Final Report for Publication

STREAMS
(Strategic Transport Research for European Member States)
ST 96-AM-105

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Project Duration:
24/05/96 to 24/05/99

Date: October 2000

PROJECT FUNDED BY THE EUROPEAN COMMISSION UNDER THE TRANSPORT RTD PROGRAMME OF THE 4th FRAMEWORK PROGRAMME

List of Tables

List of Figures

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Executive Summary

The central objective of the STREAMS project was to build and implement a prototype model to (i) predict the demand for transport across the EU, and (ii) assign this demand to a set of networks representing transport supply in the EU. An initial 'Reference Scenario' forecast for 2020 were also to be produced. In parallel with model development, there were objectives to research modelling issues applying to the development of strategic models. An important element of this objective was the development of new software products, designed to make the use of large, strategic models more straightforward.

The STREAMS model structure includes both passenger and freight traffic, and incorporates all modes. The model is constructed as two main 'modules' – one determines the demand matrices and the other assigns the combined matrix to the networks, using cost and tariff data (in association with other network characteristics). There is a further interface mechanism between these two 'modules' in order to account for the effects of one upon the other. The model is specified at the NUTS2 level, leading to the implementation of approximately 200 internal zones for EU15.

A key design principle implemented within STREAMS was that the model should encapsulate all travel within the EU, i.e., it should include all short distance and slow mode trips (including walk). This called for a new approach to the treatment of 'local' (or intra-zonal) trips which account for the vast majority of trips made within the EU, given the zoning system. Using this system, it was possible to model more accurately the number of passenger trips within certain 'distance bands' by mode as a representation of 'local' trips. The model is therefore suitable for forecasting aggregate transport statistics for the whole of the EU area, including as it does all trips (including short and walk trips).

The structure of the project was to calibrate the model using economic and demographic data for 1994. The model outputs were then validated in terms of reproducing the 1994 levels of transport demand by mode by EU country. An initial STREAMS Reference Scenario forecast was then made for 2020 using independent socio-economic and demographic forecasts or 'in-house' assumptions as model inputs. The purpose of this Reference Scenario was to demonstrate the use of the model in forecasting mode, rather than to produce definitive forecasts *per se*.

The demand element of the model comprises independent passenger and freight components, since they employ different methodologies. The passenger demand model is based on trip rates (trips per person per annum) by journey purpose and person type. These data can be extracted from National Travel Surveys, which are published in several, although by no means all, European countries. The trip rates are applied to the population at a highly segmented level – in this way key factors which influence the number and types of trips made, such as car availability, age and employment are accounted for. The freight demand matrix is calculated using a Regional Economic Modelling approach, based on a spatial adaptation of the input – output (IO) table methodology. This methodology produces a matrix of trade by value, which is subsequently transformed into a matrix of volume of goods in the interface module. International freight trade is constrained to match a calculated 'observed' matrix of trade by commodity in the base case, and the effects of this 'constraint' are carried forward into the future to represent the non-transport cost elements which influence the distribution of trade in the EU.

The combined matrix of tonnes and persons is then applied to the multi-modal transport networks. These are 'real' networks, and operate at the 24-hour level representing a typical day. Capacity restraint relationships are used on the road networks to reproduce the reduction in average speeds caused by increases in traffic (particularly through peak spreading). There is a full representation of the costs and fares faced by both passengers and shippers of freight. In this way, it is possible to accurately match the modal split characteristics of the base year. The resulting average costs and times are then read as inputs in the demand model on the next iteration. In this way, the effects of infrastructure and pricing changes on overall transport demand are incorporated within the model structure. For example, an increase in transport costs in isolation leads to increases in transport disutility, and thus to less travel in the shape of reduced average trip distances.

With regard to the 1994 Base, the model produces a good match with the 'observed' published transport statistics in terms of the following key characteristics for passenger travel:

- overall number of trips;
- number of trips considered over different distances;
- average trip distance by mode;
- volume of travel (passenger-kilometres) by country by mode;
- overall modal split;
- modal split considered over different distances; and,
- a matrix of international 'tourism' trips.

For the 1994 Base year freight transport model, the following characteristics matched well with the 'observed' data sets (which were partially developed within STREAMS):

- total volume of EU freight by commodity flow;
- national volume of goods moved by commodity flow;
- international volume of goods moved by commodity flow;
- national and international modal split;
- international modal split;
- national freight volume by handling category by country by mode;
- international freight volume by handling category by country by mode;
- national tonne-kilometres of freight moved; and,
- a matrix of international freight movements.

The 2020 Reference Scenario model run produced the following key results for passenger transport:

- a 12% increase in the overall number of trips made between 1994 and 2020;
- a 5 percentage point increase overall in the modal share of the car to 60%;
- the modal share of car reduces markedly over longer distances due to competition from rail and air modes;
- significant increases in High Speed Rail over the medium to longer distances;
- the average passenger trip distance increases to from 13.1km to 17.3km, and
- the increase in trips and average trip distance leads to an increase in passenger-kilometres of approximately 50% (1.5% per annum).

The 2020 Reference Scenario model run produced the following key results for freight transport:

- the total volume of freight tonnes moved increases at 1.8% per annum;
- international volumes increase at a greater rate than national volumes;
- the greatest increases in volume of freight moved are within the unitised sectors;
- considering all freight traffic, modal shifts are not significant, although rail gains by 1 percentage point;
- for intra EU freight however, truck's share increases at all distances;
- truck mode sees the greatest increase in average trip distance; and,
- the overall increase in tonne-km on EU territory is 2.8% per annum – this reduces to 1.7% per annum if only intra-EU freight is considered.

When the results from 1994 and 2020 are compared in terms of the proportion of congested road network, the kilometres of 'over-loaded' links more than doubles. This increase in congestion varies widely between EU countries however.

In summary, the 1994 Base and 2020 STREAMS Reference Scenario have been demonstrated to produce practical model outputs, based on a highly disaggregated demand model structure and set of 'real' transport networks.

As an extension to the STREAMS project, the model was also applied in the 'Forecasts of EU/TEN-T transport and emissions: A Pilot Study' project for DGTREN. In this application, the model was used to produce traffic forecasts by mode at the level of individual links, for use in calculating various emissions data at the EU level associated with the TEN-T. This application of the model enabled valuable lessons to be learned, which are being applied in the development of the model within the follow-on SCENES project (see below).

It is also clear that a model of this nature has however, to be used carefully due to its strategic nature. The type of applications to which it is currently best suited are those which require an overview forecast of the levels of all transport demand by mode for passenger and freight traffic throughout the EU taken as a whole. At a level beneath this, the model can also provide similar output at the national level – incorporating as it does the key characteristics of the transport system in each member state. The model is well suited to estimating modal shifts and changes in transport demand associated with transport cost changes in particular. Given the spatial scale of the model, it is less well suited for instance to assessing the effect of a particular piece of infrastructure. In this respect, a strategic model can be no substitute for more detailed local models.

The model is also well suited to testing 'demand' scenarios in terms of their effects on the overall level of transport demand. Variations in population, employment and car availability on the passenger side, and production, and growth by sector on the freight side can be tested using the STREAMS model structure. Combinations of these 'demand' and 'transport policy' scenarios can of course also be run.

Given the prototype nature of this 'Phase A' project, consideration has been given throughout the STREAMS project's duration to areas of possible model development in 'Phase B' (i.e., the SCENES project). The basic design of the model has however been seen to handle the main causal mechanisms on the transport demand side well. The fundamental structure of the demand model will not therefore change in SCENES. Instead, a series of carefully considered more detailed model improvements will be implemented, targeted in particular at the potential needs of the policymaker – with reference in particular to the lessons learned as part of the EU/TEN-T project referred to above.

Part A - Objectives

The STREAMS project had four main objectives. The three original objectives of the project were to:

- develop a prototype multi-modal, network based, transport demand and supply model of the EU, covering passengers and freight;
- produce an initial reference forecast of transport in the EU; and,
- develop new modelling software to make the model easier to use.

During the course of the project the STREAMS contract was extended to include an additional objective:

- for ME&P to coordinate a project called ‘Forecasts of EU/TEN-T transport and emissions: a pilot study’. This project was based on the STREAMS work and three other (then) ongoing Fourth Framework Programme research projects. The objectives were to provide an initial attempt at quantifying the impacts of the TEN-T in terms of travel patterns and emissions, and to assess the feasibility of the method for a more detailed study. This work has been reported in a separate final report (ME&P, 2000).

Hence this deliverable only covers the three original objectives of the STREAMS work.

Part B - Means used to achieve the project objectives

The means used to achieve the project objectives were a combination of (i) data collation / collection, (ii) model design, implementation and testing, and (iii) a programme of software development.

The work was divided into three main elements, development of the multi-modal networks, development of the freight model and development of the passenger model. These three main components were then ultimately brought together by the project co-ordinator who produced the final combined model runs. Within these three very broad tasks were of course very many sub-tasks. These were organised by the partners responsible for each of the main model components.

The development of the STREAMS project followed three distinct phases:

(i) basic model design and creation of initial Pass 1 model;

(ii) innovative work in strategic transport model development, and implementation of STREAMS software; and

(iii) development of Pass 2 model, the final STREAMS model, building upon the work undertaken in (i) and (ii).

The main aspects of the STREAMS model can be summarised as:

- the model is multi-modal. The base year is 1994, the STREAMS forecast year is 2020, and the model currently works at the level of a typical day,
- it has comprehensive 'real', i.e., not corridor, networks for all modes and inter-modal connections,
- there are independent passenger and freight demand model components, each highly segmented for forecasting purposes,
- it includes a special treatment of trips within zones, and
- the modelling system incorporates the STREAMS software development programme which is designed to make the model easier to use.

Some of the main characteristics of the STREAMS model which was developed are now described, together with the associated programme of software development.

