the next step was to disaggregate it to full SCENES size.

In summary, the IOT data on which the model is based does not provide any information about the pattern of intra-EU trade. For each country information is only provided about imports from and exports to the rest of the EU as a whole (i.e. not on a country by country basis). The pattern of trade between zones therefore had to be determined using DEFR and the information on intra-EU trade ('observed' trade matrices) provided by TRT. The (adjusted) import and export totals for intra-EU trade, taken from each country's IOT, were combined with 'observed' trade data using a matrix expansion procedure to produce a zone to zone pattern of trades that was consistent with the overall totals for the fifteen EU countries.

4.3.7 The full model

The final step in developing the regional economic model is to disaggregate the model from fifteen to two hundred and five internal zones. The data for each country had to be divided up between its constituent zones. To achieve the required zonal disaggregation two sources of information were used. These were, first, the 'observed' intra-EU freight matrices, and second, a set of data that was originally used to carry out a similar procedure in the STREAMS project.

4.3.8 Using the 'observed' intra-EU freight matrices

The processing of the 'observed' data for use in the freight/regional economic model is discussed in Annex C. From these data, two additional tables were calculated. One of these was the sum of tonnes received plus intra-zonal trade, the other was the sum of tonnes despatched plus intra-zonal trade.

The freight flow data was provided for thirteen transport flow types. Table 4.5 shows the correspondence between factors 1 to 23 (the 'transportable' trades) and the 13 freight transport flow types.

Table 4.5: Correspondence between factors 1 to 23 and the associated transport flow types

	Factors		**Transport flow**
1	Agriculture, forestry and fishery products	1	Agricultural products
2	Coal, coke and lignite	4	Solid fuels and ores
3	Extraction of crude petroleum and gas	-	-
4	Manufactured fuel	5	Petroleum products
5	Other fuels	-	-
6	Ferrous and non-ferrous ores	4	Solid fuels and ores
7	Metals	6	Metal products
8	Cement and building materials	7	Manufactured building materials
9	Glass and ceramic materials	13	Miscellaneous articles
10	Other non-metallic mineral products	8	Crude building materials
11	Basic chemicals	9	Basic chemicals
12	Fertilisers and chemical products	10	Fertilisers, plastics and other chemicals
13	Metal products except machinery	13	Miscellaneous articles
14	Agricultural and industrial machinery	11	Large machinery
15	Electrical products	12	Small machinery
16	Transport equipment	11	Large machinery
17	Food, beverages and tobacco – consumer	2	Consumer food
18	Food, beverages and tobacco – conditioned	3	Conditioned food
19	Textiles, clothing, leather and footwear	13	Miscellaneous articles
20	Paper pulp	10	Fertilisers, plastics and other chemicals
21	Printing products	13	Miscellaneous articles
22	Other manufactured products	13	Miscellaneous articles
23	Other chemical products	10	Fertilisers, plastics and other chemicals

The data was also broken down by zone, though the breakdown is not complete and varies in its coverage by country. Alone, therefore, it could not be used to satisfactorily disaggregate country totals to zonal level. A similar task was carried out in the STREAMS project, however and data from this work was used to fill the gaps.

A procedure was used in STREAMS to disaggregate country level data to STREAMS zonal level. In order to make use of the STREAMS data, two sets of modifications were needed. These related to the zoning and factor definitions used in the two projects. Table 4.6, below, compares the factor definitions used in SCENES and STREAMS.

Table 4.6: Comparison between the 44 SCENES factors and 33 STREAMS factors

	SCENES Factors (44)		**STREAMS Factors (33)**
1	Agriculture, forestry and fishery products	11	Agriculture, forestry and fishery products
2	Coal, coke and lignite	12	Coal and coking
3	Extraction of crude petroleum and gas	13 15	Crude petroleum Natural gas
4	Manufactured fuel	14	Petroleum products
5	Other fuels	16	Other power, water and manufactured gas
6 7	Ferrous and non-ferrous ores Metals	17	Ferrous and non-ferrous ores and metals
8 9	Cement and building materials Glass and ceramic materials	18	Cement, glass and ceramic products
10	Other non-metallic mineral products	19	Other non-metallic minerals and derived products
11 12	Basic chemicals Fertilisers and chemical products	20	Chemical products
13	Metal products except machinery	21	Metal products
14	Agricultural and industrial machinery	22	Agricultural and industrial machinery
15	Electrical products	23 24	Office machines, etc. Electrical goods
16	Transport equipment	25	Transport equipment
17 18	Food, beverages and tobacco – consumer Food, beverages and tobacco – conditioned	26	Food, beverages and tobacco
19	Textiles, clothing, leather and footwear	27	Textile and clothing, leather and footwear
20	Paper pulp	28	Paper Pulp
21 22	Printing products Other manufactured products	30	Other manufacturing products
23	Other chemical products	29	Rubber and plastic products
24	Building and civil engineering works	31	Building and civil engineering works
25 26	Recovery and repair services Wholesale and retail trade	32	Recovery, repair services, wholesale and retail trade
27	Lodging and catering services	33	Lodging and catering services
28	Railway transport services	34	Railway transport services
29	Road transport services	35	Road transport services
30	Inland waterways services	36	Inland waterways services
31	Maritime and coastal transport services	37	Maritime transport services
32	Air transport services	39	Air transport services
33	Auxiliary transport services	40	Auxiliary transport services
34	Communications	41	Communications
35	Credit and insurance	42	Credit and insurance
36 37 38 39 40	Business services provided to enterprises Renting of immovable goods Market services of education and research Market services of health Market services n.e.c	43	Other market services
41 42 43 44	General public services Non-Market services of education and research Non-Market services of health Non-Market services n.e.c	44	Non-market services

More recent data was available on freight flows between EU zones. Rather than relying entirely on the STREAMS data, this data was used, where possible, to split the SCENES data from country to zonal level. The freight flow data was used to calculate proportions with which to disaggregate country level data. These proportions were combined with the STREAMS derived proportions.

Where possible, the freight flow data was used to calculate the necessary proportions. Where freight flow data were not available at a sufficiently detailed level, it was supplemented with STREAMS data. Thus, for example, in the case of Austria it was possible to use the freight flow data alone to disaggregate the country level data. For Belgium, freight flow data was used to disaggregate data for zones 10 and 11 and for zone groups 12 to 15 and 16 to 20.

STREAMS data then had to be used to further disaggregate zones 12 to 20. For certain countries, including Denmark, no freight flow data was available hence only STREAMS data could be used. In addition, for all countries, for factors 3 and 5 STREAMS data had to be used because no freight flow data was available. For the same reason STREAMS data had to be used entirely for factors 24 to 44.

The proportions (values) calculated were used to disaggregate the existing sixteen zone model to zonal level, ready for input to a new model. Note that the same set of proportions were used to disaggregate all types of data.

The data on total production (total uses) by factor in each country, for factors 1 to 44, were therefore disaggregated to zonal level, i.e. for zones 1 to 205. The data on total exports to EU countries by factor from each country, for factors 201 to 244, were disaggregated to zonal level. The constraints on production of factors 1 to 44 and factors 251 to 294 in zone 17 (the zone used to take account of the gap in intra-EU trade) were switched to zone 273, the new dummy zone. The constraints on production of factors 1 to 44 and 201 to 244 in zone 16 (the external zone) were extended to all the new external zones, zones 206 to 265. The gap totals for intra-EU trade, for factors 201 to 244, previously taken up by zone 17 were switched to zone 273, the new dummy zone.

The constraints on the production of factors 251 to 294 in zones 1 to 15 (the previous internal zones) were switched to cover all of the new internal zones, 1 to 205. Their production in the dummy zone, zone 273, has already been barred, above.

The data on domestic final demand by country, for factors 1 to 44, were disaggregated to zonal level using the same approach as above. The data on final uses of EU imports by country, for factors 201 to 244, were disaggregated to zonal level using the same approach as above. The data on final uses of ROW imports by country, for factors 251 to 294, were disaggregated to zonal level using the same approach as above. Exports to external countries for factors 1 to 44, previously going to zone 16, were temporarily changed to become exports to a single external zone, say zone 262 (this would be changed to cover all external zones, later). Demand in the previous dummy zone, zone 17, for factors 1 to 44 was shifted to the new dummy zone, zone 273.

The data processing procedure presented above has provided a sound basis for the calibration of the regional economic model. The final model specification includes:

(a) Verification of the zonal socio-economic data and the transport disutilities associated with each industry

(b) Estimation of the spatial distribution model for each industry

(c) Application of the DERFR procedure to refine the representation of inter-country trade distribution

(d) Implement the future reference scenarios

(e) Test the model for the future scenarios, in particular in relation to the model responses in terms of trip lengths and the tonnes generated

5. Developments in the freight transport model

5.1 Introduction

The freight component of the SCENES transport model is composed of the Regional Economic Model (REM), described in Chapter 4, which generates the transport demand, and the transport module, which performs modal split and assignment of transport demand. The REM uses a combination of Leontief input-output (I/O) structures in conjunction with a spatial allocation procedure and a matrix of transport disutilities to produce a matrix of trade in terms of value. Other routines convert these values to volumes (by commodity type and origin-destination pair) in order to produce origin/destination matrices of tonnes by flow of transport.

In the transport module, origin/destination matrices are then assigned to the transport networks in a more 'conventional' fashion. Modal split and route choice are determined in the transport assignment module based on the characteristics of the flow type (e.g., bulk or unitised).

The specification of the observed data set for the validation of the SCENES freight model is contained separately in Annex C. Traffic in terms of tonnes and tonnes-km has been estimated from the available sources of data according to the set of flows defined for the model. The procedure for making these estimations is also contained in this Annex. The observed data discussed encapsulates national data (tonnes), international data (tonnes) and tonne-km data by country (i.e., within national territories).

Finally, a brief summary of the comparative work between the NEAC freight database and the STREAMS model output is presented, together with some comparative figures from SCENES. A fuller version of the comparison is contained in Annex D.

5.2 Model formulation

The formulation of the SCENES freight model is derived from the STREAMS model. In the following sections, the main elements are introduced with special reference to the new features added.

5.2.1 Freight flows

For the SCENES freight model, thirteen flows have been defined in comparison to the ten flows used in the STREAMS model. There are different factors in favour of a revision of the structure of the freight model flows used in the STREAMS model, mainly:

- transport requirements are different among different commodities; the more detailed the classification is, the more appropriate can be the description of the model parameters;
- enhanced computing power allows us to manage a larger number of flows; and,
- the logistic appended module included in the freight model with the aim of taking into account the logistics chains, requires a configuration of the freight flows into logistics families. A suitable definition of the flows according to their handling requirements eases the correspondence with the logistics families.

At the same time, the definition of freight flows takes into account the following main constraints:

- availability of detailed data. Apart from TREX, other data sources generally provide data at the NST/R chapter (1-digit) level or even more coarsely. The EUROSTAT Carriage of Goods database, which is the main reference for the national flows, provides data according to a different grouping of the NST/R 2-digit named Group of Goods. Therefore, defining a highly detailed set of flows in the model might be useless as a number of assumptions would require to be formulated to estimate observed data by flow, starting from aggregated figures;
- flows are linked in the model with the trades of the REM, which are defined from the NACE-CLIO 59 sections. When a NACE-CLIO section does not correspond exactly to a NST/R code, some assumptions are needed to define the correspondence between trades and flows;
- the number of flows affects the computational resources needed to run the model. The computer power currently available allows us to increase the number of ten flows used in STREAMS, but not too many new flows could be added to the model.

In short, a compromise among the ideal level of detail, the availability of data and the level of simplicity required by the other points raised above has been pursued.

5.2.2 Flows and handling categories

The definition of the freight flows had its main aim in obtaining a set of flows which were more homogenous. The homogeneity of flows can be defined on the basis of different elements.

- a flow is homogenous in terms of the handling requirements when all the commodities included in it are carried as bulk or in container, etc.;
- a flow is homogenous in terms of modal choice when the modal split is similar disregarding the specific context: origin-destination pair, national or international shipments, etc.

However, the analysis of data shows that it is very difficult to identify homogenous flows. The main element which actually identifies homogenous flows in a practical form is the handling category. Homogeneity in terms of handling category is particularly relevant because different aspects which are represented in the model (e.g., modal choice and intermodal chains, cost functions, load factors, logistic chains) are dependent on the logistics requirements. Besides this, in the SCENES model, the logistics chains are represented by means of a suitable appended module (SLAM) which works with groups of commodities called logistics families. The logistics families are built according to the handling requirements of goods and therefore the flows have been defined on a similar basis to make the interface with the SLAM logistics module easier.

When the structure of the STREAMS freight model was defined, the whole TREX data was not available, therefore, the flows were set up on the basis of the NST/R chapters (1-digit) or sub-chapters (2-digit). As a result, not all the 10 flows of the STREAMS model were homogenous in terms of handling category. As the handling requirements affect modal choice, costs, load factors and other elements relevant for the model calibration, these non-homogeneous flows represent a problem.

TREX data does not give information about the handling category. To identify homogenous groups of commodities, two different additional sources have been used: the database of Trieste port (the full database was not available, but extractions of the information included have been obtained) and the classification of the NST/R 2-digit groups into logistical families produced for SLAM. The first part of the analysis has been based on the Trieste database information. Once a definition has been obtained on this basis, it has been compared to the SLAM classification, in order to detect and understand the differences between them.

On the basis of the analysis a set of thirteen flows for the SCENES model have been defined as shown in Table 5.1.

Table 5.1: SCENES freight flows

Flow	NST/R group	Group of Goods	Handling category
1- Cereals and agricult. Products	00 01 04 05 06 09 17 18	1 3 4 5 part of 6 7	General cargo
2 – Consumer food	02 11 12 13 16	Part of 2 Part of 6	Unitised
3 – Conditioned food	03 14	Part of 2 Part of 6	Unitised
4 – Solid fuels and ores	21 22 23 41 45 46	8 11 12	Solid Bulk
5 – Petroleum products	32 33 34	10	Liquid Bulk
6 – Metal products	51 52 53 54 55 56	13	General Cargo
7 – Cement and manuf. Build mat.	64 69	14	Unitised
8 – Crude building materials	61 62 63 65	15	Solid Bulk
9 – Basic chemicals	81 83	17 part of 18	Solid Bulk
10 – Fertil,, plastic and oth. Chem.	71 72 82 84 89	16 part of 18 19	General Cargo
11 – Large Machinery	91 92 939	part of 20	General Cargo
12 – Small Machinery	931	part of 20	Unitised
13 – Miscell. Manufact. Articles	94 95 96 97 99	21 22 23 24	Unitised

The flows have been obtained trying to aggregate the NST/R codes with the same handling category. The type of the commodity is also a relevant criteria: agricultural products have not been mixed with solid fuels though both are solid bulk in terms of handling category. In making the aggregation some assumptions have been made to make the task easier and reduce the number of flows. All spurious aggregations, however, regard flows whose global volume is of minor importance[7]. In some cases, the SLAM classification has been adopted.

The definition of the flows has also been described in terms of aggregations of the Groups of Goods. This is because national data from the Carriage of Goods is provided according to this classification and it is useful to have a straightforward correspondence.

From Table 5.1 above, it can be seen that in most cases the flows are simple aggregations of Groups of Goods without need for splitting the Groups themselves. However, four Groups are part of two different flows. Groups 2 and 6 (foodstuff) are both part of flow 2 and flow 3. Group 18 (chemicals) forms both flow 9 and flow 10, because it includes general chemical products like plastic and medicinal as well as coal chemicals. Finally, group 20 (machinery and transport equipment) gives rise to both flows 11 and 12. In all cases, it has been considered that the need for splitting the national observed data is justified by the relevant difference in terms of handling category of the commodities. Moreover, the NACE-CLIO data available is often more aggregated than the R-59 used in this analysis, the final definition is a fair compromise between the need of assumptions to process transport data and economical data.

The freight flows are also linked with the trades of the REM (which are built according to the NACE-CLIO classification of economical activities). Such a classification is different from the NST/R, and even if both are considered at their maximum detail, the correspondence between them needs some assumptions. Table 5.2 below reports the correspondence which has been assumed in the definition of the freight flows[8].

[7] This is true also if the traffic between EU15 and the rest of the world is considered.

[8] In Table 5.1 only the NACE-CLIO codes used to define the REM factors have been introduced.