It was decided at an early stage to use a zoning system based on the 'NUTS' classification ('nomenclature of territorial units for statistics', the system of classification used by Eurostat for EU data collection) to make it easier to acquire the necessary data. NUTS2 was felt to be the maximum practical level of detail, which means the model structure contains approximately 200 internal zones.

The basic structure of the modelling system comprises two main 'modules', which are connected with an interface 'module'. The main modules are the 'land use' or the 'demand' module and the 'transport' module. The demand module is separately developed for the passenger and freight elements of the model. In each case however, the demand module takes as input a set of transport disutilities and combined with economic, socio-economic, and demographic data produces a demand matrix. These demand matrices are combined and assigned to the transport networks in the transport module, producing a set of transport disutilities which feeds the demand module and so on, in an iterative manner.

The STREAMS model aims to provide medium to longer-term forecasts of changes in transport demand. This implies that the model structure should be based on the need to understand why and how travel demand tends to grow over time. The model structure should also be based on assumptions about what policy options the model would be required to test, and what outputs would be expected. These considerations led to a set of design principles on the treatment of short trips, the segmentation of the model, and the approach to including explicit transport networks.

One option in a strategic model is to include only certain types of trips, such as long distance trips. It was decided in the STREAMS project to model all trips, of whatever length, partly to provide a more stable basis for forecasting and partly because there would be policy interest in seeing EU transport as a 'whole'. By definition this means that in a model with NUTS2 zoning, a very large proportion of trips will be within zones. This in turn implied the need to improve the treatment of intrazonal trips compared to their treatment in most transport models. Thus a new system was developed to deal with this.

Both the passenger and freight demand modules are based on the need to understand why travel demand tends to grow over time. For the passenger model this meant a detailed representation of traveller types and trip purposes. For the freight model it meant using a Regional Economic Model (based on input–output tables) and a spatial allocation process to generate freight flows, segmented by industry and commodity type (e.g., bulk and unitised).

In large scale models, transport networks are often represented as corridors. In STREAMS, given the need to represent transport costs accurately, the level of policy interest in understanding travel patterns and also their environmental impacts, this suggested a need to develop a link-based model.

The strength of the model is in producing EU-wide transport forecasts for the impacts of socio-economic change and different transport policies, together with an indication of the distribution of results by country and region. The model design allows countries with different behavioural and socio-economic characteristics to be modelled within a consistent overall structure. The detailed multi-modal approach coupled with a good representation of costs and tariffs allows a wide range of policies to be tested, including the impact of differential price changes between the modes. The highly segmented passenger and freight demand models provide a mechanism to represent the impact of economic and demographic change on the transport system.

However, there are inevitably limitations on the likely reliability of the model results at a detailed spatial level. A model of the whole of Europe cannot be expected to produce the same degree of local accuracy as, say, fifteen national models, or a greater number of regional models. The nature of these spatial limitations is being explored in a follow up project, SCENES (see Conclusions). There also remains a general technical issue of the extent to which a strategic model of this nature can provide accurate flows across the entire network. Incorporating a real network, as opposed to a stylised or corridor representation is of importance for achieving accurate cost and time estimates, but obviously the link flow results themselves will also be of interest. This point has been taken forward as part of the pilot study which formed the fourth STREAMS objective and is also being considered further in SCENES.

The general aim of the software development work was to improve the speed and accuracy with which a large scale model such as STREAMS can be used. A Scenario Manager was developed to assist in setting up model runs, a Network Tool to aid network changes and editing and a Presentation Tool to enable a striking visual representation of results.

The Scenario Manager is a tool for automating and managing policy testing with the STREAMS model. The system allows policy tests to be quickly and easily defined and automates the running of tests.

In addition, the Scenario Manager provides a reference system for storing the inputs to model runs, allowing rapid cross checking of scenarios and reducing the possibility of errors through wrongly specified policy tests.

The Network Tool performs four main tasks: network management, minimum path calculations, network consolidation, and results analysis. In the first instance the tool allows the user to build and modify networks on-screen using an interactive point and click interface. This dramatically increases the speed at which new networks can be generated and new policies tested. It allows the user to plot minimum paths through the network based on distance, cost and time for network checking purposes. The tool also incorporates a consolidation feature which enables the user to remove unnecessary links and nodes to obtain a smaller network but without any loss of information relevant to a transport model. In terms of results analysis, it is possible to present link flows from the model in a GIS environment.

The STREAMS Presentation Tool presents travel time maps for Europe in the form of isochrone maps, i.e., for a selected destination travel times from all parts of Europe can be displayed for different modes, flows and years. Travel times can be distinguished on the map by different colours. The innovation compared to common isochrone maps is that the isochrones are not presented as lines, but that for each point of the map a travel time is calculated and displayed which leads eventually to the display of a continuous travel time surface. For this purpose, the European territory has been disaggregated into some 70,000 raster cells, each representing an area of 7.5km by 7.5km. For all raster cells, travel times are calculated and displayed.

Part C - Scientific and technical description of the project

1. Introduction

Part C of this report contains the main description of the STREAMS project. It is divided into six chapters which deal in turn with:

- the representation of transport supply in the model;
- the development of the demand modules for passenger and freight;
- the 1994 base year model validation;
- the STREAMS software development programme;
- a summary of the 2020 Reference Scenario assumptions; and,
- selected 2020 Reference Scenario model results.

Note that the ‘Forecasts of EU/TEN-T transport and emissions: a pilot study’ project, which formed part of the STREAMS contract is reported in a separate document (ME&P, 2000).

2. Transport Supply

2.1 Introduction

The supply side of the STREAMS model consists of the multi-modal networks and the costs of using each mode. After a brief description of the model zoning system, this Section describes how the transport networks were defined and derived, together with their main characteristics. It then describes the methodology for dealing with intrazonal trips, before outlining the structure of the cost functions used in the model, for both passenger and freight transport.

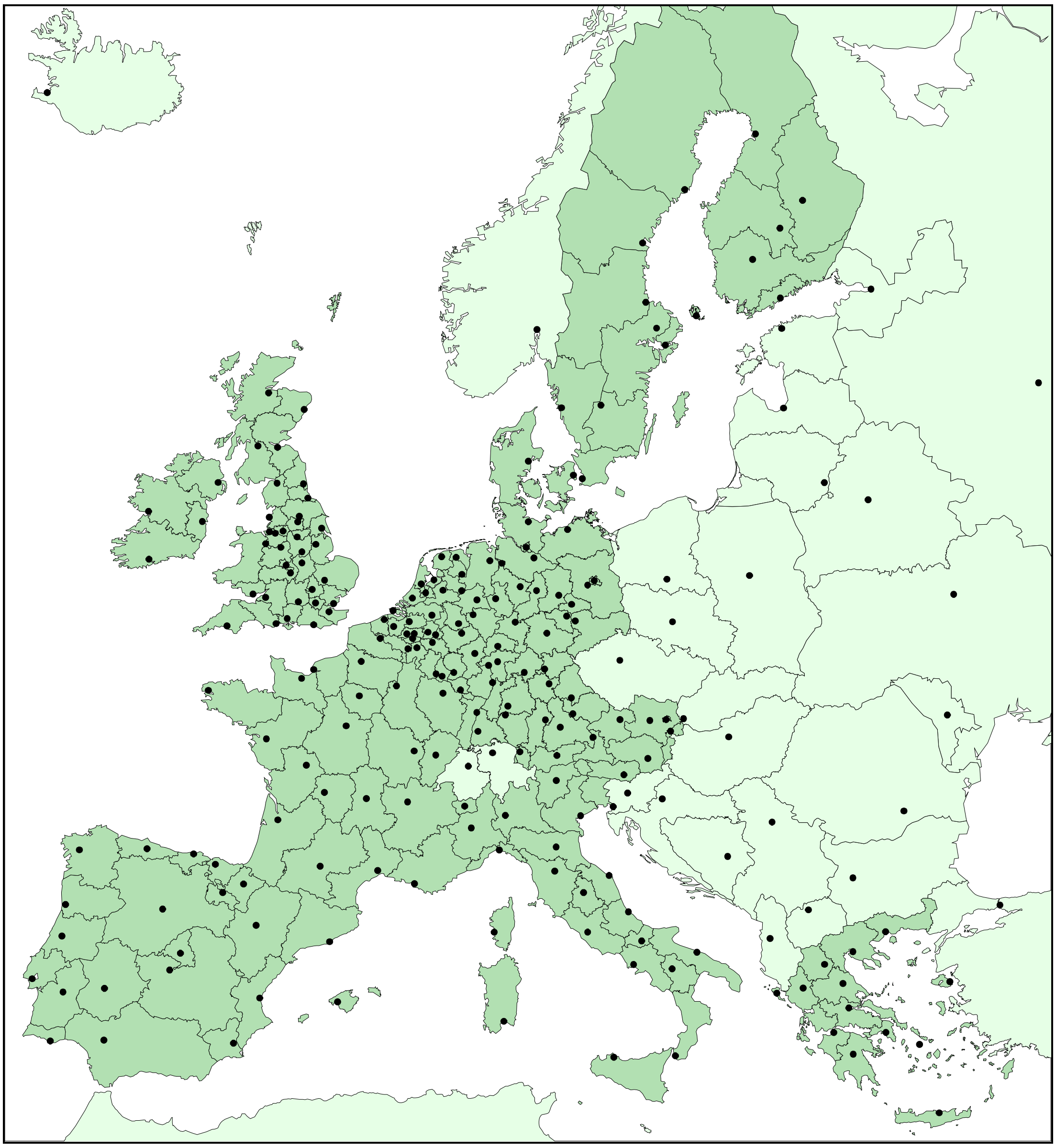
2.2 The Zoning System

The zoning system has 201 internal zones (NUTS2 regions for EU15 countries), 27 external zones for the remaining European countries and 4 external zones to represent the rest of the world. Each internal zone is linked to a number of 'distance band' zones representing intrazonal passenger traffic.