Table 5.2: Correspondence between NACE-CLIO and NST/R codes

NACE - CLIO code	NST/R code				
010	00 09	01 17	04 18	05	06
031	21				
033	22				
050	23				
073	32				
098	33				
110	34				
135	41	45	46		
136	52	53	54	55	56
137	51				
151	64	69			
153	95				
155	95				
157	61	62	63	65	
170	71 892	72 893	81 894	82 895	83 896
190	94				
210	92	939			
230	931				
250	931				
270	91				
290	91				
310	14				
330	14				
350	02				
370	11				
390	12	13	16		
410	96				
430	96				
450	971	975	976	979	99
471	84				
473	972	973	974		
490	891				
510	971	975	976	979	99

Source: ME&P - TRT

The correspondence between flows and trades is straightforward in the majority of cases, which means that the 13 flows defined are consistent with the REM factors structure. However, there are two issues to take into account.

- In some cases the NACE-CLIO classification is too coarse with respect to the NST/R one. For instance, NACE-CLIO code 010 includes all agricultural products which NST/R classifies into seven different 2-digit groups in 2 different chapters. Similarly, NACE-CLIO code 170 includes 6 different NST/R groups in two different chapters.
- In other cases, the correspondence between NACE-CLIO and NST/R would be valid, but the STREAMS REM factor associates codes which are not consistent with the freight flow definition. For instance, trade 16 is made up of NACE-CLIO codes 471 and 473. Code 471 is fully correspondent to NST/R 84, which forms flow 10, whereas code 473 is part of the products included in NST/R 97 which forms flow 12.

When the NACE-CLIO classification is coarse there are two options: either a unique flow is defined by grouping all the NST/R codes included in that NACE-CLIO branch, or the REM trade made of the NACE-CLIO branch gives rise to more than one flow. The first choice have been made. For NACE-CLIO code 170 this choice has not been difficult because all the NST/R groups included in it are quite fairly classified as ‘Other chemicals’. For code 010, a split would have been advisable, because the agricultural goods included are well-distinguished into two big groups: general cargo goods and solid bulk goods. However, there is no way to split NACE-CLIO data without a considerable amount of arbitrariness, so a unique flow has been defined.

It was therefore decided to re-define the factors in order to achieve a more direct correspondence among trades and flows. Table 4.6 shows the new set of REM factors used in the model.

The set of freight flows defined in Table 5.1 can be linked to the REM trades without too many approximations. In Tables 5.3 and 5.4 below, the composition of flows in terms of trades and of trades in terms of flows is shown. With this correspondence, all the REM factors give rise to one transport flow only. This simplifies the link between the trade matrix and the flow matrix.

Table 5.3: Correspondence between the freight flows and the REM factors

Flow	NST/R group	REM factor	NACE-CLIO section
1 – Cereals and agricult. products	00 01 04 05 06 09 17 18	1	010
2 – Consumer food	02 11 12 13 16	17	350 370 390
3 – Conditioned food	03 14	18	310 330
4 – Solid fuels and ores	21 22 23 41 45 46	2 6	031 033 050 135
5 – Petroleum products	32 33 34	4	073 098 110
6 – Metal products	51 52 53 54 55 56	7	136 137
7 – Cement, Manuf. Build. mat.	64 69	8	151
8 – Crude building materials	61 62 63 65	10	157
9 - Basic chemicals	81 83	11	170
10 – Fertil., plastic and oth. Chem.	71 72 82 84 89	12 20 23	170 - 471 490
11 – Large Machinery	91 92 939	14 16	210 - 270 290
12 – Small Machinery	931	15	230 250
13 – Miscell. Manufact. articles	94 95 96 97 99	9 13 19 21 22	153 155 190 410 430 450 473 510

Table 5.4: Correspondence between the REM factors and the freight flows

REM factor	NACE-CLIO section	Flow	NST/R group
1 – agricultural, forestry and fishery products	010	1	01 17 18 00 04 05 06 09
2 - coal and coke and lignite	031 033 050	4	21 22 23
3 – extraction of crude petroleum and gas	071 075		
4 – manufactured fuel	073 098 110	5	32 33 34
5 – Other fuels	095 097 099		
6 – ferrous and non ferrous ores	135	4	41 45 46
7 – metals	136 137	6	51 52 53 54 55 56
8 – cement and building materials	151	7	64 69
9 – glass and ceramic materials	153 155	13	95
10 – other non metallic mineral products	157	8	61 62 63 65
11 – basic chemicals	170	9	81 83
12 – fertilisers and chemical products	170	10	71 72 82 892 893 894 895 896
13 – metal products except machinery	190	13	94
14 – agricultural and industrial machinery	210	11	92 939
15 – electrical products	230 250	12	931
16 – transport equipment	270 290	11	91
17 – food, beverages, tobacco – consumer	350 370 390	2	02 11 12 13 16
18 – food, beverages, tobacco – conditioned	310 330	3	03 14
19 – textiles and clothing, leather and footwear	410 430	13	96
20 – paper pulp	471	10	84
21 – printing products	473	13	972 973 974
22 - other manufactured products	450 510	13	971 976 975 979 99
23 - other chemical products	490	10	891

With this correspondence between trades and flows, the observed matrix of values can be obtained in a straightforward way at the nation-to-nation level directly from the TREX data. Indeed, all factors are made up of different NST/R codes. The matrix at zone-to-zone level (both for volumes and for values) result from the NACE-CLIO data. Also the whole national traffic in terms of value should be estimated from the NACE-CLIO data as figures in terms of value are not available from the EUROSTAT Carriage of Goods database.

The connection between freight flows and the SLAM logistical families is straightforward because each flow is also a logistical family. Indeed, the distinction between Consumer food and Conditioned food and between Large Machinery and Small Machinery have been introduced among flows in order to match the logistical families definition.

5.2.3 Freight transport modes

5.2.3.1 Main transport modes

The structure of the main modes in the SCENES freight model is derived from that used in the STREAMS model, but with some relevant difference:

- a new main mode has been defined for representing shuttle rail services;
- several intra-zonal modes have been defined instead of one mode, in order to enhance the representation of intra-zonal trips;
- as the intra-zonal trips are modelled with dedicated modes, Light Goods Vehicles is used as a mode to represent rigid trucks only used on the medium distances.

Ten main modes (or user modes) of transport are implemented in the model (Heavy Goods Vehicle (HGV), Light Goods Vehicle (LGV), bulk rail, bulk ship, bulk waterway, product pipelines, air freight, container rail, container ship, container waterway, and shuttle rail). In addition, there are nine intra-zonal modes (representing trips of different length and by different mode), therefore a total of nineteen modes are included in the model. HGV represent articulated trucks used on the longer distances whilst LGV represents rigid trucks with a lower average distance. Lighter vehicles used for local distribution are modelled by intra-zonal modes.

Each mode is available to a set of flows, according to its specific features with respect to the nature of the flows, which are grouped into four handling categories with similar requirements:

- Solid bulk (B)
- Liquid bulk (L)
- General Cargo (G)
- Unitised freight (U)

5.2.3.2 Segmenting the inter-modal transport services

The selection of how transport flows choose between modes and combinations of different journey stages during a typical origin – destination trip, is determined by stochastic choice models based on the ‘user mode’ and ‘network mode’ concepts, which is explained below. A structure which involves the use of various user modes at different parts of the shipment, can be represented unambiguously by defining a hierarchy of modes. Among the network modes that the shipment uses, a shipment is said to belong to that user mode which lies highest in the mode hierarchy.

For example, a particular shipment is said to be of user mode 'air freight' provided that it uses the air network during the journey. It is of user mode 'inland waterway' if it uses the river network (and possibly other modes) but not the air network. Truck is considered as a user mode only if the shipment does not use any of the other modes.

The full hierarchy is pipeline, air freight, ship, inland waterway, railway, then truck. Ferry is not included as a user mode as it is always assumed to be serving some other mode. The model distinguishes between unaccompanied trucks (i.e., trailers dropped at ports and then sent by ship to another port for later onward driving), and accompanied trucks (i.e., when the truck and the driver are loaded onto the ferry), on the basis of the typical commodities carried by each of these services.

5.2.3.3 Transport travel stages (network modes)

The modes introduced above are the main modes of the model. A consignment made by means of one of such modes can be regarded as a collection of travel stages. Each main mode has its own relevant travel stages. For instance, for ship, port operations are a relevant stage which has no correspondent stages for truck.

More than one user mode can be used for the same consignment. In this case, one is the main mode while others are 'feeders' (according to the hierarchy presented previously). In the model, network modes are used to represent travel stages and the role of feeder assumed by user modes.

Deep sea shipping is the transport mode used for intercontinental shipments (i.e., Europe to and from Asia or Europe to America) and its relevance for the European Transport network is due to the choice of the feeder mode from the origin to the deep sea port or conversely from the deep sea port to final destination. Had deep sea shipping been modelled as a main transport mode, feeder modes competition would have been simulated at the level of travel stages (network modes components) and then not easily managed. Instead the mode was modelled as a travel component of all the transport modes that might be used as feeders, so that their competition is better simulated at the modal split level.

5.2.3.4 Modal split

Modal split is performed using a multinominal nested logit model. The nested logit has three different level of choice:

- the first choice is between land modes and other modes (shipping and pipeline, or shipping and air for unitised flows);
- the second choice is between land modes (rail, barge and truck);
- the third one, at the lowest level, is between HGV and LGV.

5.2.3.5 Assignment units

The assignment unit is tonne for each mode except for road transport, where the unit is represented by vehicles. Tonne has been chosen as assignment unit for rail, ship and air freight because, an average load factor for trains or ships has a lower degree of significance than truck load factor, as the dimensions of vessels are much more variable. Finally, available statistics for such modes are mainly expressed in terms of tons rather than vehicles.

The assignment unit for road transport is truck. The load factor depends upon the type of flow. The values implemented in the model are described in section 5.3.

5.2.4 Supply description

On the freight supply side, there are three main enhancements in SCENES over the STREAMS model. They are:

- the implementation of rail shuttle services;
- the revision of the shipping port description; and
- the implementation of a more detailed description of intra-zonal trips.

The first two areas here were described in Sections 2.2.7 and 2.2.8. The revised treatment of intrazonal freight traffic is now discussed here. It should be noted that the modelling of intra-zonal freight takes place on a quite separate network from the intra-zonal passenger trips. There is no interaction between the two.

In the STREAMS freight model, intra-zonal trips were represented in a simplified way, with a single mode. For the SCENES model a much more detailed structure has been adopted. Five intra-zonal distance bands have been implemented. The lengths of such bands have been set to values consistent with the database of intra-zonal road consignments available. These lengths are:

- less than 10 km;
- 10-25 km;
- 25-50 km;
- 50-100 km; and,
- 100-200 km.

For each zone a different number of intra-zonal bands have been defined depending on the size of the zone itself in a similar fashion to the passenger model. The larger bands have been applied to the larger zones in Spain, Sweden, etc.

Since in some countries, rail and IWW can be used in addition to road for intra-zonal trips for some flows (according to data drawn from NEWCRONOS), the three bands over 25 km have been defined more than once to allow more modes for intra-zonal trips in the relevant countries. In Table 5.5 below, the different link types are shown together with a description of the mode allowed and the countries where each link type has been defined.

Table 5.5: Freight intrazonal link types

Link Type	Description	Countries
910	Intra-zonal link under 10 km – only road	All
911	Intra-zonal link between 10-25 km – only road	All
912	Intra-zonal link between 25-50 km – only road	All
913	Intra-zonal link between 50-100 km – only road	All
914	Intra-zonal link between 100-200 km – only road	All
922	Intra-zonal link between 25-50 km – road and rail	BEL FIN FRA GER LUX POR SWE
923	Intra-zonal link between 50-100 km – road and rail	BEL FIN FRA GER LUX POR SWE
924	Intra-zonal link between 100-200 km – road and rail	BEL FIN FRA GER LUX POR SWE
932	Intra-zonal link between 25-50 km – road and IWW	NED

For instance, link type 922 represents both road and rail intrazonal trips. In Belgium, Finland and so on, this link is coded to represent intrazonal trips between 25 and 50 km instead of link 912 which is used, for instance, in Italy, where rail is not used for short trips.

Only one link has been defined for modelling road and IWW competing for intra-zonal trips, because this competition takes place only in The Netherlands and bands over 50 km are not required for such a country given the size of the zones.

On each intra-zonal link, different modes are allowed. Thus nine intra-zonal user modes have been defined. The list of the intra-zonal user modes and network modes is presented in Table 5.6 below together with the link types where each mode is allowed. The table also shows the flows (see Table 5.1) for which each mode is available, as non-road modes are used by some kind of goods only.

Table 5.6: Freight intrazonal modes

User mode	Network mode	Description	Link type	Flow
21	91	Road vehicles for intra-zonal link under 10 km	910	All
22	92	Road vehicles for intra-zonal link between 10-25 km	911	All
23	93	Road vehicles for intra-zonal link between 25-50 km	912 922 932	All
24	94	Road vehicles for intra-zonal link between 50-100 km	913 923	All
25	95	Road vehicles for intra-zonal link between 100-200 km	914 924	All
26	96	Rail for intra-zonal link between 25-50 km	922	4 6
27	97	Rail for intra-zonal link between 50-100 km	923	4 6
28	98	Rail for intra-zonal link between 100-200 km	924	4 6
29	99	IWW for intra-zonal link between 25-50 km	932	4 5 8

Road is the only mode used for intra-zonal trips for most of the flows. According to NEWCRONOS data only flow 4 (Solid Fuels and Ores) and 6 (Metal Products) use rail and only flow 4, 5 (Petroleum products) and 8 (Crude Building Materials) use IWW. Therefore, the three intra-zonal modes ‘rail’ and the intra-zonal mode ‘IWW’ have been set as usable only for those flows.

A tree logit structure rules the choice among the different intrazonal modes (and therefore among the different distances). The hierarchy of the tree logit structure includes three different levels. At the first level, an intra-zonal ‘super-mode’ (i.e., a mode representing the intra-zonal trips as a whole) is the alternative to inter-zonal modes.

At the second level, if the intrazonal ‘super-mode’ is chosen, the alternatives are the five distance bands; each band is represented in turn by another ‘super-mode’ representing all the modal alternatives within that band. In the two shortest bands only one mode is available. At the third level, the choice is between the alternative modes within the chosen band (for instance, modes 23, 26 and 29 in the distance band 25-50 km).

For each flow a different hierarchy has been implemented according to the number of modes available. With the described structure, specific modal constants can been calibrated for each intrazonal mode, in order to match observed patterns of local traffic, although little data is available on this matter.

5.2.5 Interface with the Appended Logistic Module (SLAM)

The features of the Appended Logistic module are fully described in Chapter 6 – the main features of the system and its implementation in the overall modelling process are described below**.**

5.2.5.1 Objective of SLAM

In brief, the role of such a module is to allow a representation of logistical chains to be modelled. The matrix of flows produced by the Regional Economic Module (REM) via the interface ‘FREDA’ is a matrix of economic trades translated into volumes (in the following paragraphs, the term ‘trade flow’ will be used for the amount of goods traded between two zones in terms of tonnes as reported by the 'FAF' file). However, when two zones trade a certain amount of goods, the shipments which will be generated could not be just between the two zones themselves. Instead part of the shipments can pass through third zones, e.g., where a warehouse is located. At the same time one or more changes of mode can take place, e.g., the final distribution from the warehouse normally uses road transport even if the shipment started by train.

Due to SLAM, the original matrix derived from the REM can be re-adjusted in order to incorporate the logistical chain: that part of 'trade flow' which does not go directly from its first origin to its final destination is split among various logistical chains. In principle, this should enhance the capability of the model to represent the transport performance in terms of tonnes-km derived from the overall amount of trades in terms of tonnes. Secondly, the modelling of loads on links loads should see an improvement, because the traffic should be distributed on more routes. Finally, also modal split could be improved as the final distribution legs of the chain are normally short distance trips made by truck.

Therefore, the major role of SLAM is improving the representation of freight traffic on the network.

5.2.5.2 Implementation of SLAM / SCENES freight model connections

The transport module produces transport disutilities by OD pair according to which the REM allocates factors among zones. Such disutilities would be affected by the intervention of SLAM (disutilities will change if part of the trade between two zones has to pass through a third zone) and so a specific piece of software would be needed to adjust the disutilities to be fed into the REM. An alternative solution would be to put the SLAM off-line and not to include it in the LUSA-TASA interaction[9]. We discuss these alternatives and the final choice for the SCENES/ SLAM connection below.

(i) Full connection - using SLAM to revise matrix and to affect disutilities

In the first alternative, other than for revising the matrix, the outcomes of SLAM would be fully used in the calibration process, because the disutilities by OD pair produced by the transport module would be weighted according the distribution of the trades among the alternative OD chains. For instance, if 50% of the trade between zone A and zone B would pass through a zone C, the generalised cost for trading between zone A and B would be calculated as the weighted average of the generalised cost incurred travelling directly from A to B and of generalised cost of travelling from A to C and than from C to B. The new disutilities would be fed into the REM module via the DERF interface so that the distribution of the factors among zones would take into account the logistical chains.