The internal zones are linked to some or all of these 'distance band' zones depending upon the size of the zone, and these zones represent short distance, intrazonal trips of different distances in a more comprehensive way. It is clear that the adoption of the NUTS2 zoning system results in an uneven physical zone size across the EU. A more detailed zoning system has been developed as part of the SCENES project for use at the traffic assignment stage in order to improve this aspect of the model, by spreading the traffic load more evenly around the network (see Conclusions).

Figure 2.1 shows the internal and external zones of the STREAMS model, together with the location of the zone centroids.

Figure 2.1: STREAMS zoning system



2.3 General Network Description

The STREAMS network is an integrated multi-modal network, which allows flexibility in the treatment of multi-modal trips for both passengers and freight. The following networks are represented: road, rail, air, inland waterway, shipping, pipelines (for petroleum products) and inter-modal networks (ports, terminals, etc.).

Links represent either physical connections such as roads or transfer links between the modes. The model contains around 5,500 road links, 2,300 rail links, 1,300 waterway links, 1,000 air passenger and freight links, and approximately 3,000 intermodal links (such as ports and terminals). Each of these links is coded as two links (by direction).

The model also contains access links, which represent connections from the zone centroids onto the model network, and intrazonal links.

Each element of the networks is now described in turn. The network is largely based on the IRPUD GIS network[1]. This GIS based network has been converted into a network suitable for modelling purposes and then supplemented and enhanced by the inclusion of relevant attribute data from other sources.

2.3.1 Road Network

The STREAMS road network contains the main European roads and aims to provide a realistic representation of the routes used for medium and long distance road traffic. For a strategic European-level model such as STREAMS, it is not feasible to include all minor roads, although they may have some part of the traffic moving between modelled zones on them. Hence the STREAMS road network is a balance between realism and practicality.

The road links included in the model are distinguished as toll motorways, toll-free motorways, dual carriageways and single carriageways. The links are further distinguished by classifying the links for each EU country. Road link lengths were derived directly from the IRPUD database. The International Road Federation (IRF) produces a database which was used as a source of information on speed limits and the number of lanes on each link. This information on the number of lanes was then used to calculate road capacities. Information on the actual (observed) loads on roads was collected from national sources supplemented by the IRF count data.

2.3.2 Rail Network

In urban rail models, individual train services are usually represented with realistic headways and sometimes the inclusion of accurate capacity restraint functions based on engineering data. For STREAMS, it was decided not to try to represent actual rail service patterns across Europe. Given the scale of the model, the task would be overwhelming in terms of both manpower resources and computing power. Representing rail capacity therefore raises specific problems for an inter-urban model without the explicit coding of services, as there is no simple function which can accurately simulate capacity restraint on a rail network like one used in STREAMS.

Each rail link is classified according to the different services that are currently operating on that line. This encompasses a wide range of passenger, freight or combined use links. The links are further differentiated into country-specific link types, which have different speeds. The speed varies according to the type of service that is using the link.

The strategic rail network is based on the ‘Trans-European Transport Network Outline Plan, Section: Railways’ as published by the European Commission in December 1995. All rail links indicated as existing in this document are included in the strategic network. Some additional links have been added into the strategic rail network to guarantee appropriate connectivity.

Scheduled international unitised services have been defined on the basis of freight railways network maps received from the international organisations InterUnit and InterContainer. Data regarding scheduled container rail services across Europe have been collected and particular attention has been given to shuttle trains, which offer a scheduled fast service with fixed composition of the wagons.

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[1] This GIS transport network was developed by Institut für Raumplanung, Universitat Dortmund

As for roads, link lengths are taken from the IRPUD database. Rail freight cost structures are differentiated by bulk and unitised flows, and are based on a variety of industry sources. The Thomas Cook European timetable has been used to derive rail speeds for passenger traffic. Scheduled unitised rail speeds have been collected from industry sources, while non-scheduled unitised loads are assumed to travel at a proportion of the passenger speeds.

Little published information is available on observed loads for rail links, mainly due to issues of commercial confidentiality. Some data has been collected relating to number of trains, but there is little data on passenger link flows which is not subject to commercial confidentiality considerations. On the whole, aggregate passenger and tonne-kilometres by country data were used for validation of the rail sector.

2.3.3 Inland Waterway Network

The strategic inland waterway network contains the main trans-European inland waterways. It is based on two different sources. One source map[2] illustrates the inland waterway network for the heart of the Europe in a very detailed way. This map includes the Netherlands, Belgium, Germany, Northern Austria, Northern Switzerland and France, and the western parts of Poland and Czech Republic. The second source[3] map shows the inland waterway network on a rather aggregated level and is used to code the waterways for Scandinavia, East and South Europe.

Link lengths are given by the IRPUD database while cost functions are based on a detailed study made by the Netherlands Economic Institute. Capacity is generally not a problem on inland waterway networks, except at some bottlenecks and capacity has not been explicitly represented in the model. Observed link loads are useful for validating model output and some information is available for key links such as the Rhine.

2.3.4 Shipping Network

The shipping network is divided into short sea shipping and deep sea shipping networks. The short sea (or coastal) network connects the countries around the European continent and the latter (deep sea) simulates the long-distance goods movement from the EU countries to the more distant external zones such as the Americas, Africa / Middle East and the Far East. Access to deep sea shipping is available only from selected ports.

Shipping costs are based on functions which are discussed later in this Section. On the short sea shipping links an average ship speed is assumed together with loading / unloading times in the port for different type of goods. For deep sea shipping time is not an important issue, because those notional links are merely used to separate different flows to suitable ports as well as to differentiate the flows to short sea shipping ports and deep sea shipping ports.

2.3.5 Air Network

The air network connects all the main European airports. Only one airport is coded in each zone, which represents the flows and services of a number of airports in the zone in some cases. Some regions contain no airports but the model will allow users of the air network to access airports in neighbouring zones by road or rail.

A scheduled passenger service between any two airports is provided in the STREAMS networks if they are listed in the 'On-Flight Origin and Destination' publication (ICAO 1994

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[2] Published by Binnenschiffahrts-Verlag GmbH, Duisburg (Germany).
[3] Published by the United Nations (Economic Commission for Europe: European Inland Waterways).

and 1995), with additional links added where necessary for connectivity (or for passenger charter services). Other links are provided for air freight, which connect the air freight terminals. An air freight connection between airports is provided if the freight flow is, at least in one direction, more than 2000 tonnes per year according to the 'On-flight Origin and Destination'[4].

The lengths of the passenger air links are also based on the above publication. The lengths of air freight links is measured using the maps and coordinates. Journey times are based on the 'OAG World Airways Guide' (November 1996) and an allowance is made for time spent in terminals.

2.3.6 Pipelines Network

Only petroleum product flows are modelled in pipelines (i.e., not crude oil). The source for the pipeline network is a map produced by The Petroleum Economist Ltd: 'Oil in the Former Soviet Union and Europe'.

2.4 Distance Bands: Dealing with Local Traffic

The previous sections have described the zoning system and the representation of the network. Within each internal zone there are also links to further zones, which represent short distance passenger trips of different lengths.

As discussed in the Introduction, the STREAMS model represents all European travel (i.e., all trips, including short distance and slow modes). Since the model only has around 200 internal zones, this necessarily means that most passenger trips will be 'intrazonal'. That is, these trips will take place entirely within a zone and hence will not travel on the transport network (which only handles traffic between zones). Conventionally in a strategic transport model, local trips would simply be represented on an intrazonal link. But it was clear from an early stage that the treatment of these intrazonal trips would be a fundamental factor in how well the model worked, and hence a new approach was developed, based on 'distance band' zones.

The main reason for this approach is that it allows the modelling of all trips as a continuum. This allows the model to simulate the response of travel demand between intrazonal and interzonal trips where the interzonal network either improves, or where the interzonal network is heavily tolled or congested. Trips can 'spill' out onto, or away from, the interzonal network in response to these changes.

The distance bands used are as follows:

- 0 – 1.5km, represented by a link of 0.6km (based on observed data),
- 1.6km - 3.1km, represented by a link of 1.97km (based on observed data),
- 3.2km – 7.9km, represented by a link of 4.74km (based on observed data),
- 8.0km – 15.9km, represented by a link of 10.56km (based on observed data),
- 16.0km – 39.9km, represented by a link of 23.42km (based on observed data),
- 40.0km – 79.9km, represented by a link of 54.55km (based on observed data), and
- 80.0km – 160km, represented by a link of 109.9km (based on observed data).

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[4] ICAO Digest of Statistics No. 424.

The STREAMS zoning system is not geographically uniform and the percentage of intrazonal trips varies widely because of this (e.g., small zones in Benelux and large zones in Spain). Zones also differ considerably in their characteristics (e.g., urban, non-urban) and access to modes. Therefore, for passengers, zones were classified in two ways: firstly by settlement type (to reflect typical travel speeds and modal availability characteristics) and secondly by implementing a varying number of distance band zones for each zone depending on its size. Thus, firstly, six settlement types were defined depending upon the level and nature of urbanisation (ranging from metropolitan area to wholly rural). Then, secondly, each zone was specified in terms of the number of distance band zones to which it is attached. Large zones with a long intrazonal distance (approximate radius) thus have more bands than smaller zones with a shorter intrazonal distance.

The network for the distance band zones is necessarily simple. The characteristics are the availability of modes by zone, and the coding of appropriate speeds, costs, and terminal costs and times. These characteristics are sufficient to distinguish the main intrazonal travel characteristics between the six different zone types.

Intrazonal freight traffic is treated in a simpler fashion, using a solitary intrazonal link for each zone based on the size of the zone. Within STREAMS, the emphasis was on inter-zonal freight movements since the balance of intra / inter zonal movements is not as extreme as is the case with passenger travel.

2.5 Road Capacity Restraint Functions

An important element of the assignment model has been the specification of 24-hour capacity restraint relationships for different road types. These are required since the STREAMS model works on the representation of real links rather than aggregated or corridor links. The relationships have been based on extensive hourly flow data which were obtained from many sites in the UK (supplemented by data from other countries, including Italy and Finland) relating to motorways and dual carriageways with varying numbers of lanes, and to normal two way ‘A class’ roads.