SLAM should be therefore run after the interface FRED and comes up with two outcomes: the new matrix to be fed into TASA and the distribution of each OD trade among the alternative OD chains. The second output would be used to weight the disutilities produced by TASA in the 'TAD' file before to run the interface DERF. Figure 5.1 shows the sequence of operations.

(ii) Light connection - using SLAM to revise matrix without affecting disutilities

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[9] LUSA and TASA are the 'land use / demand' and 'transport' modules of the SCENES model software. FRED / DERF are the interaction modules going between LUSA and TASA and between TASA and LUSA respectively.

The second alternative is using SLAM for its main scope, that is improving the description of the matrix to transform it from a matrix of ‘trade flows’ into a matrix of shipments. In other words, the interface between the transport module and the REM module should be based on the disutilities produced by the assignment and the modal split of the original matrix. SLAM would not enter in the calibration of the overall model (i.e., calibrating the REM module and reproducing correctly the observed matrix and the observed modal split in terms of volumes).

In operating terms, the usual LUSA - FRED - TASA - DERF - LUSA sequence would be followed for the calibration, while SLAM should be run ‘off-line’ after the FRED interface and followed by an independent TASA.

The following point should be taken into account when considering the implementation of this second alternative. Ideally, SLAM should read all the transport information from the TAM file: volumes, times and costs by OD pair. This would mean that the transport module TASA would need to be run every time before than running SLAM to let SLAM know the new matrix and the new set of costs and times. However, while the matrix is to be updated every time, costs and times rest virtually unchanged unless major changes are included in the cost functions or in the network. Therefore, if the matrix is read directly from the FAF file, one can avoid to run TASA before SLAM; costs and times can be read at the beginning of the operations and, in the following of the calibration, only when substantial changes are introduced in the model. This allows a further reduction in data handling activities and simplifies the running procedures, while it hardly affect the accuracy of the outcomes.

(iii) Approach for appending SLAM

The immediate advantage of choosing alternative (i) is that transport disutilities would reflect more correctly the generalised cost of trades between the OD pairs. On the other side, there would be some disadvantages:

1. the calibration process would be more complex because it would involve the calibration of REM, TASA and SLAM at the same time. Changes in the outcomes of SLAM (which is a new element whose behaviour is to discover) could affect REM by making the equilibrium of the model more unstable. This would require the solution of an equilibration problem, requiring convergence of flows and disutilities throughout the SCENES model.

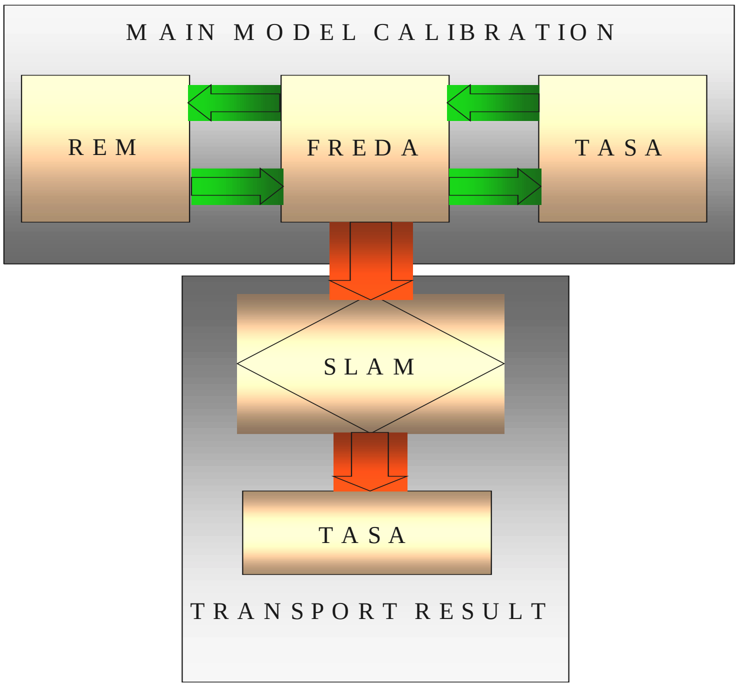
2. additional software to perform the weighting of disutilities according to the SLAM results would be required, this software should be developed and tested and this is time-consuming;

3. finally, there are fears that the a huge amount of computer memory could be required. The experimental version of SLAM with 10 flows produced a ‘RouteOut’ file (the file where the composition of each OD by OD chain is stored) of 400 Mb. Changing format can reduce this dimension and, presumably, the calibrated version of SLAM should give rise to less OD chains for each original OD pair, but on the other side the SCENES model has 13 flows and not only10.

The second alternative (ii) has the disadvantage of not considering the additional information produced by SLAM about the transport disutilities. The advantage would be that calibration could be carried out in the usual way, more independently from SLAM and without the need for new software.

Assuming that disutilities only exhibit a marginal change after re-configuration, and in the light of the other disadvantages of the equilibrium approach, we have chosen to implement the second, ‘light’ alternative (see figure 5.1).

Figure 5.1: Approach chosen to append SLAM to the main SCENES model



5.3 SCENES freight model parameters

This section describes the main parameters used in the SCENES freight model, namely:

- load factors;
- cost functions; and,
- values of time.

5.3.1 Load factors

In the SCENES freight model the assignment unit is ton for each mode except for road transport, where the unit is represented by vehicles (trucks). The number of truck units correspondent to a certain level of road traffic (expressed in tons) is obtained by means of suitable load factors. Different road modes are present in the model: HGV, LGV and road intrazonal modes. Such modes are different in terms of dimensions and typical range of operating distance, so different load factors have been implemented.

A re-estimation of the load factors included in the STREAMS freight model has been performed, partly because LGV and intra-zonal modes are now considered separately.

Many elements affect the number of tonnes carried and a representative load factor can only be drawn from observed data either in terms of vehicles and tonnes or in terms of vehicle km and tonnes km. Different sources of data can lead to different estimates depending on the type of traffic monitored (e.g., HGVs on longer distances, national traffic by all road vehicles, etc.). For instance, the Alps Crossing database reports the amount of trucks and the amount of tonnes crossing Alps by NST/R chapter, therefore the average load by truck can be easily calculated. This database was used to assess the average load factor in the STREAMS model in conjunction with Italian data regarding empty trips. However some comparisons of the data suggests that these figures were perhaps overestimates, since the Alps crossing traffic is most likely formed by a larger amount of fully loaded HGV than the average road traffic. For that reason, additional new data, such as UK data from the Annual Report of the Continuing Survey of Road Goods Transport (CSRGT) has also been considered for SCENES.

The set of load factors by flow which were derived by the comparison of data from these various sources are reported in Table 5.7 below. The load factors for intra-zonal modes have been set according to suitable assumption regarding the share of HGVs in each distance band. Such assumptions have been made according to CSRGT data and Sweden data about freight road traffic by distance band.

Table 5.7: Load factors for Heavy Goods Vehicles including empty trips (Tonnes/vehicle)

Flow	HGV	LGV	Intra-zonal road modes				
			<10 km	10-25 km	25-50 km	50–100 km	100–200 km
Agricultural products	10.7	3.2	3.2	3.2	3.2	5.1	6.9
Consumer food	10.8	3.2	3.2	3.2	3.2	5.1	6.9
Conditioned food	9.8	3.0	3.0	3.0	3.0	4.7	6.4
Solid fuels and ores	10.8	3.3	3.3	3.3	3.3	5.2	7.1
Petroleum products	11.9	3.6	3.6	3.6	3.6	5.7	7.8
Metal products	11.6	3.5	3.5	3.5	3.5	5.6	7.6
Manufact. Building Materials	11.3	3.4	3.4	3.4	3.4	5.4	7.3
Crude Building Materials	10.7	3.2	3.2	3.2	3.2	5.1	6.9
Basic Chemicals	10.9	3.3	3.3	3.3	3.3	5.2	7.1
Fertil., Plastic and other Chem.	11.7	3.5	3.5	3.5	3.5	5.6	7.6
Large machinery	8.3	2.5	2.5	2.5	2.5	3.9	5.4
Small machinery	7.4	2.3	2.3	2.3	2.3	3.6	4.9
Miscellaneous articles	7.4	2.3	2.3	2.3	2.3	3.6	4.9

Sources: TRT estimates on: *GS EVED/Dienst fur Gesamtverkehrsfragen* data (Alps Crossing database), UK CSRGT data and CONFETRA data

5.3.2 SCENES freight model cost functions

In the following sections, the cost functions used are presented mode by mode.

5.3.2.1 Road cost functions

For road transport, different cost functions have been estimated. The model includes different modes relating to road: HGV used on longer distances, LGV used on shorter distances, and an intra-zonal road mode which represent vehicles used for local distribution. For each of these modes, a new cost function has been developed. Also motorway tolls and ferries tariffs have been re-estimated with respect to the values used in the STREAMS model.

(i) Heavy Goods Vehicles cost

The cost function for HGV has been estimated using a new approach from that used in STREAMS, where operating costs had been used. Instead, for SCENES, a large sample of rates for road consignments between Italy and other European countries (both EU and CEEC countries) is used. These data were collected in 1998 and 1999 (TRT 1998, TRT 1999). This sample of road tariffs was used to estimate the value of road haulage for Italian international freight traffic.

From the sample of rates, a cost function using distance and consignment time as the explanatory variables was estimated. This function was compared against the STREAMS approach (road costs resulting from operating costs) and was broadly comparable. From this function the cost function for the SCENES freight model for HGV has been drawn. The original function was converted from Liras per consignment to EUROs per tonne, using 'official' exchange rates. Also, values have been deflated according to the average Consumer Price Index for EU15 countries drawn from OECD data (OECD main indicator, August 1999).

In order to transform the cost in EURO/consignment to EURO/tonne, the average load per truck has been considered. The estimation of load factors is described in the section above. Table 5.8 below shows the cost functions which were determined.

Table 5.8: Heavy Goods Vehicle cost function

Flow	Constant (EURO/ton)	'DistPar' (EURO/ton-km)	'TimePar' (EURO/ton-hr)
Agricultural products	13.9	0.0409	0.2727
Consumer food	14.1	0.0414	0.2760
Conditioned food	14.0	0.0410	0.2738
Solid fuels and ores	13.3	0.0391	0.2606
Petroleum products	11.5	0.0338	0.2252
Metal products	13.1	0.0383	0.2555
Manufactured Building Materials	13.5	0.0397	0.2648
Crude Building Materials	13.5	0.0397	0.2648
Basic Chemicals	13.3	0.0389	0.2592
Fertilisers, Plastic and other Chemicals	13.0	0.0381	0.2540
Large machinery	18.4	0.0539	0.3597
Small machinery	18.4	0.0539	0.3597
Miscellaneous articles	18.4	0.0539	0.3597

In the model only part of the total cost affects the path choice. These costs are: driver cost (which is a time-related component) and fuel, lubricant and maintenance cost (which are distance-related component). According to the split of operating cost reported in TUTTOTRASPORTI 1997, the driver cost is about 65% of the whole time-related costs, while fuel, lubricant and maintenance account for about 60% of distance-related costs. Therefore, these percentages have been applied to the average of 'TimePar' and 'DistPar' of Table 5.8.

(ii) Light Goods Vehicle cost

For LGV, data regarding rates data were not available. In order to estimate the cost function, a comparison between the operating cost of medium size trucks and heavy trucks drawn from TUTTOTRASPORTI 1997 has been made. According to this source, the time-related operating costs of a medium size vehicle are about 90% of those for a heavy vehicle. On the other hand, however, LGV has a lower average load. On the basis of the average dimensions of medium and large size vehicles, LGV load has been estimated as about 40% of HGV load. Therefore the time-related cost per ton has been obtained by dividing the 90% of HGV TimePar by 0.4.

Secondly, as LGV should be competitive over the shorter distances, the constant cost has been excluded and the DistPar has been estimated to make the cost of LGV and HGV equal at the distance of 300 km. Such a distance has been estimated as no data were found about the mix of light and heavy vehicles by distance class. It might be noted that this distance threshold is longer than that used to define the LGV cost function for the STREAMS model. Indeed, in the STREAMS model LGV represented also small vehicles used for local distribution, whereas in the SCENES model such modes are represented only by the intra-zonal road modes.

The result of the estimation is reported in Table 5.9.

Table 5.9: Light Goods Vehicle cost function

Flow	**'DistPar' (EURO/ton-km)**	**'TimePar' (EURO/ton-h)**
Agricultural products	0.0727	0.6135
Consumer food	0.0736	0.6210
Conditioned food	0.0730	0.6160
Solid fuels and ores	0.0695	0.5863
Petroleum products	0.0601	0.5067
Metal products	0.0682	0.5749
Manufactured Building Materials	0.0706	0.5959
Crude Building Materials	0.0706	0.5959
Basic Chemicals	0.0692	0.5833
Fertilisers, Plastic and other Chemicals	0.0678	0.5716
Large machinery	0.0960	0.8094
Small machinery	0.0960	0.8094
Miscellaneous articles	0.0960	0.8094

In terms of implementation, the same rule adopted for HGV applies: only part of the total cost affects the path choice.

(iii) Intra-zonal road modes

The intra-zonal road mode represents small vehicles used for local distribution of freight. The cost function for this mode has been estimated in a similar way to that used to estimate the cost function for LGV, that is according to the operating costs and the different average load.

The time-related operating costs for a van are about 90% of the correspondent costs for medium size vehicle (as stated before, 60% of time-related costs are driver costs which are not very different between various types of vehicle). The average capacity for van (no sources were available about average load) is 1.6 tonnes. Therefore, the Time-relating cost has been estimated as the 90% of LGV cost and distributed on 1.6 tons.

The same criteria has been followed for distance-related costs. However, as the distance cost parameter for LGV had been estimated to match the HGV cost at 300 km, the HGV parameter has been used as a starting point: distance-related costs for a van are about 27% of costs for HGV.

Parameters have not been distinguished by flow, as it is unlikely that the nature of the commodity is a relevant element for local distribution. The cost function estimated is shown in Table 5.10.

Table 5.10: Intra-zonal mode cost function

Flow	**'DistPar' (EURO/ton-km)**	**'TimePar' (EURO/ton-h)**
All	0.1664	3.3301

The cost function has not been distinguished by flow, but as the load factor along the distance bands changes, a different parameter is introduced for each intra-zonal mode.

(iv) Truck on ferry

The cost incurred by truck on ferry is made up of two components: the ferry tariff and a portion of the operating costs. The two components are considered separately as follows.

The **ferry tariffs** for heavy vehicles have been estimated from different sources:

- a sample of tariffs for Baltic service reported in the VTT–NEA 'study Transport Routes Between Western Europe and Russia';
- the official tariffs of the ferry company 'Adriatica di Navigazione' for the Brindisi (Italy)-Greece services;
- the official tariffs for two Channel services (Dover – Calais and Harwick – Hoek van Holland) found on the A2b travel web site; and,
- the tariffs implemented in the STREAMS model.

For Baltic services, a linear function of time has been estimated from the sample of tariffs reported by the VTT-NEA study. The function concerns HGV and it is:

$$Tariff = 194.2 + 45.5 * Travel\ time \qquad [1]$$

For the other European zones where ferries are modelled, tariffs for heavy vehicles have been estimated starting from the car tariffs implemented in STREAMS. The ratios between the truck tariffs and the car tariffs have been estimated in the different contexts according to the observed tariffs. The ratio has been found being dependent upon the travel time for Channel and Baltic services while it was considered fixed for services between Italy and Greece:

$$Channel\ ratio = 4.95 - 0.15 * travel\ time^2 + 0.58 * Travel\ time \qquad [2]$$

$$Baltic\ ratio = 4.1 - 0.11 * travel\ time^2 + 0.40 * Travel\ time \qquad [3]$$

$$Italy/Greece\ ratio = 4$$

By applying the ratios to the car tariffs implemented in STREAMS, new truck tariffs have been estimated. The Channel ratio has been applied also to ferries operating on domestic routes in France and UK, the Italy / Greece ratio has been also applied to domestic routes in Italy, Greece and Spain, while the Baltic ratio was used for domestics services in Scandinavian countries and for routes between Scandinavian countries and UK. In any case a minimum ratio of 2 has been applied.

The tariffs estimated concern with the HGV. For LGV tariffs have been halved.

Travelling by ferry, in addition to the tariff, trucks still bears a certain amount of **operating costs**. In particular, distance related costs are zero, because the lorry is not moving, but time-relating costs are totally or partially present. They are totally paid if the lorry is accompanied, while when the lorry is unaccompanied on ferry, also a share of time related costs, those related to driver, are saved.

The ferry tariffs are modelled as a charge on each ferry links. The share of operating costs to be considered are modelled by imposing a null value to the distance terms and to the constant term in the HGV function because the latter is already paid on the main truck network mode.

(v) Truck on rolling roads

From the point of view of the costs, Rolling Roads are like accompanied ferries in that trucks pay a tariff and bear also time-related costs.

Rolling roads tariffs have been estimated from the official lists provided by Ökombi. From the tariffs by O-D relation a linear function has been estimated with a fixed cost and a distance-related term. Parameters of the function are shown in Table 5.11.

Table 5.11: Rolling Road cost functions

Mode	Constant Cost (EURO/veh)	'DistPar' (EURO/veh-km)
Truck on Rolling Road	112.4	0.42

As stated before, the mode 'Rolling Road' is equivalent to accompanied truck on ferry. Therefore, the cost function is implemented by excluding distance-related terms and adding the tariff on the link type (transit lines) representing rolling road services

(vi) Tolls

Tolls on motorways for freight vehicles in 1995 have been drawn from AISCAT (the association of tolled motorways concessionaires).

Tolls have been considered both for 3-axis vehicles and for more than 3 axis trucks. The former has been used for LGV, the latter for HGV. Tolls are reported below in Table 5.12.

Table 5.12: Tolls per km in European countries

Country	3-axis Vehicles (EURO/veh*km)	> 3-axis Vehicles (EURO/veh*km)
France	0.129	0.129
Italy	0.053	0.098
Spain	0.137	0.163
Portugal	0.113	0.122
Greece	0.036	0.044

Source: AISCAT 1995

In other EU countries – Austria, Denmark, Germany, Sweden, Netherlands, Luxembourg and Belgium – truck drivers have to purchase a vignette which has a fixed annual cost. The same principle is applied in Switzerland.

As the truck costs have been estimated from rates, tolls have been implicitly included in the cost function since rates take into account tolls. For countries when motorways are tolled on a distance-related basis, tolls are to be implemented separately in the model because they affect route choice and hence subtracted from the distance parameter cost estimated from the tariffs. Instead, for countries where a vignette is paid, using motorways does not mean paying an extra-cost. On the contrary, once the vignette has been purchased, motorways are most likely to be used. Therefore, the cost of vignette has not been implemented in the model.

The toll per vehicle is added to distance-related cost on the link types representing tolled motorways.

5.3.2.2 Rail cost functions

In SCENES there are three different rail modes: conventional rail, unitised rail and shuttle services. The cost functions for each are now described below.

(i) Conventional rail

The source of information used to estimate a cost function for conventional rail are:

- the EUNET Deliverable D12 'The Transport Cost Database Report and Software Prototype', which reports data of 'behavioural cost' (representing tariffs to be paid by the consumer) in terms of cost per tonne-km by country and cost of loading and unloading for different kind of commodities;
- the EUFRANET Deliverable D3 'Study of Long Term Flow Scenario' which reports a unique average cost per tonne-km and a loading/unloading cost; and,
- a document from TNO where another unique average cost per tonne-km is reported as well as another figure for loading and unloading cost.

The average cost per tonne-km figures reported by these sources are very close one to each other. The value is around 0.04 EURO/tonne-km. This value has therefore been chosen as distance-related parameter.

In STREAMS, different distance-related cost parameters were implemented. For SCENES a unique term is considered. The reason for this choice is that costs by country had been estimated from data of national railway companies, but such a data was relating to national shipments. Tariffs for international shipments are quite different because they are set by the companies according to the tariffs charged by the companies of the destination and transit countries and taking into account additional elements like compensation for hiring rolling stocks. Therefore, tariffs for international shipments tend to converge towards an average value.

On the other hand, using a single value means that the cost of national shipments might be overestimated or underestimated. Corrections at the country by country level will be introduced in the model during the calibration phase.

The sources used to estimate the conventional rail cost do not report any fixed cost term. A fixed cost term is desirable as the cost function estimated for HGV includes a fixed term and the absence of a similar term for conventional rail might induce problems of modal shares on shorter distances where rail is actually not competitive. However, the cost function for HGV includes also terminal costs (loading/unloading). Such costs for conventional rail have been drawn from the EUNET Deliverable D12 and considered as the constant component of the cost function. As for any shipment both loading and unloading occur, the parameters for the model are the double of cost reported by EUNET.

The loading / unloading cost by kind of commodity and the parameters used are reported in Table 5.13.

Table 5.13: Loading and unloading costs for conventional rail

Commodity	Goods unitised on pallet (EURO/ton)	Goods not unitsed (EURO/ton)
Agricultural products	3.3	5.0
Solid fuels and ores	-	2.2
Petroleum products	-	2.2
Metal products	-	2.2
Building Materials	1.9	3.3
Fertilisers, Chemicals	2.0	4.1
Machinery and miscellaneous articles	5.1	8.5

Source: BVE Berategruppe, quoted in EUNET Deliverable D12 *The Transport Cost Database Report and Software Prototype*

(ii) Combined transport cost

The cost function for combined transport has been estimated from a sample of tariffs relating to several consignments on different routes. The data has been collected from two different sources. One source is a study on freight transport costs (TRT 1998, TRT 1999). The second source is represented by the companies which provided information regarding the shuttle services, and also included tariffs lists. From the two series of data, two linear regression functions have been estimated with the distance as independent variable.

The function estimated from the first set of data resulted in a function similar to that used in STREAMS (this was estimated from a different sample of consignments). This therefore represents a good instance of cross-validation by comparison.

Also the function estimated from the second set of data, relating to 'shuttle' services, resulted in a very similar function to the other two. It might be thought that 'shuttle' services should be more expansive as their quality and speed is higher. However, data does not confirm this assumption. This could be explained by the fact that railway companies charge lower tariffs to produce 'shuttle' trains, which attract shipments of larger size on a regular basis.

As both combined transport and 'shuttle' services are present in the model, both functions have been used. The parameters of the function estimated from the first set of data represent the parameter of the cost function for the mode 'Unitised Rail', while the parameters from the second set of data have been used for the 'shuttle' services.

For terminal costs (loading and unloading at terminal), the EUNET deliverable quoted above have been considered. Such costs are slightly lower than those reported by the sources used in STREAMS; so an average has been used.

The cost parameters estimated are shown in Table 5.14.

Table 5.14: Combined transport cost functions

Mode	Constant Cost (EURO/ton)	DistPar (EURO/ton-km)	Loading/Unloading (EURO/ton)
Unitised Rail	11.36	0.0342	1.1
Shuttle	10.28	0.0140	1.1

(iii) Rail on ferry

Rail on ferry pays the same distance-related parameter used on track links: 0.04 EURO/tonne-km.

5.3.2.3 Shipping costs

Shipping costs have been estimated from a study of transport cost (TRT 1998, TRT 1999). The sample of shipments was not very large and what could be estimated was an average rate for intra-Europe shipping transport for different kind of commodities. Average rate means that cost is independent from time and distance. However this is not completely true, even though many other elements (size of the shipment, frequency, season, etc.) affects rates in a more decisive manner. Also for modelling purposes, a time related parameter has been estimated.

Costs for port operations have been drawn from the same survey as a fixed cost. Port operations include, loading and unloading, piloting and others. For ship in port, the same time-related parameter estimated for the rates had been used.

A different value of port operations cost could have been estimated by flow, however the model does not include different port links and network modes for each flow. Besides this, the differences among costs for flows belonging to the same handling category (e.g., general cargo) are lower than the sampling error stemming from the survey. Therefore a unique port operation cost has been estimated by handling category. The average rates and port costs estimated are reported in Table 5.15, below.

Table 5.15: Shipping transport cost functions

	Ship in navigation		**Ship in port**	
Commodity	**Constant Cost (EURO/ton)**	**TimePar (EURO/ton-h)**	**Ship in port (EURO/ton-h)**	**Port Operations (EURO/ton)**
Agricultural Bulk	9.6	0.01050	0.01050	2.2
Solid fuels and ores	5.9	0.00722	0.00722	2.2
Chemical bulk	18.5	0.01839	0.01839	2.2
Petroleum products	7.4	0.00719	0.00719	0.5
General Cargo agricultural	26.3	0.03839	0.03839	25.5
General Cargo - metal products	17.0	0.03972	0.03972	25.5
General Cargo – Chemicals	20.8	0.04510	0.04510	25.5
General Cargo – Machinery	25.8	0.04316	0.04316	25.5
Container	42.5	0.04279	0.04279	5.6

5.3.2.4 Inland waterway costs

Different sources have been considered to estimate the transport costs for inland navigation. EUNET Deliverable D12 reports behavioural costs by vessel size and by country as well as costs for loading and unloading. The NEA report 'Market Observation System Inland Navigation', provides detailed figures about costs and prices of inland waterways also by groups of commodities (solid and liquid cargoes). The EUFRANET deliverable quoted above also includes an average cost per tonne-km for inland navigation and port operations costs. A further document regarding transport of containers by inland waterways was obtained, where a cost function and terminal costs are reported.

The costs reported by these sources have been compared and the costs are quite similar on average. The EUFRANET costs are generally lower on shorter distances and increase more rapidly; the NEA costs, the TNO function for container and the EUNET costs are close to each other.

TNO and NEA costs have been chosen for navigation as they have some references to the kind of commodity. Instead, EUNET terminal costs have been considered for the same reason: they are more detailed according to the freight type.

The cost function parameters are shown in Table 5.16. For port operations the same criterion as for shipping has been used, namely a unique cost by handling category has been considered though the source used would report differentiated values.

Table 5.16: Inland navigation cost functions

	Barge in navigation		Loading/Unloading
Flow	**Constant Cost (EURO/ton)**	**DistPar (EURO/ton*km)**	**Constant Cost (EURO/ton)**
Agricultural products	0	0.0135	1.4
Solid fuels and ores	0	0.0135	1.7
Petroleum products	0	0.0136	1.5
Metal products	0	0.0135	3.4
Building materials	0	0.0135	2.4
Fertilsers and chemicals	0	0.0135	2.4
Machinery, misc. articles	0	0.0135	1.6
Container	1.5	0.0091	1.5

5.3.2.5 Air freight costs

The air freight cost function estimated for STREAMS came from the official tariffs reported by TACT (The Air Cargo Tariff). The same functions updated to 1995 have been considered for SCENES with a 20% discount, which, according to ALITALIA, is normally applied on the official rates. The terminal costs have been considered equal to those used in the STREAMS model.

The cost function includes a fixed term plus a distance-related term and it has been drawn from a sample of O-D pairs throughout Europe.

Table 5.17: Cost function of air freight (costs per tonne)

	Air freight fare		Terminal costs	
Flow	**CnstCost (EURO/ton)**	**DistPar (EURO/ton*km)**	**Airport taxes (ECU)**	**Loading/Unloading (ECU)**
Consumer food	375.2	0.4347	13.2	2.2
Conditioned food	375.2	0.4347	13.2	2.2
Small machinery	375.2	0.4347	13.2	2.2
Miscellaneous articles	375.2	0.4347	13.2	2.2

5.3.2.6 Eastern Europe countries

All the sources used to assess the cost functions for freight modes, are mainly focused on EU countries, even though road, unitised rail and shipping costs have been drawn from rates regarding a sample of consignments where Eastern European countries were represented. In such countries, especially for domestic consignments, transport costs are most likely lower than those estimated above. However, including this aspect in the model is not straightforward for different reasons.

Firstly, there is lack of data about the cost of transport in Eastern European countries. Some data about rail tariffs were collected, but for road transport only a reference to operating cost in Poland could be obtained.

Secondly, the representation of transport modes in SCENES does not take into account the nationality of the vehicle itself and, more important, the experience with the STREAMS freight model (where national tariffs were explicitly implemented) was unsatisfactory as assignment problems can be induced.

For such reasons, at present specific cost functions for Eastern countries have not been defined. Instead, a discount will be implemented in the model for domestic trips and for trips among Eastern European countries during the calibration phase.

5.3.3 Freight Value of time

In STREAMS, the values of time used were only crudely differentiated by flow. For SCENES, new literature has been obtained which allows the implementation of different values according to flow type. Of course, an average value of time in absolute terms, which can be applied to all the different conditions simulated by the freight model is difficult to assess. What can be achieved is to scale values in relative terms among flows according to the broad value of the goods, the logistic requirements and so on.

5.3.3.1 Assessing freight value of time

In assessing a Value of Time (VOT) for a freight flow, the first difficulty is the lack of empirical studies: they are far less prevalent than passenger VOT studies. The market for freight transport does not have a homogeneous structure. Freight consignments are very different in terms of the characteristics of the goods carried (e.g., value, weight, volume, deterioration, etc.). In freight transport there are also many decision makers: forwarding-agent, carrier, consignee etc. On a wider perspective the producer and the consumer also have an important role in freight transport.

Interviews with passengers are the best source of information for passengers transport models – an option not readily available for freight. Besides, whilst passengers have the same price to pay, or face uniform and objective rules of toll, who is involved in freight transport isn't in every case a price taker. The customers can negotiate long and short period contracts directly with the carrier. In this way rates can be very different and it's difficult to obtain consistent information. In some situations prices don't even exist - this being the case where firms decide to manage freight transport on own account.

Analyses of the elements affecting the freight VOT have however been carried out since late ’60. EMNID (1967) and ifW (1972) underline the importance of variables as cost, speed, and reliability. EBV (1978) suggests a factor analysis for flows: speed is an important variable for foodstuffs, semi-manufactured goods and manufactured goods but it isn't so fundamental for minerals, cellulose, crude petroleum and cement. Flows with low value seem to show a lower VOT; for them the price has a fundamental role. Regarding more recent studies, most of them do not provide useful data because of a number of reasons: they don’t distinguish VOT by flow and / or mode, or they furnish elasticity for change in transport time but not VOT or, finally, aggregate goods in a way which is not easily transferable to the SCENES freight model.

Among these, Chow and Poist (1982), Van Rens (1985) and Matear and Gray (1993) confirm the relative importance of speed. Unfortunately they don't differentiate by type of flow and mode. Oum (1989) suggests a high value of demand elasticity of transport by road and train for variation of the railway speed. This study doesn't give VOT values regards to type of flow and mode. The same problem appears in the studies of Florio and Negri (1992) and Vieira (1992), where, VOT cannot be obtained from the elasticities differentiated by mode.

De Jong, Gommers and Klooster (1992) used an SP experiment to define freight VOT in The Netherlands. In general, the study seems to indicate a manufactured products VOT higher than raw one. Railway transport VOT is less than the road one. Between 1990 and 1992, MVA carried out some studies on freight, highly disaggregated by flow. The results point out that flows with high value (metallic products) have a higher VOT.

Fowkes's study of 1993 is very useful also because it supplies VOT for sets of flows that are similar to SCENES ones. Unfortunately the direct implementation is hampered by problem about unit of measure: in SCENES it's Euro per hour for a carried ton, while the study uses percentages of transport cost for percentages of transport time. The first general indication associates high VOT with goods introduced in a production chain. It could be that firms, whose productive performances are extremely influenced by the availability of an input, have a particular need for transport speed: VOT becomes a key variable in order to value the quality of the offered service. This is the case, for example, of the automotive electronic (VOT=26), of paper (VOT=32) and of metal tubes (VOT=25). In this last case, studies point to the possibility of widening the results to the whole group in which the product is (group 4: metallic products). The literature doesn't supply aggregated data for the group where the electronic elements are (group 7: miscellany). It could be possible to generalise the results for electronic elements to the whole group, assuming that the most of flow, belonging to the group, is in a production chain.

A second ‘rule of thumb’ which can lead to a flow VOT is the value of the flow. A high value of goods corresponds high VOT: for example, there is a high value associated to metallic products (VOT=25). Also in this case results can be led to a particular managerial logic: goods in movement are considered as unused capital, and thus as more unproductive, so the value is higher. Instead, fertilisers (group 10) show a particularly low value (VOT = 5). In this last case the means of transport can be considered by the management as a ‘store on movement’. Because of this fact, it’s possible to justify the particularly low valuation of VOT.

A particular case offered by the literature gives us a confirmation of this logic. VOT associated with the transport of refrigerated goods is negative (Ortuzar, 1988): if we consider the high cost of staying in refrigerated containers, the ‘gained’ productivity gets over the ‘lost’ one and it makes convenient, for the firm. Another result of literature, important in the perspective of subdivision of goods used in SCENES, is the low VOT that could be associated to oil products. Table 5.18 below summarises the results of the empirical studies discussed above.