In the derived relationship, the average 24-hour speed for each road type gradually reduces as the flow volume / road capacity ratio increases. The speed never drops to a very low level however, because this ratio takes account of the ‘peakiness’ of traffic through the day – rather it is showing how the average speed reduces as the degree of ‘peak spreading’ increases.

Thus the functions obtained show how average daily speeds decrease as effectively the degree of ‘peak spreading’ increases for each road type. This enables functions to be formulated to simulate the effects of increased traffic levels in the future year scenario running.

2.6 Passenger Transport Costs

The model represents the actual costs faced by the user of the different modes. For rail, air and coach this is the fare paid, although this fare may vary considerably according to the type of service - first or second class rail, high speed or ordinary train for example. For cars, the cost to the user depends on what costs they actually take into account when making a journey, which varies by whether the journey is in the course of work or not. There are four main passenger modes and cost functions have been developed for each of them.

2.6.1 Car operating costs

The perceived cost function for car has been set to equal the operating cost of running the vehicle, that is the ‘out-of-pocket’ money spent e.g., for petrol. It is related to distance and distinguishes the different fuel prices and the different tolls applied in each country across

Europe. The fuel prices and motorway tolls for each country for 1994 were taken from reports published by the Automobile Association in the UK. For car-borne business trips the full costs of the journey are incorporated such as depreciation and wear and tear. These non-fuel costs were derived from the UK Department of Transport Highways Economic Note 2 (HEN2) (1996).

2.6.2 Air fares

For the air mode, different cost functions were used for different market segments and different countries, based on a survey of air fares, which specifies fares per kilometre by typical ticket type (see Cranfield University, (1997)). These functions comprise leisure and business tariffs. A separate simple tariff is used for charter flights – this is not important in a modelling sense as there is no modal competition for those specified in STREAMS as being air charter passengers.

2.6.3 Rail fares

There are many sources of European rail tariff data available both on the Internet and in printed form. They break down into two major categories - national rail companies and tourism companies / travel guides. The most reliable information was assumed to come from the websites of the national rail companies. An initial review of data sources showed that relatively good information could be obtained for France, Belgium, Spain, Finland, Sweden, the Netherlands, and the UK. For the other EU countries data proved either difficult to collect or interpret.

For STREAMS, simple rail fare functions are needed which give a reasonably accurate simulation of how fares change with distance. From initial investigation of the data it appeared that there are two main types of fare structure - one where the ecu / km charge varies with the distance travelled and one where it stays constant. For most of the countries for which data has been obtained, the ecu / km charge declines with the distance of the journey (care is therefore required when specifying the functions to avoid negative fares over very long distances).

For each country which had relatively good information, a function was developed showing how standard (second class) fares varied with distance and then a weight was calculated to represent the extra cost of business class (first class) tickets. For the other countries, fare structures were either (a) calculated on the limited available evidence and then compared to other countries with good data availability to check on their plausibility or (b) assumed to be the same as in one of the countries with good data availability.

2.6.4 Coach fares

Data were collected for international coach fares from UK, Denmark, Spain, Sweden and the Netherlands to a wide range of EU destinations. The values of ecu / km were plotted against distance for all the city pairs.

There were few significant or systematic differences between countries and it was decided to implement the same relationship between fares and distance for all EU countries, which was simply the average of all the fares collected for all sampled routes.

Fare data was also needed for local buses. In this case UK local base fare data was used (in the form of aggregate revenue and passenger numbers / passenger-kilometres) with some checks carried out to assess its suitability for other countries. Not surprisingly, the fare per km is significantly above that for long distance coach services.

2.7 Passenger Value of Time & Vehicle Occupancy

There are two other issues which are of particular importance in the development of the supply side of the passenger model - values of time and vehicle occupancy.

The value of time in the model varies by trip purpose and population segment, to take account of differences in average income levels within the different segments – and thus reflect their different trip making characteristics. Little information was readily available and hence a fairly detailed method had to be implemented to derive the necessary values.

Within the model, travellers are segmented according to their age / employment status and car availability (see Chapter 3). Income levels for the EU countries were obtained from Eurostat. These values were used to derive an EU wide average and it was this value which was used in the model. Detailed UK data were used to calculate relative income levels for each of the modelled population segments, and these were applied to this EU average value. The next stage of the work is to link income levels to values of time using recent World Bank research (Gwilliam, 1997). This research gives typical percentage variations on value of time by trip purpose. These variants are therefore used to derive values of time by trip purpose.

Assumptions are needed regarding vehicle occupancy in order to convert transport flows (in terms of persons) into numbers of cars (and coaches) for assignment to the network. Although some vehicle occupancy information is available from a range of EU countries, it is rarely at the detailed level of disaggregation. Only the UK National travel Survey provides a sufficiently detailed breakdown and hence the approach was to use this source and to compare it against available evidence from other countries.

2.8 Freight Transport Costs

As for passengers, freight costs need to be implemented for each mode. These costs often consist of different stages such as the main journey plus loading / unloading.

2.8.1 Truck costs

Truck costs were based on operating costs collected from different Italian and UK studies[5], producing two different functions for 'long distance truck' and 'short distance truck', in order to more accurately reflect actual transport costs.

2.8.2 Rail costs

The rail mode is distinguished in the model between 'Bulk Rail' and 'Unitised Rail'. The cost functions were estimated separately for these modes.

The cost function of bulk rail was estimated on the basis of the official tariffs for different cargoes charged by the Italian, French and German railways. A sample tariff of the Italian railways (FS) in 1992 for a consignment of 20 tonnes of bulk freight was considered for different distances. From the same source, the index of other countries' fares with respect to Italian ones was known. Therefore the figures of tariffs per ton for some countries was obtained and a function was estimated. As the official fares for bulk transport by rail represent in practice an upper threshold for the actual cost of shipments, figures of revenues by tonne-km of different European railway companies were used to adjust the figures.

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[5] CSST, (1996); Supplemento a '*Tuttotrasporti 97'*, 1997; The Department of Transport, (1996); *Relazione etc.*, 1992 (see 'References & Bibliography' for full details)

The cost function for unitised rail was based on a set of data available from a detailed study on inter-modal centres (which contains figures both for rail charges and for cost of operations at terminal) (Corazza, 1996/97) and from tariffs applied by the most important European operators.

2.8.3 Ship costs

Sea shipping transport costs consist of loading and unloading, ship in port, and ship in navigation. Cost functions for sea shipping were analysed differently for bulk freight and for unitised freight.

Given the wide range of different conditions in the shipping market, a source of average rates is not readily available. Therefore, costs were estimated with reference to prices applied by relevant shippers with regard to 'typical' consignments. Data were analysed for different ship dimensions and different loads. The costs of port operations were assessed starting from costs of loading and unloading goods in different ports.

2.8.4 Inland waterway costs

Cost functions for inland shipping were extracted from a detailed study made by Netherlands Economic Institute (NEI, 1997) regarding barge tariff and cost structure. Port costs are represented by a fixed term, while the barge tariffs are modelled by means of both a time-related and a distance-related term.

2.8.5 Air freight costs

The cost function for air freight was estimated starting from 'The Air Cargo Tariff (TACT)' (1997) which reports the official fares for each origin – destination pair. These figures were used as the highest threshold of charges for freight transportation as some direct interviews with a sample of air companies (interviews were carried out in a study for the Italian Bureau of Exchange (TRT, 1998)) showed that actual tariffs are often smaller than the official ones.

2.9 Freight Value of Time & Load Factors

As for passengers, there are further assumptions needed for the value of time and vehicle occupancy levels for use in the freight model. Literature estimates from a number of studies have been used as a reference in the assessment of the values of time. As such studies take into account one or two modes only, suitable assumptions had to be made in order to widen the estimates to the other main modes of transport (ship, inland waterway, air freight).

Starting from the general level of values of time derived, some modifications have been made for some particular modes. In particular, for bulk freight flows the actual journey time is generally of little relevance, so only nominal values of time have been implemented.

A limited range of data sources were used to estimate load factors for trucks based on the different types of commodity being moved. In particular, a Trans-Alpine database[6] was obtained which reports international road traffic crossing at Alps customs in terms of tonnes

[6] 'Alpenquerender Güterverkehr auf Strasse und Schiene' (Alps Crossing Traffic by Road and Rail).

and vehicles by NST/R chapter, including empty trucks. This was supplemented with data from the PETS[7] project for Germany and similar data from the UK.

Using these data sources, values of tonnes / truck (allowing for the empty running of trucks) were obtained for both ‘short’ and ‘long’ distance truck modes. These modes represent local delivery style operations and long distance truck transport respectively.

2.10 Other Network / Supply Characteristics

Two further elements of the network supply characteristics are firstly terminal costs, times, and, ‘disutilities’, and secondly time dependent additional costs and disutilities. Terminal costs, times and disutilities are applied for both passengers and freight and allow a representation of e.g., walk time from home / waiting time for public transport. In the passenger model these entities vary by the six zone classifications to reflect for example the more limited public transport provision in rural areas. They are also used in freight modelling where such aspects are not modelled explicitly.

The other additional costs / disutilities are those associated with very long journeys. For example values are input to simulate rest and sleep time for road mode trips, whether by statute or inclination (e.g., European legislation on truck and coach drivers’ hours, Lowe (1998)). Similar values are included to deter some rail trips over the very longest distances. These considerations apply particularly to business trips where there is a greater inclination to make trips which can be completed outward and return in one day (i.e., without incurring the additional cost of an overnight stay).

[7] PETS (Pricing European Transport System) Deliverable D6: Data on Flows, Parameters and Scenarios EC DGVII

3. Transport demand

3.1 Introduction

This Chapter describes the methodological approach for estimating demand matrices within the STREAMS model and outlines how this demand is implemented in the transport model. Different approaches are necessarily used for the passenger and freight elements of the model and these are described in turn for the 1994 base year model. The assumptions made to run the model for the example 2020 Reference Scenario are reported in Chapter 6.