Table 5.18: Freight value of time - Empirical results

Author	Mode	Flow – Notes	SCENES Flow	Sample	VOT [1] Euro/hour
IRU (1993)		Within experiment (Germany)	n.d.	50 Shippers	0.658
		Within experiment (France)	n.d.	51 Shippers	0.728
		Within experiment (The Netherlands national)	n.d.	50 Shippers	0.884
		Within experiment (The Netherlands international)	n.d.	50 Shippers	0.878
		Between experiment (Germany)	n.d.	50 Shippers	n.s.
		Between experiment (France)	n.d.	51 Shippers	n.s.
		Between experiment (The Netherlands)	n.d.	50 Shippers	0.375
De Jong, Gommers e Klooster (1992)	Road	Raw or semi-finished, low value	6 (partially)	75 Shippers 44 Carriers	1.025
	Road	Raw or semi-finished, high value	6 (partially)		1.072
	Road	Finished, loss of value	1		0.942
	Road	Finished, no loss of value	7 – 8 - 10 – 11 – 12		0.834
	Rail		n.d.		0.875
Fowkes e Tweddle (1992)		Chocolate (lrg firms)	2	50 Firms	13
		Chocolate (sm. firms)	2		7
		Beer	2		29
		Oil products	5		10
		Cement and lime	7		11
		Fertilizers	10		5
		Metal tube	6		25
		Consumer durables	12		14
		Automotive Electrics	11		26
		Paper	10		32
MVA (1990)	2	Accompained Ro-Ro unitised	n.d.	20 Firms	7
	25	Others unitised	n.d.	18 Firms	8.3
	26	Mean	n.d.		7.7
MVA (1991)	27	Accompained Ro-Ro unitised	n.d.	47 Firms	11.3
	28	Unaccompained Ro-Ro unitised	n.d.	15 Firms	11.4
	29	Lo-Lo users unitised	n.d.	27 Firms	7.8
	30	Mean	n.d.		9.5
MVA (1992)	31	Aggregates	8	8 Firms	1.7
	32	Metals	6	11 Firms	4.8
	33	Oil products	5	10 Firms	2.3
	34	Sludges	n.d.	6 Firms	0.6
	35	Wastes	n.d.	10 Firms	0.8
	36		n.d.		1.2
Tweddle e Fowkes (1995) [2]	37	Accompained Ro-Ro	n.d.	25 Firms	14.8
	38	Unaccompained Ro-Ro	n.d.	6 Firms	12.2
	39	Lo-Lo Users	n.d.	3 Firms	4.6
	40	Mean	n.d.	34 Firms	12.1

(1) percentage variation of cost equivalent to a percentage unitary variation of time
(2) in parenthesis we indicated the main results of Fowkes, 1993, in terms of percentages of transport price to discount in case of half day more of transport

5.3.3.2 Estimating VOT parameters for the SCENES freight model

Fowkes's empirical results have been assumed as a basis to differentiate SCENES values for flows. Following testing with the STREAMS model, a set of data has been chosen for the definition of the starting VOTs to be implemented in SCENES.

These VOT have been used in a simulation of the logit mode choice mechanism. The new cost functions estimated for SCENES have been used to evaluate the competitiveness of the alternative modes on different distance bands for different flows. According to such simulations, some VOTs should be reduced otherwise slower modes (mainly ship, sometimes Inland navigation) would become uncompetitive. Also, the VOT for metal products seem too high with respect to the observed modal split, where rail and IWW has a significant share.

Therefore, the initial set of values have been scaled with respect to the theoretical proposal and represent both a starting point and a term of reference; they are reported in Table 5.19 below. These values may by adjusted slightly during calibration.

Table 5.19: Values of time for the SCENES freight model

SCENES Flow	Value of time (EURO/h)
1 – Cereals and agricultural products	1.00
2 – Consumer food	1.30
3 – Conditioned food	2.50
4 – Solid fuels and ores	0.30
5 – Petroleum products	0.70
6 - Metal products	0.75
7 - Cement, Manufactured Building materials	1.00
8 - Crude building materials	0.10
9 - Basic chemicals	0.30
10 - Fertilisers, plastic and other Chemicals	1.00
11 - Large Machinery	2.50
12 - Small Machinery	2.50
13 - Miscellaneous Manufactured articles	2.50

5.4 Analysis of observed trends of European freight traffic

This section presents a comparison among observed trends of European freight traffic drawn from different sources. This provides a context for the freight forecasts which are produced during the SCENES modelling work.

5.4.1 Comparison among observed trends

Before examining the data, it should be noted that although different sources provide data about freight traffic at different years in the past from which an average growth rate can be calculated, for each source, different assumptions are required in order to have homogenous data for each year. As each source has its own features in terms of what traffic is considered and for what years, missing data and so on, a comparison among the different sources is not always immediate: different growth rates can be due to different data used, different time periods considered and so on.

5.4.2 Observed trends of volumes (tonnes)

Observed trends in terms of tonnes can be drawn from TREX data and from the ECMT publication ‘Statistical Trends in Transport 1965 – 1992’.

TREX includes data in terms of volumes for EU countries from 1989 to 1995. Before 1995, there were 12 EU countries, while after 1995 three newcomers joined the EU. In order to have a consistent set of data, only EU12 countries have been considered. The volumes reported by TREX concern international trade of each member country whatever means of transport is used, for different kind of commodities (NST/R chapters); as ECMT data are mainly focused and reliable on EU countries, only intra-EU trade has been taken into account.

The ECMT publication reports data of tonnes carried by mode and by country, from 1965 to 1992. All traffic on national networks is reported separately from international traffic. Road, rail, shipping, and inland navigation are considered; road data is available only as sum of country-based figures which refer only to vehicles registered in each country. Statistics are generally not complete: data is missing for many countries in some years, especially for the period 1965 – 1975. Therefore, to have a comparable set of data, only traffic from 1980 has been considered. The average growth rates extracted from the two sources are shown in table 5.20.

Table 5.20: International freight traffic in EU countries (tonnes), average % growth p.a.

NST/R chapter	TREX (1989-1996)	ECMT (1980-1992)
Agricultural products	4.2%	
Foodstuff	3.4%	
Solid fuels	-5.7%	
Petroleum	2.1%	
Ores	-0.1%	
Metal products	3.6%	
Building materials	0.7%	
Fertilisers	1.8%	
Chemicals	4.3%	
Machinery – Miscellaneous	9.2%	
Total	**3.1%**	**2.5%**

Notes: TRT estimates on EUROSTAT – ECMT data.
ECMT: *total goods carried for international transport in EU countries*

The observed average growth rates are similar even though the two sources are focused on two different contexts. From the TREX data, the very different trends among commodities can be appreciated.

ECMT also offers some figures for all traffic on national networks (i.e., including both transit and national transport). Such figures are not available for all countries, an average yearly growth rate could be estimated only for a subset of seven countries (BEL - GER - DK - FRA - NED - SWE - UK) and the figure is 0.4%.

This would mean that national traffic – which is of course predominant in terms of volumes, had been growing at a very low rate or indeed was virtually the same both in 1980 as in 1992. As reported in Table 5.21 below, UK data between 1974 and 1996 shows an average growth rate of tonnes lifted for domestic transport of about 0.5% per year (Williams, 1998). The rate in Italy is much more significant, lead by the growth of road transport - about 840 million tonnes lifted in 1986 and about 1150 in 1996. The Italian data are very similar to those reported by NEWCRONOS, whereas this source reports data which is quite different from, for instance, the HMSO publication 'International comparisons of transport statistics 1970-1993'.

Therefore it is not straightforward to identify a general trend for national transport. For other countries, like Germany and France, the NEWCRONOS statistics allow us to estimate an average growth rate of about 2.5% per year (NEWCRONOS data does not include sea shipping), while the UK rate estimated from this source is 1.6% per annum.

Table 5.21: National freight traffic in Italy and UK (tonnes), average % growth p.a.

	Italy (1986 – 1996)	**UK (a) (1974 – 1996)**	**UK (b) (1982 – 1994)**	**France (b) (1983 – 1994)**	**Germany (b) (1983 – 1994)**
National traffic	3.0%	0.5%	1.6%	2.5%	2.4%

Notes: Italy: TRT estimates on data of Conto Nazionale dei Trasporti (road + rail + sea).
(a): data from Williams (1998)
(b): estimation on NEWCRONOS data (road + rail + IWW)

5.4.3 Observed trends of tonnes-km

Observed trends in terms of tonnes-km can be drawn from ECMT publications 'Statistical Trends in Transport 1965 – 1992' and 'Statistical Trends in Transport 1970 – 1997', and from the EUROSTAT booklet 'Transport in Figures 1999'.

The first ECMT publication has been described previously regarding tonnes data. The same comments apply for tonnes-km data, with the exception that not all the EU countries can be considered for road transport because data for Austria, Ireland, and Portugal are missing. For the remaining countries, however, data from 1970 can be considered instead of 1980.

The second ECMT publication is an update of the first one, it has more recent data and some missing data has been fixed, however, shipping data is no longer reported. The EUROSTAT booklet is similar to the ECMT one, it offers a section where the total amount of traffic in different years is reported without the need for summing figures by mode. Shipping data is included and road traffic should include all means of transport and not only vehicles registered in each country. The comparison among the three sources is reported in Table 5.22.

Table 5.22: International freight traffic in EU countries (tonnes-km), average % growth p.a.

	ECMT (a) (1970-1992)	**ECMT (b) (1970-1996)**	**EUROSTAT (1970-1997)**
Total traffic on EU countries networks	2.0%	2.5%	2.7%

Notes: TRT estimates on EUROSTAT – ECMT data.
ECMT (a): *Statistical Trends in Transport 1965 – 1992*, AUT, IRE and POR road data excluded
ECMT (b): *Statistical Trends in Transport 1970 – 1997*, shipping excluded

The average growth rates are quite similar among the sources. The EUROSTAT trend is 35% higher than the older figures from ECMT, but the different features of the two sources (missing data in ECMT and the inclusion of foreign road vehicles in EUROSTAT statistics) could explain the difference.

In comparison with the previous figures regarding tonnes, the average growth rate of tonnes-km is much higher (the comparison is with the 0.4% rate quoted at the end of Section 5.4.3 concerning both national and international traffic). Unfortunately, neither data regarding only international traffic nor data by commodity group are readily available. NEWCRONOS data could provide such an information, however the time series in NEWCRONOS is full of missing data for almost all countries and a time-consuming analysis would be needed to build a set of consistent figures.

In terms of national statistics, NEWCRONOS data has not been used for the same reasons just mentioned. Again UK and Italian data has been examined. Here figures are much more consistent than that for tonnes; they are shown in Table 5.23. UK data reported from Williams corresponds to a 2.4% per annum growth rate between 1980 and 1992. Italian data drawn from Conto Nazionale dei Trasporti (Ministero dei Trasporti e della Navigazione, 1999) shows an average yearly increment of 3% of domestic tonnes-km between 1970 and 1997.

Table 5.23: National freight traffic in Italy and UK (tonnes-km), average % growth p.a.

	Italy (1986 – 1996)	**UK (1974 – 1996)**
National traffic	3.0%	2.4%

Notes: TRT estimates on data of Williams (1998) and Ministero dei Trasporti e della Navigazione (1999).

5.5 Comparison with 1994 data (STREAMS and NEAC database)

5.5.1 Overview of comparison

The observed traffic is compared in this section with the 1994 figures reported in the comparative work undertaken between the STREAMS model and the NEAC freight flow database. The STREAMS results and the NEAC database are compared in a number of different ways. Here, only the total amount of international traffic by country, divided into intra-EU, to/from other European countries and to/from the Rest of World is considered. Other aspects of the data are reported in Annex D.

The corresponding figures from TREX 95 and from the SCENES observed data have been added to be compared in following tables. For the record, petroleum is excluded from the comparison.

Figures from the NEAC database concern 1994, the comparison is therefore not quite exact, however its scope is show the position of the SCENES estimates with respect to the STREAMS and NEAC figures, when such figures are quite different. As the original data from TREX 1994 which were used to estimate the STREAMS observed data are generally not very different from the TREX 95 figures, the comparison should give some indication about differences between TREX, STREAMS and NEAC. For example, whether the difference is between TREX and NEAC or just between STREAMS and NEAC, which would mean that the STREAMS model was not capable to reproduce the observed date defined starting from TREX.

Table 5.24: Intra-EU15 traffic (import) - comparison (million tonnes / year)

Country	STREAMS results (1994)	NEAC database (1994)	TREX (1995)	SCENES (1995)
Austria	16	15	18	18
Belgium + Luxembourg	74	92	97	88
Denmark	15	16	16	16
Finland	7	11	11	11
France	102	91	97	87
Germany	180	144	176	135
Greece	11	7	10	10
Ireland	10	10	10	10
Italy	65	64	65	65
Netherlands	112	111	103	101
Portugal	12	10	12	12
Spain	33	33	38	38
Sweden	15	16	17	17
UK	64	58	58	58
TOTAL	***716***	***678***	***728***	***666***

Note: petroleum products are excluded

Table 5.25: Traffic between EU and other Europe - comparison (million tonnes / year)

Country	STREAMS results (1994)	NEAC database (1994)	TREX (1995)	SCENES (1995)
Austria	3	17	18	18
Belgium + Luxembourg	7	8	10	10
Denmark	11	11	12	12
Finland	0	20	20	20
France	22	24	28	28
Germany	40	87	90	90
Greece	2	5	6	6
Ireland	2	1	1	1
Italy	19	31	34	34
Netherlands	12	18	20	20
Portugal	0	1	1	1
Spain	5	9	17	17
Sweden	0	15	18	18
UK	16	16	17	17
TOTAL	***139***	***263***	***292***	***292***

Note: petroleum products are excluded

Table 5.26: Traffic between EU and rest of World - comparison (million tonnes / year)

Country	STREAMS results (1994)	NEAC database (1994)	TREX (1995)	SCENES (1995)
Austria	3	11	3	3
Belgium + Luxembourg	39	67	53	59
Denmark	12	18	16	16
Finland	0	14	9	9
France	77	88	84	94
Germany	74	106	78	119
Greece	17	10	9	9
Ireland	4	2	2	2
Italy	65	114	81	81
Netherlands	88	99	93	64
Portugal	14	14	14	14
Spain	52	65	63	63
Sweden	0	30	14	14
UK	41	78	74	74
TOTAL	***486***	***716***	***593***	***621***

Note: petroleum products are excluded

The comparison between the four different source shows that the observed data estimated for SCENES are closer to the NEAC figures than the original TREX data is. At the same time, the STREAMS data is sometimes very different from the 1995 TREX data.

The main differences are registered for Spain with reference to traffic between EU and other European countries and for Austria, Italy, the Netherlands, and Sweden about traffic to and from the rest of world. With the exception of the Dutch traffic the difference is already in the TREX figure and therefore it is difficult to find an explanation.

The overseas traffic of the Netherlands should be closer to that shown by the NEAC database if the amount of ores and solid fuels from overseas passing through Rotterdam towards Germany were not be excluded from Dutch statistics, though it is difficult to say whether this is the actual reason of the difference.

In general, it can be said that the corrections operated to the TREX data produce a more realistic set of observed data. At the same time most of the differences between NEAC and STREAMS are due to problems in modelling the matrix rather than a wrong database. Nevertheless the comparative exercise was useful in developing the SCENES 'observed' freight matrix.

5.5.2 Conclusions base year 1994

In general, total domestic transport, total import from EU countries and total export to EU countries are comparable between STREAMS and NEAC. This holds for the total trade by country, trade by mode of transport and trade by commodity group. There are a number of exceptions. Total domestic transport of Germany in NEAC is much lower than in STREAMS, which is caused by the fact that in NEAC no data is available for short distance road transport of domestic transport in Germany. Differences occur for Sweden, Finland and Austria. These differences are mainly caused by the fact that these countries are included in the TREX 95 database and not in the TREX 94 database. Because NEAC is based on TREX 95 (the actual base year of NEAC is 1995 and not 1994) and STREAMS on TREX 94 there are differences for these countries. Trade between the Netherlands and Germany is lower in NEAC than in STREAMS. This difference is caused by an error in the TREX database that has been corrected in NEAC and that is not corrected in STREAMS.

The differences for trade with rest Europe and trade with rest world are much higher than for domestic transport and intra-EU trade. In general the trade in NEAC is higher than in STREAMS. A comparison of both databases with TREX 94 showed that the NEAC database and the TREX 94 database are more comparable than the STREAMS database and the TREX 94 database. Also the comparisons of trade by mode of transport and trade by commodity group show large differences. One reason for differences in trade volumes is the fact that during the calibration phases of the STREAMS model it appeared that the model was not entirely capable to reproduce the correct matrix, especially for non-EU countries. The amount of data regarding Eastern European countries and the quality used in the STREAMS model were not as good as for the EU countries. Also for trade with rest world it appeared that during the calibration phases of the STREAMS model the model was not entirely capable to reproduce the correct matrix.