The freight and passenger demand elements of the model operate separately. The resulting demand matrices are then combined and assigned to the multi-modal transport networks. The relevant output costs and times associated with zone to zone travel are then applied to both the freight and passenger demand models in the next iteration.

3.2 Passenger Demand and Transport Model Structure

There are many difficulties attached to the collection of observed data for the purposes of passenger modelling at the strategic and especially European level. Conventional approaches used in urban modelling, such as using survey data and matrix estimation techniques based on observed count data, cannot easily be applied at the strategic level. In addition there are no ‘observed’ European travel matrices, and even at the nation state level, travel matrices only exist in a limited number of countries, and may not be comprehensive.

For the STREAMS model, a different approach therefore had to be devised. The approach taken was rooted in the overarching objective of the STREAMS model – to provide a comprehensive strategic view on all transport in the EU. This objective necessitates the modelling of all trips and all modes. An approach based on existing National Travel Surveys (available from several although not all countries) was therefore devised to build up a picture of European travel.

National Travel Survey publications and special data requests were obtained for Denmark, Finland, France, Germany, Netherlands, Sweden and the UK. There is currently no equivalent study which deals with the EU as a whole. Typically, surveys of this nature provide data on factors such as: annual trip rates per person, average trip distances and modal split, all disaggregated to varying degrees by journey purpose and population group. These surveys were analysed and attempts were made to adjust them so that all could be meaningfully compared. The main problem when comparing the NTS is the wide range of definitions and sample specifications used in the respective surveys which makes comparison between the countries difficult (especially at any disaggregate level). The basis of the passenger model is however in the NTS as reported by the different publications.

3.2.1 General approach

In outline, the trips are generated using a highly segmented representation of the population at the zonal level, and several trip purposes, using annual trip rates. The generated trips are then distributed using the zone to zone transport costs, model distribution parameters, and zonal ‘attractors’. Aggregated travel groups are then used for modal split calculations and a further aggregation occurs for network assignment which uses capacity restraint functions on the road networks (at the daily level). This overall process produces the matrix of costs, times and disutilities. This matrix forms the input to the demand model and this process is repeated in an iterative procedure until overall convergence.

The main aim of the model is to forecast passenger travel over the medium to long term, hence the passenger model structure has been based on an analysis of what factors have caused the past growth of passenger traffic, which can be briefly summarised as:

- population growth - a relatively minor source of road traffic growth;
- more people have access to cars - the increased car ownership is due largely to the average incomes of individuals increasing more rapidly than the cost of car ownership;
- changing household structure – multi-car households and lower average household size;
- the car has captured a greater share of all the trips that are made, because the cost-effectiveness of car travel has improved relatively more quickly than that of other modes (except air);
- people now tend to make longer trips due to the improved cost effectiveness of travel, especially by car. This has been a significant source of growth e.g., in the UK average trip lengths for car drivers have increased by 12% to 13.5km over the 20 years to 1995 (DETR, 1997). This growth is due both to lower car operating costs, and to higher average road speeds due to the greater availability of and the more intensive use of the motorways;
- people are likely to travel further due to the increased average income of individuals;
- people make longer trips because of the population shift away from dense urban areas. This increase in demand results from the migration of households and jobs to areas which are less congested for cars;
- car occupancy levels have fallen; and
- overall, a greater proportion of the population are now in those population age segments that tend to have higher trip rates, that make the longest trips and that are most likely to use cars.

The STREAMS model segments population by age group, employment status and household size / car availability, and has full cost / tariff representation for each mode. Through changes in car ownership and the impact of GDP growth it simulates the impact of rising incomes. It therefore provides a basis for modelling these key mechanisms - income growth, growth in car ownership and relative costs between the modes - which explain increased car travel in particular.

There are therefore a number of key relationships which form the theoretical underpinnings of the STREAMS passenger model, concerning the nature of trip making behaviour and its evolution through time. Once such relationship is the relative constancy of trip rates over time. Examination of time-series trip rate data reveals that trip rates change only very slowly over time, (once the population is segmented to an appropriate level and when all trips are included in the analysis), and this factor certainly contributes less to the growth in traffic than one might expect. Thus, in forecasting with STREAMS, trip rates grow very slowly and only for particular travel purposes.

Although, the passenger demand model uses UK NTS data as its starting point, a number of hypotheses regarding a wide range of passenger travel behaviour were examined in the context of all the EU countries' NTS which were obtained.

3.2.2 Population segmentation

Five different population groups are identified in the model, as these population groups have very different trip making characteristics[8]. The logic behind segmenting the population is to create a transparent mechanism which allows for the forecasting of travel demand, based on an estimate of the future population characteristics. These 5 population groups are then each split into 4 sub-groups[9] reflecting the level of car availability and household composition. Each of these 20 groups has a trip rate for each of the trip purposes specified in the model.

3.2.3 Trip purposes

The decision on which trip purposes to distinguish was based on information from the National Travel Surveys showing the relative numbers of trips that are made at different trip lengths classified by trip purpose. The trip purposes which are distinguished explicitly are those which are most numerous at the specified trip length, while the remaining categories of lesser importance are then aggregated into these explicit categories.

The nine final purposes listed below are coded in the model with a different trip rate for each of the 20 population segments:

- commuting, business - short distance (*defined as < 40km*);
- shopping, personal business, and education - short distance;
- visiting friends and relatives, entertainment, and day trip - short distance;
- visiting friends and relatives, entertainment - long distance (*defined as >40km*);
- day trip, shopping, personal business, and education - long distance;
- business and commuting - long distance;
- domestic holiday - long distance;
- inclusive international holiday (i.e., charter flight package) - long distance;
- other international holiday - long distance.

The segmentation by population group in terms of age / employment and car availability / household structure, combined with trip purpose is then manipulated in several different ways at each stage of the modelling process – namely trip generation, trip distribution, modal split and assignment.

3.2.4 Trip generation

At the trip generation stage, the full disaggregation of population group and trip purpose is used. This is to ensure that the total number of trips made in the model is sensitive to changes in age / employment and car availability / household structure. Trip rates also vary at the national level, using data from the different countries' NTS and other factors to adjust the highly segmented UK rates to reflect national characteristics.

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[8] They are (P1) persons under 15 years old, (P2) persons 15-64 in full time employment, (P3) persons 15-64 in part time employment, (P4) persons 15-64 not in employment, and (P5) persons 65 years and older.

[9] These are (C1) persons living in a household with 1 or more adults and no car, (C2) persons living in a household with 2 or more adults and 1 car, (C3) persons living in a household with 1 adult and 1 or more cars, and (C4) persons living in a household of 2 or more adults and 2 or more cars.

The actual rates found in other countries' NTS could not simply be imported into the demand model structure as the level of disaggregation required was not available. Other countries' NTS trip rates were therefore used indirectly to adjust the UK rates mainly through the concept of the 'headline' trip rate.

As touched upon above, the trip rates associated with the specified trip purposes and population segmentation came in the first instance from unpublished UK NTS data obtained by the consortium. A different approach was however required for holiday trips. There is considerable evidence that the characteristics and number of holiday trips varies significantly by country, whilst there is little evidence to suggest such variation for other trip purposes, e.g., commuting. Also, although the number of trips is small in the context of the whole model, they are clearly highly significant when considering international trips. An approach based on the 'Eurobarometer' survey (EC DGXXIII, 1998) of Europeans on holiday was therefore used to obtain national and domestic trip rates by country.[10]

3.2.5 Trip distribution

Using all 180 of the population group / trip purpose combinations in the distribution stage would involve a huge computational burden and is in any case unnecessary. Hence the population groups are combined (in terms of car availability and age / employment) together into larger groups – and when combined with a trip purpose, this is called a 'transportable trade' and there are 23 in the model structure. The population groups are combined on the basis that categories which have similar average trip distance characteristics can be combined. Car availability and age / employment groups with very small numbers of trips or containing few persons were also combined with others for simplicity.

The set of 'trades' that are explicitly distinguished in the model is presented in Table 3.1, numbered 61 to 84 in the 4th column. For each of the nine trip purpose in the model, the table presents firstly the number of associated trades, and then the combinations of person types (P1 to P5, from Section 3.2.2) and car availability categories (C1 to C4, from Section 3.2.2) that are included within each such combined trade. If only 'P' or 'C' appears in the table, this means all categories are included.

Table 3.1: The distribution stage model segmentation

Trip purpose	No. of trades	Trade refer.	Composition of trades
1. Commuting & business – short	5	61, 62, 63, 64, 65	(P,C1), (P2,C2), (P2,C3+C4), (P1+P3+P4+P5,C2), (P1+P3+P4+P5,C3+C4)
2. Shopping, personal business, education – short	4	66, 67, 68, 69	(P1,C), (P2+P3+P4+P5,C1), (P2+P3+P4+P5,C2+C3), (P2+P3+P4+P5,C4)
3. Visit friends, entertainment & other – short	2	70, 71	(P,C1), (P,C2+C3+C4)
4. Visit friends – long	2	72, 73	(P,C1), (P,C2+C3+C4)
5. Holiday independent – domestic long	3	82, 83, 84	(P,C1), (P,C2), (P,C3+C4)
6. Holiday independent – international long	3	74, 75, 76	(P,C1), (P,C2), (P,C3+C4)
7. Holiday inclusive – long	1	77	(P,C)
8. Day trip & other – long	2	79, 80	(P,C1), (P,C2+C3+C4)
9. Commuting & business – long	1	81	(P,C)

[10] Note that trips to and from external zones do not feature in the STREAMS passenger model.

Each of the 23 trades has a series of parameters, which are set in the calibration process, to provide the typical ‘spread’ or distribution of trips over distance associated with the available observed data for each trade. The 23 trades also have a zonal ‘size’ term that is used to denote the attractiveness of the zone as a destination. For example, the attractiveness of a zone for commuting / business trips depends on the ‘gross value added’ in that zone.

For international holiday trips a further step is involved in the distribution procedure, after the conventional calibration. An ‘observed’ matrix was constructed from World Tourism Organisation publications and other tourism sources. This was then adjusted to match the trip ends and used as a ‘target’ matrix for international trips. A residual disutility approach was then used to ‘match’ this target matrix – this procedure is required since the destinations of international holiday trips are perhaps less dependent on the ‘conventional’ determinants of travel, e.g., cost, time, and distance, compared to other trip purposes. The matrix of disutilities which results from this residual disutility procedure is used in the trip distribution process to recreate this matrix, and is carried forward into the forecasting phase of the model.

At the end of this stage in the process, a matrix of trips has been produced for each of the 23 trades.

3.2.6 Segmentation of passenger flow types for mode split and assignment

Once the procedure for the distribution of trips has been completed, the resulting O-D matrices of trades are aggregated into a set of fifteen transport ‘flow types’. A typical flow type combines trip purpose and traveller characteristics, for example commuting and business trips made by those with partial access to a car (i.e., 2+ adults, 1 car in household).

Each flow type category needs to be homogeneous in its modal split and assignment behaviour, but not necessarily in its trip generation or distribution behaviour, since these procedures have already been carried out earlier in the model at different aggregate level of segmentation. The matrix of flow types is then applied to the transport networks using both modal split and stochastic user assignment. The segmentation of flow types is primarily to distinguish income and car availability, the main influences on the choice of mode of travel. For short distance trips, the car availability effects will predominate over income effects, since in general the choice between bus and rail is determined more by their availability and by the length of trip, rather than by differences in the level of tariffs.

Before being assigned to the network the flow types are aggregated further into four aggregate flow groups. This segmentation into flow groups is primarily to ensure homogeneity of route choice in the elasticity of response of travellers to changes in monetary costs, such as road tolls. In general, the flow types within a flow group should have broadly similar values of travel time.

3.3 Freight Demand Model and Transport Model Structure

3.3.1 Background

This section introduces the freight demand and transport model structures, which consist of the following main elements:

- a Regional Economic Model (REM) (comprising input-output and spatial allocation elements) used to estimate trade flows, which in turn determine the demand for freight movement (i.e., generation and distribution),
- conversion of trade flows (monetary) to transport flows (tonnes) to determine modal split,
- aggregation of transport flows to handling categories for network assignment, and

- feedback of transport disutilities to REM.

The Regional Economic Model (REM) produces the pattern of trade for commodities between zones within the EU15, and to and from the world markets. To do this it incorporates a number of economic theories including a spatial adaptation of the Leontief input-output framework. This input-output framework provides a consistent approach for representing economic linkages between different economic factors – and thus a good foundation for forecasting. The basic concept is that the production of some economic activity or sector, an output, consumes a range of other types of economic activities as inputs. These inputs, in the process of being produced, consume further inputs, and so on.

Once a matrix of trade (in value terms) has been produced by the REM, this is transformed to a matrix of volume of goods moved using volume to value ratios. These volume trades are aggregated into ‘transport flows’, which form the basis of the modal split calculations within the transport model. The ‘transport flows’ are further aggregated into ‘handling categories’, which are used for determining the assignment characteristics, also in the transport model.

The transport disutilities for each zone pair are then attributed back to the factors in the REM and used as an input for the next iteration. The effects of transport cost and time changes are therefore reflected in the trip distribution model. This process is repeated several times.

Each of these stages are discussed below.

3.3.2 REM overview

The two main elements of the REM are the Input–Output (IO) methodology and the spatial allocation model. The main output of the IO process is total consumption and total production by industry by zone. The basic structure of an input-output table is shown in Figure 3.1. The table is set up as a matrix of commodities and industries which interact in an economy. It is divided according to consumption and production.

Figure 3.1: Input-output table structure

Inputs	Intermediate Demand					Final Demand				Total Output / Production
	A	B	C	D	E	Private Consumption	Public Consumption	Investment	Exports	
A_1										
B_1			X							
C_1										
D_1			Y							
E_1										
Value added						-	-	-	-	-
Imports						-	-	-	-	-
Total Input / consumption						-	-	-	-	-

Note: The blue area contains the technical coefficients; yellow area contains private consumption (derived from zonal population and demand coefficients), the grey area contains quantities entered exogenously

Figure 3.1 can be interpreted as follows. Leaving aside the colour coding initially, the rows of the table depict how the total output / production of a commodity (e.g., A_1) is consumed by industries (A to E) as an intermediate purchase, and as a final demand to consumers' expenditure, government consumption, changes in stocks and exports. The vertical rows therefore represent the consumption by individual industries (e.g., A) of commodities A_1 to E_1 together with the constituents of value added and imports. The row and column totals are the same in all cases.

'Final demand' incorporates the direct consumption of inputs by the population (private consumption), government and institutions (public consumption), as well as investment in industry and exports. It is the private consumption of each factor which initially drives the input – output structure. The other types of final demand (public consumption, investment, and exports) are added exogenously for each factor.

The inter-relationships among the various sectors of an economy are represented by sets of coefficients. The first type of coefficients are the final demand coefficients. These relate to the private consumption of goods and services and are determined on a per-capita basis. Private consumption of each factor is taken from each country's IO table, and divided by the population to give the average consumption per capita. These coefficients would occupy the yellow shaded area in Figure 3.1.

The second, 'technical coefficients', relate to the intermediate demand and represent the inter-linkages between the sectors. For the inter-industry section of the IO table, the absolute monetary values given in the published tables are divided throughout by the column totals to give a version of the table comprising these 'technical coefficients' – i.e., the amount of each commodity consumed by the production of 1 unit of each industry. These coefficients would occupy the blue shaded area in the Figure.

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 intermediate inputs such as energy, raw materials, financial services and labour. From Figure 3.1 above, the example shows that for each unit of factor 'C' produced, 'X' is the amount of factor 'B_1' consumed and 'Y' is the amount of factor 'D_1' consumed.

The starting point for the economic system in the model is therefore the final demand. This includes private consumption, public consumption, investment, and exports to countries outside the EU15. Imports to the EU15 are treated as an exogenous input to the model. These exogenous items (public consumption, capital formation, changes in stocks, imports and exports) are distributed as a lump sum for each factor, being derived from Eurostat harmonised national accounts data.

For public consumption, capital formation and changes in stocks, the total for each factor is distributed to each zone according to the existing level of total production. The total production by factor by zone is previously estimated using the total production by factor by country (from the relevant IO table) and distributing it to the zonal level using a mixture of gross value added (GVA) and employment data, both disaggregated by sector. Exports to and imports from the rest of the world are distributed amongst the external zones using data obtained from the Eurostat TREX database.

The economy of the study area is represented by a number of industrial branches, which generate the demand for freight movements. These are based on the NACE-CLIO R59 Eurostat system of industrial classification in which there are 59 branches of activity in total. Some of the branches have been amalgamated to form 33 factors which are used in the STREAMS model. Those branches which generate distinctive freight demand have been kept separate as far as is possible.

Table 3.2 below shows the resulting 33 factors used in STREAMS. Also shown are the corresponding transport flows and handing categories used for modal split and assignment respectively in the model. These aggregations are based on a correspondence with Eurostat's 2-digit NST/R coding for transport flow data (e.g., TREX database).

Table 3.2: REM factors, transport flow groups, and handling categories

Factor	Trade	NACE/CLIO R59 Code	Transport Flow Group	Handling Category
11	Agriculture, forestry and fishery products	010	Agriculture and food - Bulk	Solid Bulk
12	Coal and coking	031/033/050	Solid fuels and ores	Solid Bulk
13	Crude petroleum	071	Petroleum prods.	Liquid Bulk
14	Petroleum products	073	Petroleum prods.	Liquid Bulk
15	Natural gas	075	Petroleum prods.	Liquid Bulk
16	Other power, water and manufactured gas	095 – 110	Petroleum prods.	Liquid Bulk
17	Ferrous and non-ferrous ores and metals	135 – 137	Solid fuels and ores	Solid Bulk
18	Cement, glass and ceramic products	151/153/155	Mineral / building mat. - unitised	Unitised
19	Other. non-metallic minerals and derived prods.	157	Mineral / building mat. - bulk	Semi Bulk
20	Chemical products	170	Fertilisers and chemicals	Unitised
21	Metal products	190	Metal products	Semi bulk
22	Agricultural and industrial machinery	210	Machinery and miscellaneous	Unitised
23	Office machines, etc.	230	Machinery and miscellaneous	Unitised
24	Electrical goods	250	Machinery and miscellaneous	Unitised
25	Transport equipment	270 - 290	Machinery and miscellaneous	Unitised
26	Food, beverages, tobacco	310/330/350/370/390	Agriculture and food - unitised	Unitised
27	Textile and clothing, leather, footwear	410/430/450	Machinery and miscellaneous	Unitised
28	Paper Pulp	471	Paper pulp	Solid bulk
29	Rubber and plastic products	490	Machinery and miscellaneous	Unitised
30	Other manufacturing products	473 - 510	Machinery and miscellaneous	Unitised
31	Building and civil engineering works	530	-	-
32	Recovery, repair services, wholesale and retail trade	550/570	-	-
33	Lodging and catering services	590	-	-
34	Railway transport services	611	-	-
35	Road transport services	613	-	-
36	Inland waterways services	617	-	-
37	Maritime transport services	631	-	-
39	Air transport services	633	-	-
40	Auxiliary transport services	650	-	-
41	Communications	670	-	-
42	Credit and insurance	690	-	-
43	Other market services	710/730/750/770/790	-	-
44	Non-market services	810/850/890/930	-	-

Originally, input-output models were not designed for spatial applications. For regional economic modelling purposes however, it is the relationship between production and consumption, i.e., inter-regional trade, which is crucial. Therefore a spatial allocation model has been used in STREAMS.