An explanation for the differences of trade by mode of transport is that in the STREAMS model no good data was available to make corrections to the TREX database. Furthermore, the description of the sea network for Eastern European countries in the STREAMS model was very simple with a very limited number of ports available. An attempt has been made to make the modes comparable in STREAMS and NEAC, but very different definitions of mode of transport are used in the models and this also explains part of the differences of trade by mode in the comparison.

The difference in trade by commodity group can be explained by the fact that the trade values estimated on the basis of the input-output tables data in the STREAMS model were sometimes very different from the TREX values and sometimes the procedure induced some additional errors. Finally it is noticed that STREAMS includes only trade of Sweden and Finland in relation with other EU countries. Trade of these countries with rest Europe and rest world is not included in STREAMS, this trade is included in NEAC. Therefore these two countries have been left out of the analysis.

The region to region trade of France - the Netherlands is chosen to give an example of the region to region trade. The comparison shows that the hierarchy among regions for total dispatch and arrival is almost the same even though the percentages are different, the most important regions are the same in both databases and the fit for total region to region flows is quite good. Especially if one takes into account that the databases have been built using completely different methods to construct region to region flows and with a limited amount of information. For region to region flows by mode and by commodity group the fit is poor.

5.5.3 Conclusions forecast year 2020

The results of the forecast year are presented by the growth figures of the trade and not by the absolute figures. The growth of domestic transport and intra-EU trade is comparable between both databases. Except for Greece and UK for which the growth in STREAMS is much higher than in NEAC. The growth of trade with rest Europe and trade with rest world shows extremely large differences between STREAMS and NEAC. For most countries the growth in STREAMS is much higher than in NEAC and this holds especially for the import.

An explanation for the very large differences in growth, with the growth in STREAMS much higher than in NEAC, is that in STREAMS very high growth assumptions have been used (e.g., +10% per annum). These assumptions are based on relatively short time-series data and projections and they should probably be damped down more through time.

An example of import of Greece by origin country is given, where in the STREAMS model indices occur of more than 3000 compared with indices of 300 in NEAC. These extremely large differences were due to the limited data that was available in the STREAMS model for extra-EU trade. Also some of the very high growths relate to very small quantities of trade in the base year and in the forecast year in the STREAMS model.

In general the total trade by commodities fertilisers and chemicals and machinery & manufacturing is much higher in STREAMS than in NEAC. Except for commodity solid mineral fuels and ores (and apart from the absolute figures) the hierarchy of the growth is comparable over the commodity groups.

The issues raised in this comparison were taken on board in the design of the SCENES freight model.

6. The spatial logistics appended module

6.1 Introduction

This chapter contains the specification of the Spatial Logistics Appended Module (SLAM), which is being developed as a separated module in the SCENES project, linked to the SCENES European Forecasting Model model. The Appended Module transfers the intermediate results of the SCENES model, an O/D-table consisting of trade volumes in tonnes between regions, into O/D flows that incorporate alternative distribution chains[10].

The objectives of the module and its functional design were outlined in the previous deliverable[11]. In Chapter 5 these objectives were repeated for convenience, along with the connections between SLAM and the SCENES model. This chapter describes the structure of the first version of the Appended Module.

The contents per section are as follows:

- subsection 2 gives a description of the model features and the computations made within the module;
- subsection 3 provides an explanation of the content of the module's database;
- subsection 4 shows the first result of the module by mapping the concentrations of DC's throughout Europe.

6.2 Structure of the appended module

This section highlights the main features of the Appended Module, as implemented in release 1.0.

6.2.1 Overall structure

The main objective of the modules is to transform trade flows into transport flows by taking into account the logistics costs and bundling possibilities of freight flows. The logistic module does not yet specify the modality choice in a chain, but identifies typical distribution structures for chains, based on the characteristics of the region, products, and the network.

The following scheme summarises the possible chain types[12]:

	National DC (NDC)	NDC and/or Continental DC	Direct delivery
National relation	X		X
International relation	X	X	X

The appended module calculates the number and the potential locations of DC's throughout Europe on a regional level by re-assigning tonnes per Origin/Destination (O/D) in relation to

[10] A chain is here referred to as combinations of distribution centres (DC's) and transport relations for a trade flow for an O/D-relation.

[11] SCENES consortium, Deliverable D2, SCENES European Transport Forecasting Model Specification, June 1999.

[12] Chain types are here referred to as the possible distribution channel. Alternative chains are all possible chain types for a specific O/D relation.

possible alternative chains. Regions that are attractive for the location of a DC will have a higher throughput in tonnes compared with the initial O/D patterns. So the outcome of the module is a revised O/D table for transport in which some regions will benefit and attract more tonnes, compared with the O/D table based on trade flows alone. By comparing the throughput per region in the trade flow O/D table and the revised transport O/D table, conclusions can be drawn in terms of attractiveness of region as a DC location.

The appended module consists of three submodules:

1 *Location scores module*: computes for every region a score for the attractiveness of the region as a possible location for a DC. This module results in a ranking of regions for all of the 13 freight flows.

2 *Chaining module*: this module calculates the probability of using a specific alternative chain, based on the location scores and the total logistical costs of using a specific chain.

3 *Reassign module*: this module assigns volumes of the total commodity flow for an O/D-relation to chain types.

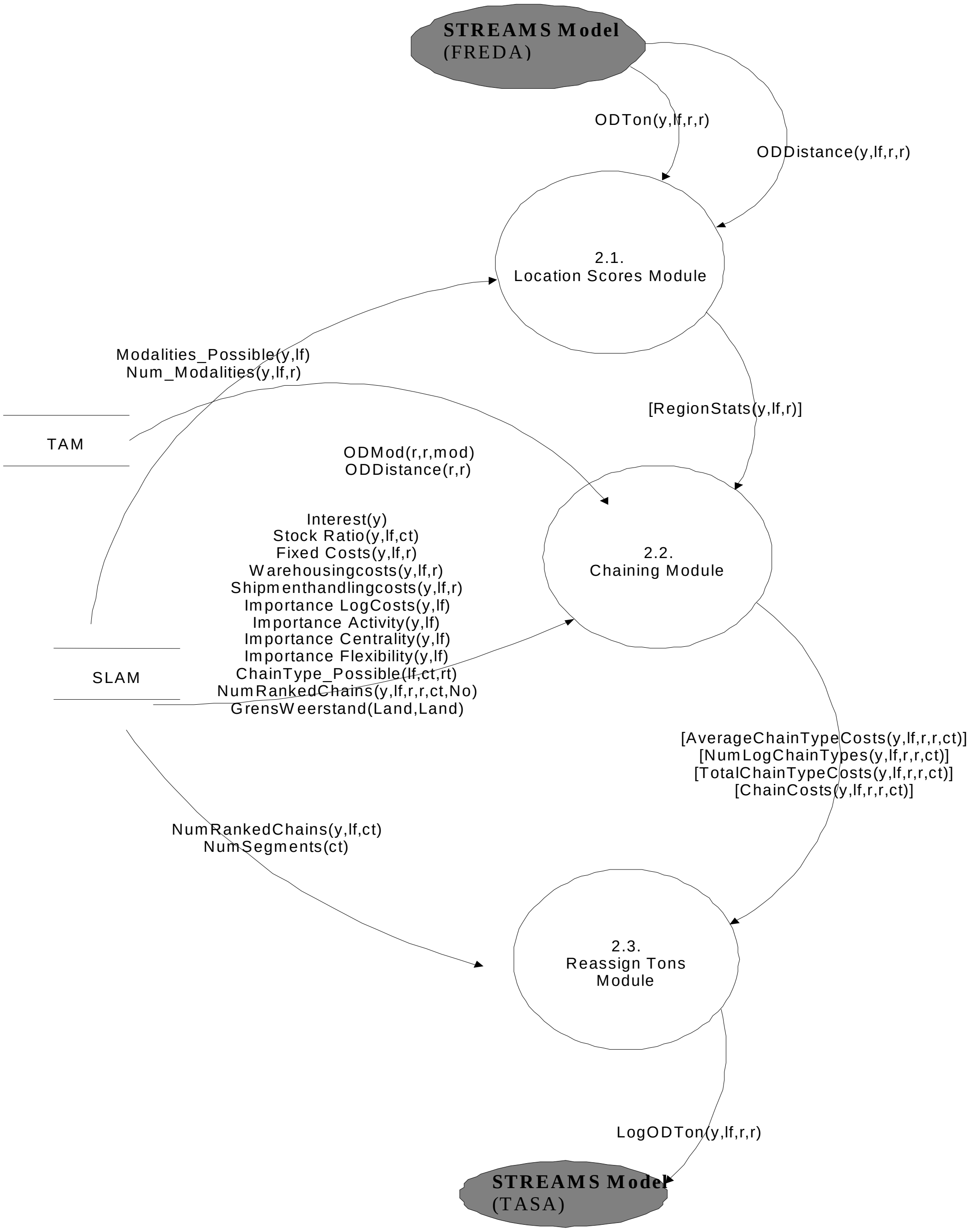
Figure 6.1 provides a graphical overview of the three modules and the data sources used within the modules. The incorporation of the SLAM module in the STREAMS model is described in section 5.2 and will not be outlined any further here. The figure shows the origins of the data, which are the:

1 SLAM database: the database is described in section 6.3.

2 STREAMS model-data; providing the input in the form of O/D matrix (FREDA) in tonnes for every O/D relation and freight flow.

Within the chaining module, modal split data, transport times and costs are also derived from the SCENES model. These data are extracted in separated files and used in the SLAM for computing the segment costs per chain type and chain segment. The TAM – database represented in the Figure contains these data. Every of the three sub-modules of the SLAM will be explained separately in the remainder of this section.

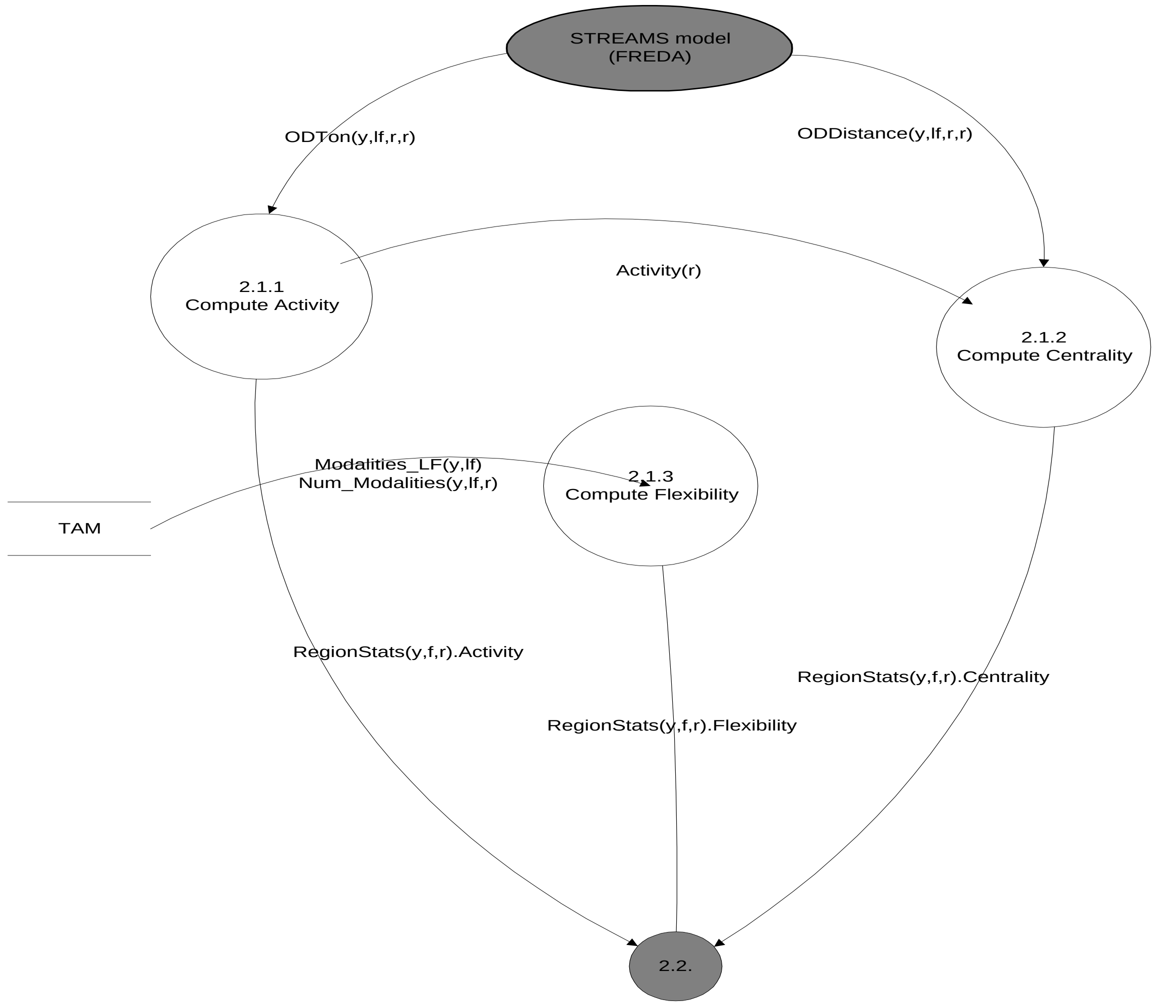
Figure 6.1: Appended module: sub-modules



6.2.2 Location scores module

This module comprises the first step of this module in which regions are ranked according to their attractiveness as DC location for each of the 13 freight flows. The attractiveness of a region is measured by non-financial criteria. These criteria are being used, because besides costs also logistical characteristics of a region determine the choice for a DC-location. The ranking is used in the chaining module to select possible regions to locate a DC and for which logistics costs are computed to incorporate financial aspects of the location choice. The final assignment of volumes to these chains is based on the logistics costs per alternative chain and chain type, as will be described in the chaining module. Figure 6.2 gives an overview of the locations scores module.

Figure 6.2: Appended Module **-** Location score module



For the ranking of regions as alternative locations for warehouses in this sub-module, in addition to the costs of alternatives, three non-financial criteria are being used:

1. *Economic activity*: is measured by a simple indicator the total volume of production and attraction to and from a region for each of the freight flows. This indicator will have a higher value if a region has a high throughput of a freight flow.

2. *Centrality*: is measured by a centrality index for every region: the weighted reciprocal of the volume of a freight flow and the distance of a possible DC location to other destinations. The use of this index assures that a region with high volumes and short distances to other regions is more attractive as a DC-location.

$$B_l = \sum_j \frac{X_{ij}}{d_{lj}}$$

B_l = centrality index for other destinations for region l

X_{ij} = volume of commodity flow between origin i destination j

d_{ij} = distance between location l and destination j

i = origin

j = destination

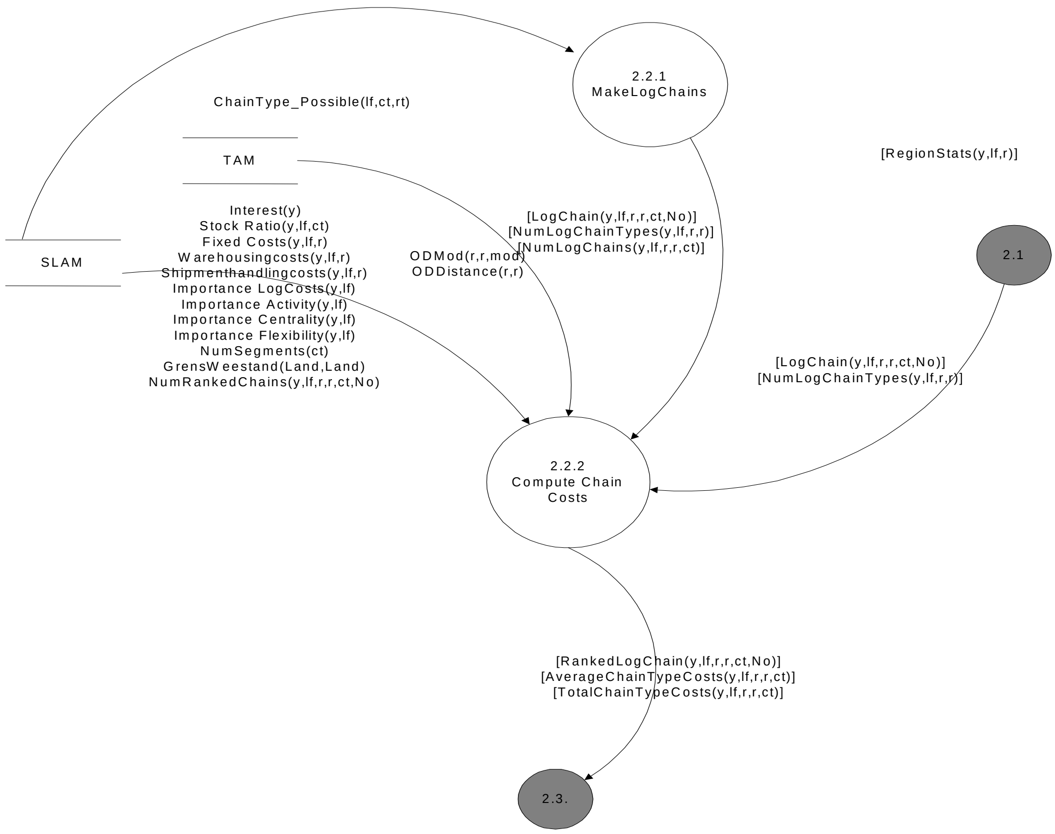
l = region of the DC-location

3. *Flexibility*: is measured by an index that reflects the available network/infrastructure in a region for a freight flow. For each of the regions the number of modes available in a region are dived by the modes that might be possibly by a freight flow. If regions have all modes available, which might be used for a freight flow, than the index will have the maximum value of 1.