This spatial allocation model primarily involves the estimation of the activity distribution calibration parameters for each factor so that the trade volumes between the zones pairs broadly reflect the observed patterns of domestic and international trade (where such data is available). For each country in the model, national production totals were divided into the zonal sub-totals on the basis of the Gross Value Added by industrial sector. These data were not available for all countries for 1994 however. In the absence of GVA data, employment by industrial sector was used. At this point the total production and consumption (estimated from the I/O structure) of each factor has therefore been established for each zone.

A common spatial allocation model was then applied to all factors. The functional form is a single level, multinomial model of discrete choice. For consumption in a particular zone, the choice is from the producers in all production zones. The trade between a pair of zones is the consumption of a factor in a particular zone multiplied by an expression of the probability of it being produced in another zone.

This probability term depends on a number of variables. One of these is a size term, which represents the level of production of a factor in each zone in the base year. Another is the disutility of transport between zone pairs (from the transport model). This includes all aspects relevant to the inter-zonal trip, such as the cost and travel time of the mode, so that it represents the generalised cost of transport between each zone pair (using a weighted averaged across modes). The greater the disutility of travel, the smaller the trade between the zone pairs.

During the calibration stage, distribution parameters were adjusted to achieve a realistic set of trades between zone pairs. This was achieved in a two-stage process. Firstly, for a representative set of destination zones, the distribution parameters were varied such that the average trip length associated with each trade fell within an expected range for that commodity type from available observed data (using principally Carriage of Goods data). In this manner, a set of distribution parameters was derived as a starting point for the model. The second step was to input these parameters to the whole demand model and trade matrices were generated. The average trip lengths by mode and tonne-kilometres modelled were compared with available data. Groups of factors were taken together depending on their flow type and their distribution parameters were varied. The factors 11-30 were grouped into the four flow handling categories (see Table 3.2) for this purpose.

Furthermore, observed 1994 international trade data was used through a residual disutility method to correct the estimated international trade flows, and take into account for example, any non-cost historic trade ties forged through linguistic and cultural connections between some of the countries. This procedure follows after the normal calibration steps.

3.3.3 Regional Economic Model output

The output of the regional economic model is a matrix of trades by industry by value and these trades then have to be converted into 'flow groups' and thus transport volumes. Volume-to-value ratios are used to transform trade values to flow volumes. These ratios were estimated from the total freight tonnage information (using the tonnes by mode statistics contained in the Eurostat TREX database) in conjunction with the total value of commodity flows estimated in the REM.

Such ratios represent, for each trade/flow pair, the number of physical units per unit of value. They are average values, which apply to the entire amount of each trade between any zone pair. A procedure was also developed to apply specific volume-to-value ratios to country specific O-D pairs by flow. The procedure allows the correct pattern of flows to be reproduced once the correct matrix of trades is available.

Table 3.3 below shows the average volume to value ratios used for each of the transport flows.

Table 3.3: Average volume-to-value ratios used

Trade	Ratio (Tons / ECU*10^6)
11. Agricultural, forestry and fishery products	2 150.36
12. Coal and coking	2 084.76
14. Petroleum products	2 820.80
17. Ferrous and non-ferrous ores and metals	2 084.76
18. Cement, glass and ceramic products	10 458.76
19. Other non metallic minerals and derived products	43 321.56
20. Chemical products	1 465.27
21. Metal products	1 462.92
22. Agricultural and industrial machinery	809.48
23. Office machines, etc.	809.48
24. Electrical goods	809.48
25. Transport equipment	809.48
26. Food beverages and tobacco	1 563.30
27. Textile and clothing, leather, footwear	809.48
28. Paper pulp	669.59
29. Rubber and plastic products	809.48
30. Other manufacturing products	809.48

A further specific Volume to Value procedure was used to apply specific Volume-to-Value ratios to each case (O-D pairs) for which the average ratio was too far away the observed one. The procedure allows the correct pattern of flows to be reproduced once the correct matrix of trades is available. Indeed, as each modelled flow generally represents a mix of commodities, the value of a unit of flow (a ton, say) may be different among single O-D pairs according to the specific goods represented by the trade between the zones. Therefore, even if the trade pattern is well-reproduced, the application of the average ratios will lead to a biased flow matrix. This procedure scales the average ratios, flow by flow, in order to overcome this problem.

3.3.4 Transport model

3.3.4.1 Transport flow types

The definition of the transport flows was based on the need to create homogenous segments for modal split. Commodities including solid fuel and metal products give rise to solid bulk flows, which tend to use slower modes like ship. Ten flows were considered a fair compromise between the need to distinguish flows with different modal choice characteristics and the need to maintain the size of the model within a reasonable threshold. These ten flows were listed in Table 3.2 above.

In general the approach was to implement a clear separation between unitised and non-unitised flows (in turn, regarded as bulk or semi-bulk flows) in the transport model. This has the advantage of reducing the number of transport modes available to each flow (or group of flows) in the modal split procedure.

3.3.4.2 Transport modes

Two modes represent truck movements: ‘short distance truck’ and ‘long distance truck’. The short distance truck represents trucks used for ‘local’ distribution at a regional level. The trucks used for short and long distance trips tend to have different cost profiles and hence are separated in the model.

For rail, shipping and inland waterways two modes have been implemented, distinguishing ‘bulk’ modes and ‘unitised’ modes. This allows the different costs and times of bulk/unitised flows to be identified. For instance, shuttle trains for containers and swap bodies offer a scheduled service among intermodal terminals across Europe. The level of service is significantly different from the normal one. In terms of shipment times, shuttle trains offer a (scheduled) 24 hours service, while the normal procedure might take some days.

There are air freight and product pipeline modes. Intrazonal mode is the transport mode allowed to move freight with both origin and destination in the same zone. It is modelled as a truck and its characteristics are similar to the short distance truck.

In general, the set of flows is more detailed for modal split purposes than is necessary for realistic network assignment. At the assignment stage the main requirement is to be able to distinguish the different types of vehicles/vessels that are used, due to their differences in operating costs. Accordingly, the flows are aggregated into a set of homogeneous handling categories (flow groups, see Table 3.2 above) on the basis of the value of time, the handling and the carriage requirements of each commodity. This reduces unnecessary computational calculations during assignment.

Flow groups range from long distance solid/liquid bulk traffic, through to high value goods that are very sensitive to journey times and quality of service, for which firms are willing to pay a price premium.

4. Model Validation

4.1 Introduction

This Chapter presents the base year model results, comparing them to ‘observed’ data where possible. The aim of the base year model calibration is therefore to reproduce a known base situation. The concept of validation is however much wider, to ensure the broad structure of the model is performing well and to cross check the forecasts against other available information. The year 1994 was chosen for the calibration year – this was the latest year for which suitable data was available.

The passenger and freight models were largely calibrated and validated separately. The combined model was then run at the end of the process. The presentation here is in three main sections – network calibration, passenger model and the freight model.

4.2 Network Calibration

Two approaches were used for the validation of the base year network:

- comparison of observed and modelled zone-to-zone distances and times, and
- minimum path checking throughout the network.

For the comparison of observed and modelled distances and times the observed city to city distances and times were collected. The sample of cities was based on the need to ensure a reasonable coverage of the network. For road the comparison between modelled and observed distances was based on published city to city distances between 20 main European cities.[11] In the comparison of observed and modelled city to city rail times the observed times were taken from Thomas Cook European Rail Services Timetable (January 1997).

Minimum paths were checked on the road and rail networks using a basket of European capitals and checking the validity of the chosen routes against the expected routes. In most cases, the minimum path routes found were in line with expectation for both road and rail modes.

4.3 Passenger Model Calibration

4.3.1 Introduction

The main elements in the calibration of the passenger model were:

- number of trips by distance band;
- modal split overall and by distance;
- modal split by trip purpose;
- passenger-kilometres travelled by mode by EU country;
- average trip distance by EU country by mode; and,
- a comparison of observed with modelled data for international tourism trips.

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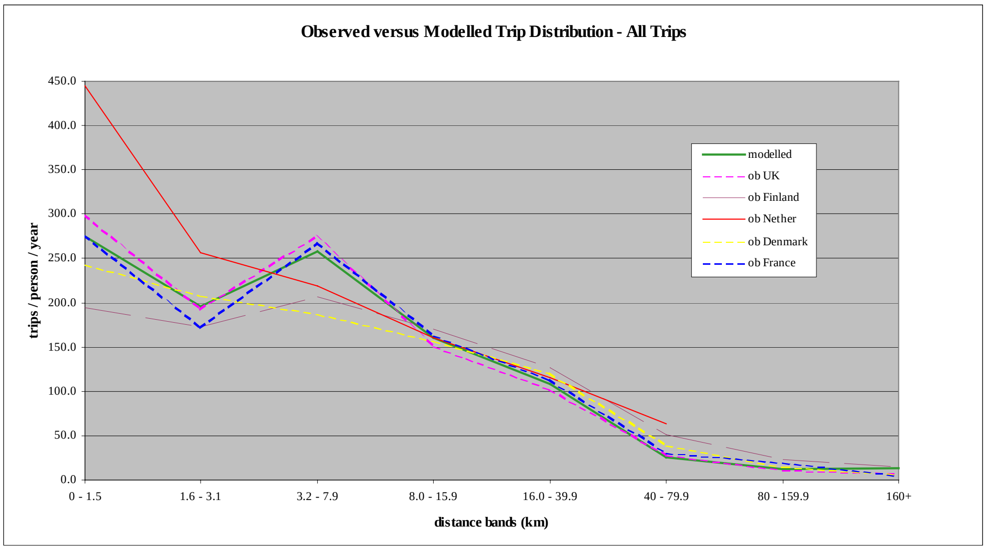
[11] Using Hallwag’s ‘Atlas Europe Ausgabe’, and the Michelin ‘Road Atlas Routier Europe’ (7th Edition, 1996)

4.3.2 Distribution by Distance

Examination of the different countries' NTS, and analysis of special data requests made by the STREAMS consortium to national governments allows a comparison of modelled flow against NTS observed flow by distance band. Figure 4.1 shows the distribution of all modelled flow by distance category compared with the NTS of Denmark, Finland, France, the Netherlands, and the UK. The comparison is shown using trips per person per year, divided up into distance ranges.