6.2.3 Chaining module

In the chaining module, alternative chains per chain type are being made and ranked according to logistical costs and the location scores as determined in the previous module. The module operates in three steps, as can be seen from the following Figure 6.3.

Figure 6.3: Appended Module - Chaining module



The chaining module works in three steps:

1. *Make log chains:* In this step the most attractive regions for a DC location are selected for every O/D relation and chain type, as long as they are possible for a freight flow
2. *Compute chain costs:* The logistics cost for every alternative chain are computed in this section. This process is going to be explained within this section.

3. *Chain ranking:* Finally every alternative chain per chain is ranked according to its logistics costs, This ranking serves as input for the final assignment of tonnes to chains in the reassigning module.

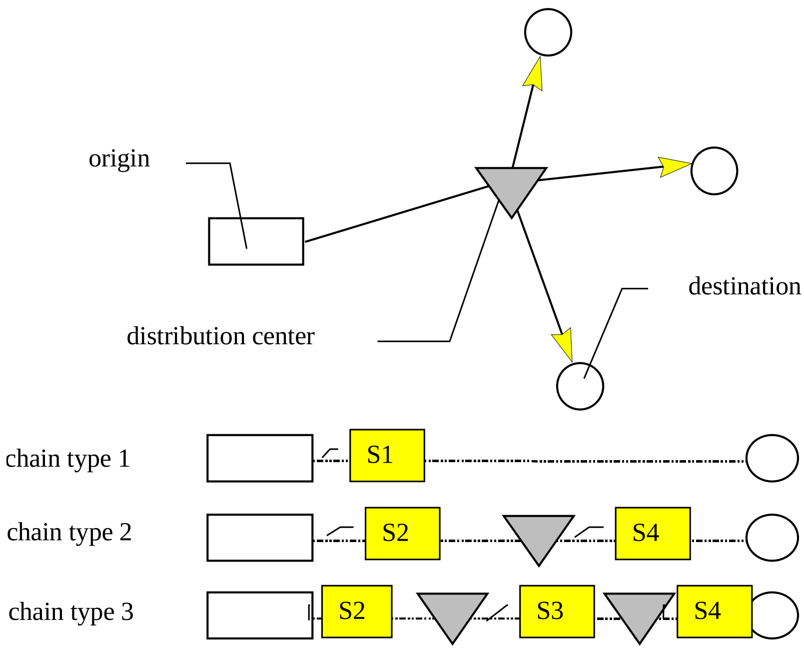
The logistic costs per alternative chain and per flow type have three components:

$$c_k = c_k^t + c_k^v + c_k^m$$

c_k	= logistic costs
c_k^t	= transport costs
c_k^v	= inventory costs
c_k^m	= warehousing costs
k	= alternative chain

In order to calculate transport costs, alternative chains are subdivided in segments representing several stages of every chain type. Figure 6.4 shows the segments Si per chain type. The logic behind the segments is that the value of time (VOT), modes available and transport costs differ in these stages. For example segment 4 represents the final leg of a chain between a DC and a customer, will have higher transport costs (usually this part is delivered with LTL trucks or vans) and a higher value of time, because of the urgency to deliver the goods in time.

Figure 6.4: Appended Module - Distribution channels and segments



The calculation of transport costs, modal split, distances and VOT are derived from the assignment module of the model. A simple weighted cost function (with weights according to the shares of different modes) was implemented to approximate transport costs as calculated during the network assignment. A condition limiting the calculation of weighted costs is provided by the modes that are allowed on different segments. On the last segment, S4, for example, only road transport is allowed.

Inventory costs

Inventory costs are specified for every freight flow and contain the inventory costs for the actual stock necessary for the demand of a period and the safety stock. To calculate this several steps are taken:

$$c^v = a_f X_{ij} (i + k)$$

i	= interest costs
k	= fixed warehousing costs
a_f	= stock ratio per freight flow

Holding costs

Warehousing costs are independent from the product and are divided into handling and holding costs.

$$c^m = a_f X_{ij} w(h_f + o_f)$$

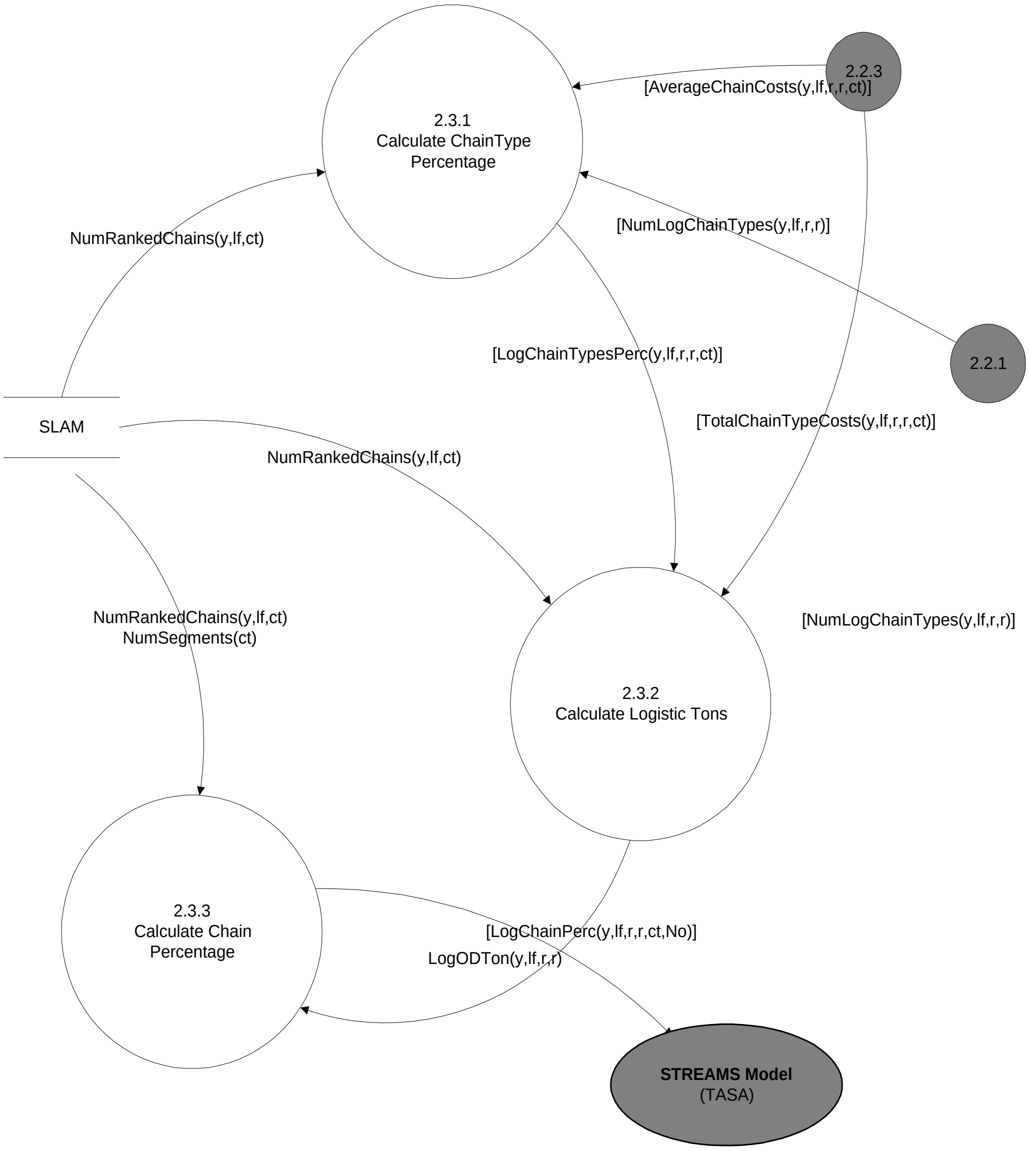
Variables:

c^m	= warehousing costs
$X_{ij,f}$	= trade flow on O/D-relation per flow type
o_f	= holding costs per m^3
h_f	= handling costs per m^3
Z	= average inventory volume (tonnes)
c^o	= handling cost per ton
w	= volume to weight ratio

6.2.4 Reassign module

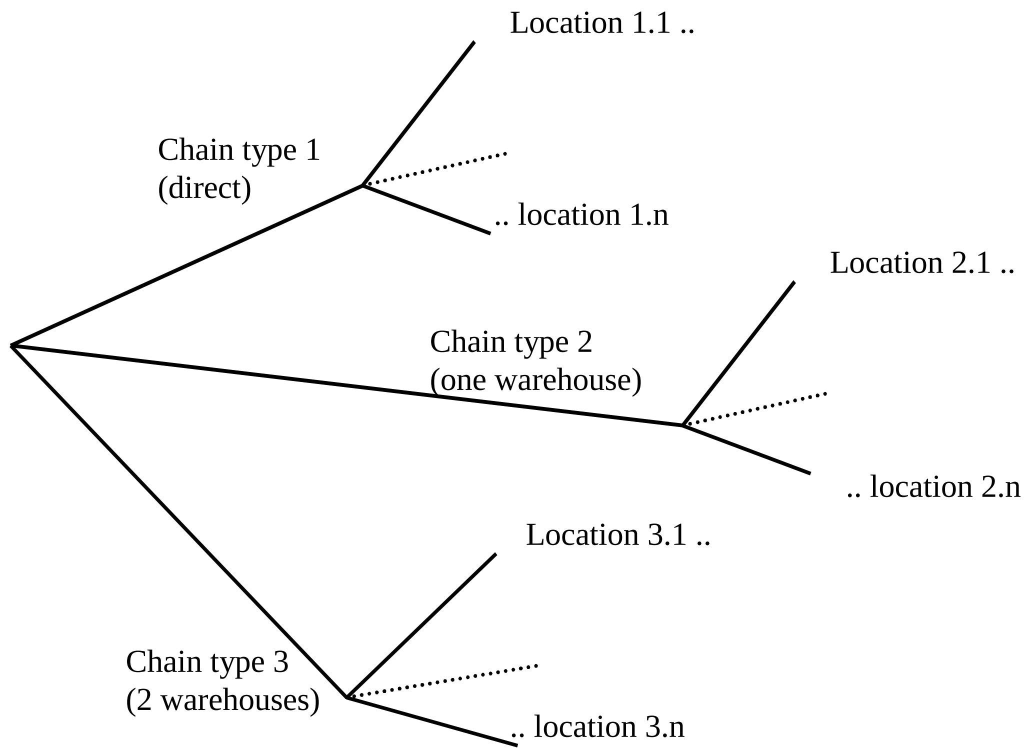
The last module of the SLAM assigns tonnes to chains by using a nested logit function. The implementation of this process is shown in Figure 6.5 below.

Figure 6.5: Appended Module - Reassign module structure



The assignment of volumes to alternative chain per chain type takes place through a nested logit approach where the nests are formed by the alternative chain types, containing a limited number of alternative locations for warehouses enumerated in the chaining module (currently 5). Figure 6.6 below shows this nested structure.

Figure 6.6: Nesting structure for AM distribution chain alternatives



The probabilities of each chain with a defined region, conditional on the chain type are calculated as follows:

$$P(i) = \frac{\exp\{\lambda\ c_i\}}{\sum_n \exp(\lambda\ c_i)} \qquad \text{and } i \in A_t$$

Where:

P (i)	=	probability of using alternative chain i
c(i)	=	total logistics costs for alternative i
i…n	=	alternative chains i per chain type and O/D relation
α	=	parameter indicating sensitivity of LF-flow x for logistics costs
A	=	collection of alternative distribution chains per chain type t

With this formula the ‘weighted’ costs for alternatives within one type of chain are computed. The P(i) provides the division of the volume over alternatives per chain type, by using a Logit-model .Parameter α gives an indication of the sensitivity of goods types for logistic costs, when making the choice for a specific chain. In this way the model includes the relevance of other non-financial factors in the choice behavior. By using restrictions for specific (non-realistic) relation types and logistical families, the set of alternative chains is limited.

Assignment of volume to chain types

Next, volumes are assigned to chain types. The first step is to compute the disutility of a chain type , relative to each other. The total disutility of a chain type per O/D relation and LF is the logsum of the disutilities of the individual alternatives per chain type. This in turn determines the choice probability of each chain type.

$$D(t) = (1/\lambda)\log\sum_{n}\exp(\lambda * c_{i,n}) \qquad \text{where} \quad t \in CT_{i,f}$$

$$P(t) = \frac{\exp\{\mu D(t)\}}{\sum_{i}\exp(\mu D(t), i)} \qquad \text{where} \quad t \in CT_{i,f}$$

P	=	Probability of using chain type per O/D relation
D	=	disutility per chain type
c	=	total logistics costs per alternative chain
λ, μ	=	elasticity parameters
i.. n	=	all alternative chains per chain type and O/D relation
f	=	logistical family
t	=	chain type
CT	=	chain types allowed per LF

Once these have been determined we can compute the probability of using of each chain. The flows are then reassigned to the O/D matrix using these probabilities.

6.3 The SLAM database

6.3.1 Overall structure of the database

This section describes the database used by the appended module. The database consists of two parts. One part is permanent, the other part is imported from the 'TAM'-file.

From the TAM-file, the following tables are imported:

- ODDistance contains the indices Region (origin) and Region (destination), and per OD couple the distance between the centroids of these regions.
- ODTon contains per OD couple and per LogFam[13] the tonnes trades between these regions.
- Num_Modalities contains the indices LogFam and region and is a summation of the number of modes in a specific region for a specific LogFam that are available.

The other part is permanent in the database. Figure 6.7 indicates the various tables in the database. These table are described the following part of the section.

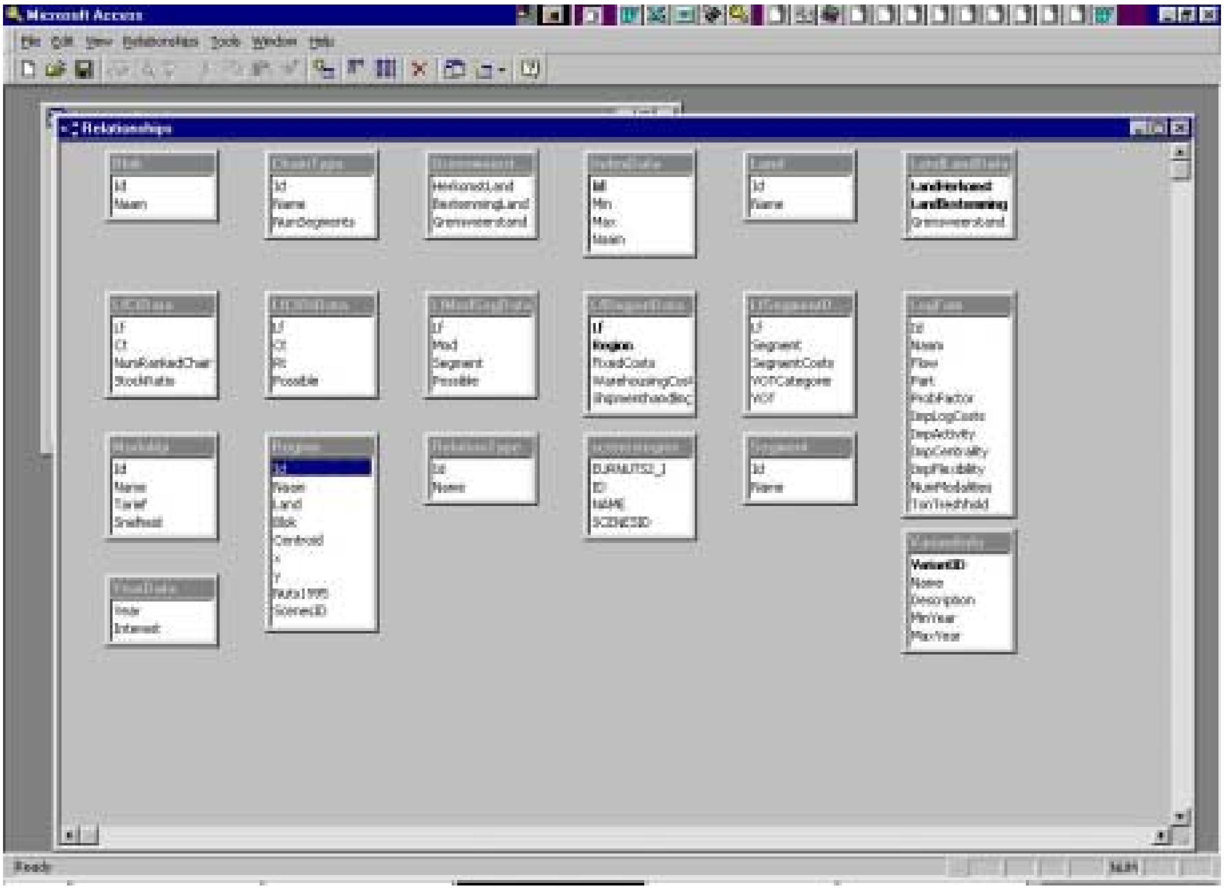
There are three sorts of tables:

- Explanation: Definitions and names of Id, not necessary for running the module

[13] LogFam=freightflow

- Support: Used for composition of the database and is not used running the appended module
- Active: table used for running the module.

Figure 6.7: Access database structure



The format used for describing the tables is:

- Name of the table and type (explanation, support, active)
- Indices
- Variables

Table: 6.1: SLAM Database variables

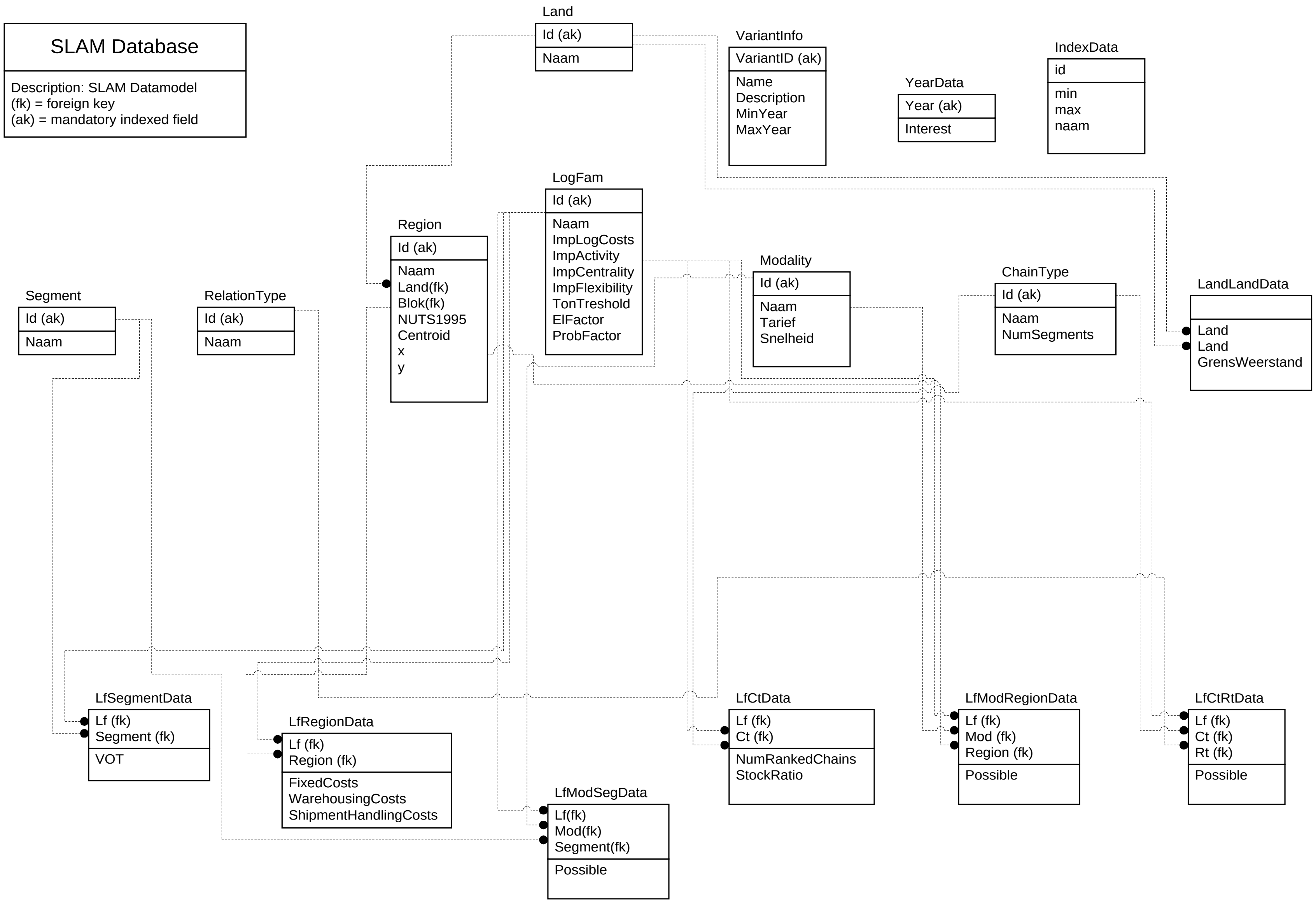
Table name and indices	Description
Blok (Explanation)	
ID	Blok-number (country blocks for border resistance)
Naam	Description blok-number (North-west Europe
Chain Type (Explanation)	
Id	Chain-type number
Name	Name chain-type number
NumSegments	Number of segments per chaintype
Grensweerstand Land Land (Support)	
Herkomst land	Country of origin for determining border resistance
BestemmingLand	Destination country for determining border resistance
Grensweerstand	Border resistance for the particular country-country relationship
Index data (Active)	

Id	Id indices
Min	Minimal value index
Max	Maximum value index
Naam	Name of the index
LandLandData (Active)	
LandHerkomst	Country of origin for determining border resistance
LandBestemming	Destination country for determining border resistance
Grensweerstand	Border resistance for the particular country-country relationship
Land (Explanation)	
Id	Id Land
Name	Name lands
LfCtData (Active)	
Lf	Logistics fam
Ct	ChainType
NumRankedChains	Number of alternative chains calculated
StockRatio	Average stock level
LfCtRtData (Active)	
LF	LogFam
Ct	Chaintype
Rt	Relationtype (national or international)
Possible	For LFx is the combination Ctx and Rtx possible
LfModSegData (Active)	
Lf	LogFam
Mod	Modality
Segment	Segment (part of the chain)
Possible	Is for LogFamx Mod_x allowed in Seg_x
LfRegiondata (Active)	
Lf	LogFam
Region	Region
FixedCosts	Fixed cost for stock keeping like landcosts or depreciation
WarehousingCosts	Costs per ton for keeping products in stock,
ShipmenthandlingCosts	Cost per ton for handling
LFSegmentData (Active)	
Lf	LogFam
Segment	Part of the chain
Segmentcosts	(Not active)
VotCategorie	Value of Time categorie (the higher, the more expensive time is) (1-5) (Not active)
Vot	Value of Time: importance of time (Active)
LogFam (Active)	
Id	Id LogFam
Naam	Name LogFam
Flow	Which flow in TAM-file
Part	What part of the TAM-flow is this LogFam
ProbFactor	Probability factor for LogFam
ImpLogCost	Importance of logistics costs for this LogFam
ImpActivity	Importance of activity in the regions for this LogFam
ImpFlexibility	Importance of the flexibility of a region by number of modes present for this LogFam
NumModalities	Number of modes allowed for this LogFam
TonTreshhold	
Modality (Active)	
Id	Id modality
Name	Name modality
Tarief	Tariff for this modality (Eu per km)
Snelheid	Speed for this modality (km/h)
Region (Active)	
Id	Id Region

Naam	Name Region
Land	Land regions belong to
Blok	Blok lands belong to
Centroid	Centroid of the region, used for distance from other regions
X	x-coordinate of centroid
Y	y-coordinate of centroid
Nuts1995	Nuts1995 number
ScenesID	ID given for translation to ArcView
RelationType (Explanation)	
Id	Id relation
Name	Name relation (national or international)
Segment (Explanation	
Id	Id segment
Name	Name segment, part of the chain (O-DC, DC-DC, Direct, DC-D)
VariantInfo (Active)	
VariantID	Variant Identification number
Name	Name of the variant
Description	Description of the variant
MinYear	Starting year of variant
MaxYear	End year of variant
YearData (Active)	
Year	Year
Interest	Interest
Scenesregios (Support)	
EURNUTS2_I	Region number in ARCVIEW
ID	Nuts1995 number region
NAME	Name region
ScenesID	ScenesID number per region for translation to Arcview

6.3.2 Relations between the various tables

The following figure (6.8, overleaf) shows the relationship between the various tables. The relational design provided, will allow changes in the database to be made consistently.

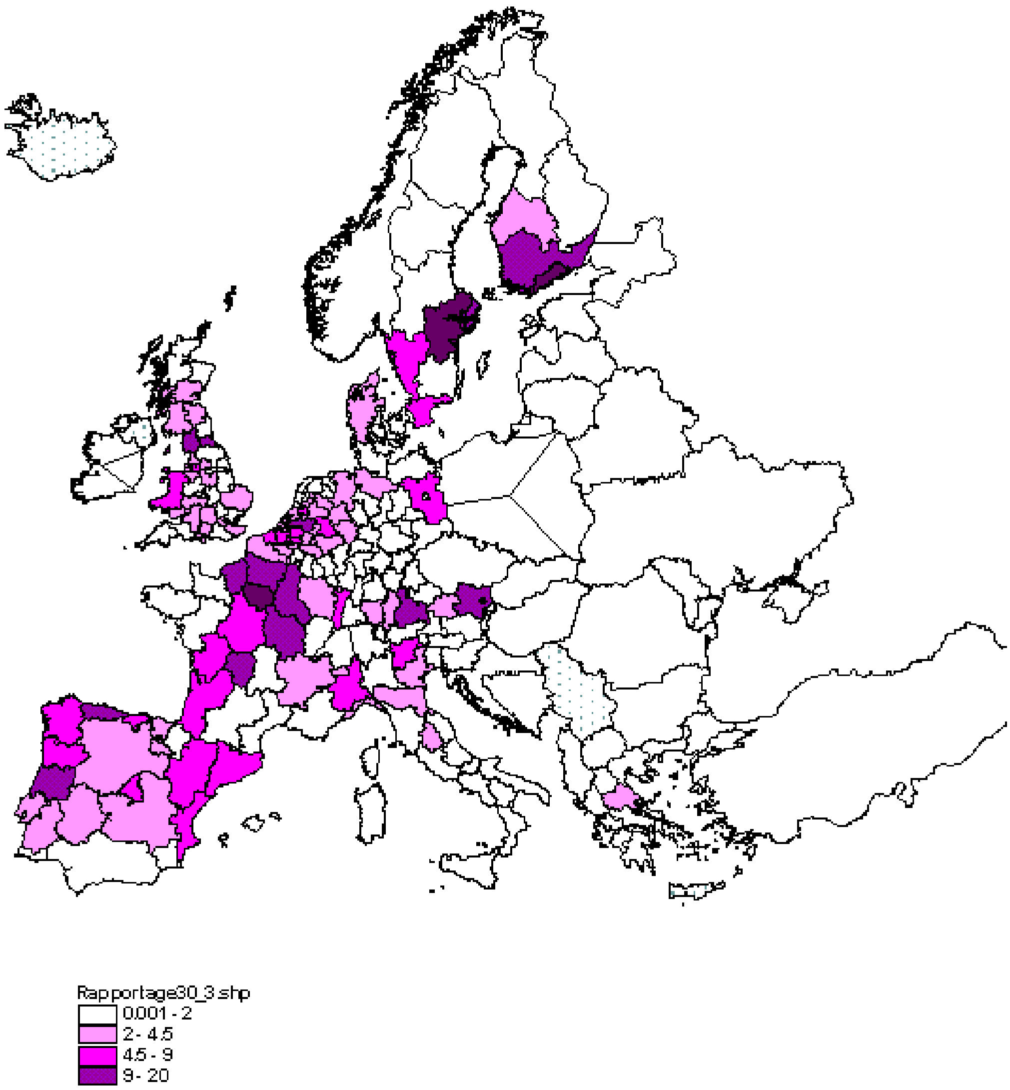

SLAM Database
Description: SLAM Datamodel
(fk) = foreign key
(ak) = mandatory indexed field
Land
Id (ak)
Naam
VariantInfo
VariantID (ak)
Name
Description
MinYear
MaxYear
YearData
Year (ak)
Interest
IndexData
id
min
max
naam
LogFam
Id (ak)
Naam
ImpLogCosts
ImpActivity
ImpCentrality
ImpFlexibility
TonTreshold
ElFactor
ProbFactor
Region
Id (ak)
Naam
Land(fk)
Blok(fk)
NUTS1995
Centroid
x
y
Modality
Id (ak)
Naam
Tarief
Snelheid
ChainType
Id (ak)
Naam
NumSegments
LandLandData
Land
Land
GrensWeerstand
Segment
Id (ak)
Naam
RelationType
Id (ak)
Naam
LfSegmentData
Lf (fk)
Segment (fk)
VOT
LfRegionData
Lf (fk)
Region (fk)
FixedCosts
WarehousingCosts
ShipmentHandlingCosts
LfModSegData
Lf(fk)
Mod(fk)
Segment(fk)
Possible
LfCtData
Lf (fk)
Ct (fk)
NumRankedChains
StockRatio
LfModRegionData
Lf (fk)
Mod (fk)
Region (fk)
Possible
LfCtRtData
Lf (fk)
Ct (fk)
Rt (fk)
Possible

6.4 First results of SLAM

Below is pictured the distribution of the warehouse throughput resulting from tests with a set data which involved partial geographic data, and a set of more or less fictitious values concerning freight flows and modal costs. Note also that this is the output for only one type of freight flow.

Although the model needs to be fine-tuned, the first results are quite reasonable. The first result of the map shows concentrations of DC's in regions where they would be expected (for example the in North Western Europe); however, it is stressed that the outcomes need to be interpreted with care, as the results are only based on partial data. Final testing will be done with the final results of the Regional Economic Module (see Chapter 4).

Figure 6.9: SLAM Distribution of regions with distribution activities



7. Conclusions

This Deliverable has outlined the design features and principles of the SCENES European Transport Forecasting model in some detail. Building upon the work undertaken in developing the STREAMS model, the SCENES model has taken account of the issues which were raised when the STREAMS model was used in practice.

It is clear that the design of the model is such that it can be continuously improved with the availability of new, better, or more comprehensive data. The limiting factor in successfully calibrating the model is now in many cases the availability of data at a detailed (or at least country) level of detail, rather than with short-comings in the model's functionality.

The new functionality of the model which allows groups of zones in the transport model to have their own parameters, effectively means that each country acts as its own 'sub-model' within the overall structure. This was a particularly important element in allowing the modelling of the EU and CEE countries in one overall model. Enhancing the software in this way is the major software improvement in moving from STREAMS to SCENES.

Comparing the STREAMS and NEAC freight results provided insight into the strengths of the two different approaches and gave insights to be acted on when forecasting in particular in SCENES. Also the inclusion of the 'Appended Module' to represent freight logistics should improve the routing of freight traffic, and thus the ultimate tonne-km figures and modal spilt.

Improvements in the data could take many shapes. Most notably on the passenger side, the availability in the future of the European level 'national travel survey' (i.e., the 'DATELINE' project) would enhance the detailed representation of countries on both the demand model and the transport model side. Any new data, which provides more details of travel behaviour by country could be incorporated within the base model relatively easily with the minor adjustment of model parameters. New 'observed' matrices (perhaps at the national level for passengers) could also be incorporated in the model calibration.

On the freight side, there is a good deal of information now available. 'Observed' matrices can be constructed from official data, at the national level at least. The major omission concerns region to region international freight movements.

Turning to forecasting, there is a need to perhaps have greater regard to the national level 'official' view of how transport demand will change over time. Forecasts produced by international organisations are also of use for placing model forecasts in context.

In conclusion, the new SCENES model will be a significant improvement on its STREAMS predecessor in terms of scope, detail and geographical coverage. The model calibration / validation and forecasting results will be reported in a succeeding Deliverable.

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