Figure 4.1: Distribution of trip rates by distance – 1994 STREAMS and EU NTS



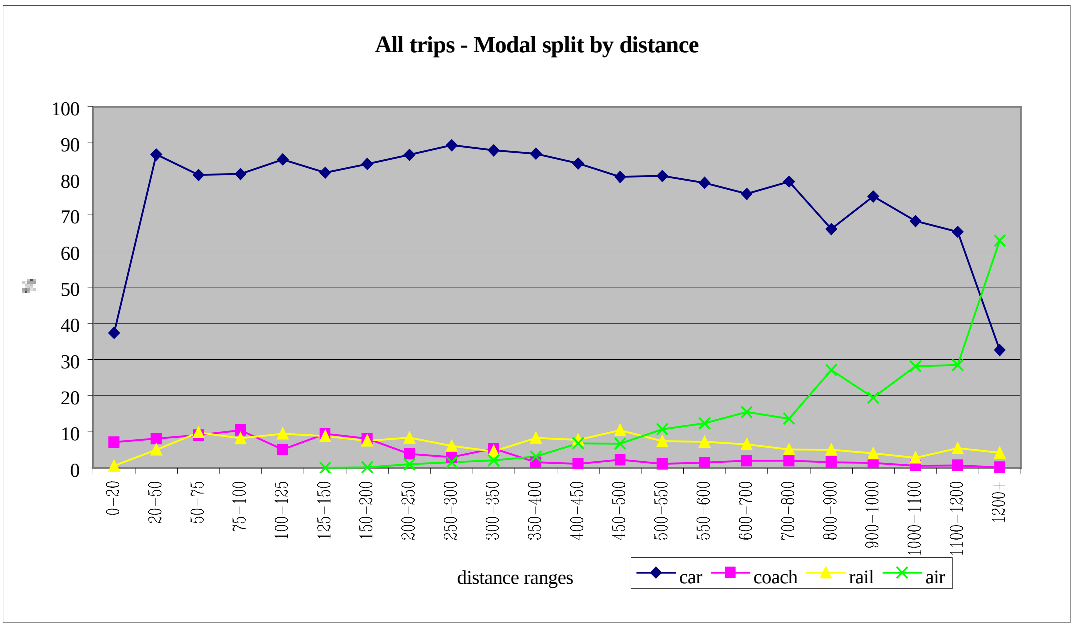
The trip distribution across the different NTS is therefore reasonably consistent, and the model output is a good match, i.e., it is within the 'envelope' formed by the various NTS. It is worth noting the very high rate of short trips found in the Netherlands – it is not clear if this is a genuine effect or if it is a quirk of the methodology used by the Dutch. The model uses constraints in the base year to 'match' the number of trips in the shortest distance bands – these trips are entirely in the local trips network (as part of the distance bands).

4.3.3 Modal split by distance and purpose

The modal split by distance range in the aggregate as well as by individual flows was assessed. Figure 4.2 shows the overall modal split by distance.

Slow mode is excluded from this chart, although included in the calculations. The overall model results show the predominance of car which only starts to tail off over longer distance as air becomes the dominant mode. Looking at the air and rail modes, rail has a higher share in the mid-range distances, only becoming less competitive with air over the longer distances. There is no comprehensive observed data with which this type of model output can be directly compared. Some comparisons were made with data obtained from the German passenger matrix, but these comparisons were limited as the matrix data relating to internal German trips could only be used – this meant that comparisons over the longest distances were invalid. At the distances where the data was comparable, a similar pattern emerged.

Figure 4.2: 1994 Modal split by distance, all trips



An analysis was also carried out for individual flow types. For example, the trend for business and long distance commuting shows the dominance of car over the shorter distance trips, which tails off beyond approximately 400km. Air becomes competitive over 550km, and rail is consistently around the 10% level throughout gaining more over the longer distances before losing out to air beyond 1200km.

The differences in modal share characteristics by car availability is therefore a key mechanism within the model to capture increased passenger-kilometres and modal share effects as car ownership increases in the future.

Comparisons with some limited observed data can be made in terms of modal split by distance. Table 4.1 shows the model results for modal split at the <40km, >40km split together with the total. Partial data for other countries is shown Table 4.2 below. Given the typical ranges of values found in the other countries the modal split by distance therefore appears to be reasonable.

Table 4.1: Overall modelled modal split by distance

Trips under 40km	%	Trips over 40km	%	All Trips	%
Car	55.4	**Car**	82.0	**Car**	56.7
Coach / Bus	9.6	**Coach / Bus**	7.9	**Coach / Bus**	9.6
Slow Mode	33.7	**Conventional Rail**	8.4	**Slow Mode**	32.0
Conventional Rail	1.2	**High Speed Rail**	0.4	**Conventional Rail**	1.6
High Speed Rail	0.0	**Air**	1.3	**High Speed Rail**	0.0
				Air	0.1

Table 4.2: Other observed modal split data

Mode %	France >100km	Finland >50km	Netherlands >40km	Germany >50km	Sweden >100km	Denmark All Trips	Netherlands All Trips	UK All trips
Car	78.8	85	76.1	86.3	69	55	54.3	59.4
Coach	5.8	6	2.1	6.6	7	7	4.1	7.4
Slow	0		0.1			31	33.7	32.0
Train	10.6	5	20.8	5.5	9	3	4.5	1.1
Air	4.8	1		1.5	8	-	-	0.0
Other	0	3	1	-	6	3	3.4	-

4.3.4 Country Specific Transport Model Results

The other main area of model validation and calibration relates to the overall volume of travel and modal split by EU15 country. This clearly depends on the number of trips and the average trip distance per country. The data used for the validation is the DGVII EU Transport in Figures Statistical Pocketbook (Revised 1998 Version). This book contains data on passenger-kilometres travelled per annum by the main transport modes for each of the European countries, and also now includes other modes such as tram / metro and slow mode.

As an example of the comparisons which can be produced, Table 4.3 shows the ratio of modelled to observed passenger-kilometres by country and mode.

Table 4.3: 1994 Modelled to Observed passenger-kilometre ratio

	Mode			
Country	**Car**	**Coach**	**Train**	**Total**
Austria	1.199	0.984	1.044	**1.154**
Belgium	1.145	1.367	1.055	**1.165**
Denmark	0.931	0.653	0.612	**0.873**
Finland	1.062	0.916	0.874	**1.033**
France	0.993	1.041	1.060	**1.002**
Germany	1.208	1.064	1.027	**1.183**
Greece	1.052	1.292	0.967	**1.066**
Ireland	0.807	0.805	0.925	**0.810**
Italy	0.884	0.839	1.153	**0.897**
Luxembourg	1.273	1.096	1.206	**1.250**
Netherlands	1.047	1.138	1.033	**1.053**
Portugal	1.010	0.933	0.924	**0.997**
Spain	1.172	0.868	1.055	**1.134**
Sweden	1.061	1.118	1.024	**1.065**
UK	1.002	0.962	0.951	**0.997**
Grand Total	**1.045**	**0.976**	**1.041**	**1.039**

Overall the proportions are such that the 'Grand Total' modelled figures per mode are within 5% of the published total EU15 'observed' figures. When considered at a country level, the results are generally good but some countries are inevitably problematic. Also some of the published data implies either an improbable trip rate or an improbable average trip distance. In any case, published data of this nature are estimated – there will be different methodologies employed by each country using different assumptions, and this may result in inconsistency between country results. Each country is discussed in turn below:

- The published data for Austria implies a very low rate of car passenger-kilometres compared to other countries – more than 5% less than any other country, so the modelled figure is high in comparison;
- In Belgium, the modal proportions are broadly correct but there are slightly too many passenger-kilometres overall;

- Denmark has only 2 zones in STREAMS and is thus problematic: interzonal distances are high and neighbouring countries have high access costs – it is therefore difficult to match the published amount of passenger-kilometres, although the modelled figure of 87% is reasonable;
- The overall number of passenger-kilometres seems slightly high for Germany – yet the trip rate is low (reflecting the low car ownership in the former GDR) and the average trip distance is not excessive. The modal proportions also seem reasonable. It is possible that the 1994 observed data from the former GDR underestimated the levels of travel;
- There are slightly too few passenger-kilometres modelled in Ireland – like Denmark, Ireland has few zones (3) and this is problematic for a strategic model of this nature;
- In Italy the number of passenger-kilometres appears slightly low – this is despite a higher than average trip rate and an average modelled trip distance which is not low. Thus either the Italian trip rate is very much higher (similar to the Netherlands) [there is no Italian NTS, so the actual figure is unknown], their average trip distance is much longer (seems unlikely) or the observed data may be unreliable. Unfortunately no trip rate data has ever been uncovered for Italy;
- In Spain the results show slightly too many passenger-kilometres – despite a trip rate which is lower than average. The modal proportions show a slight overestimate for road compared to the published figures;
- The results for other countries are in line with the observed.

For the EU15, it is possible to consider the results for all modes. Table 4.4 shows these aggregate results.

Table 4.4: Base modelled and observed aggregate passenger statistics

EU15 Passenger-kilometres – 1994, per year (million)					
	Car	**Coach**	**Train**	**Air**	**Slow**
Observed (DGVII)	3,610	398	269	254	231
1994 Model	3,888	388	280	242	265

In the aggregate, the STREAMS 1994 base model therefore reproduces the EU figures closely for all modes. At the country level there are still some minor discrepancies but given the difficulties in matching countries with different behavioural and socio-economic characteristics within a generalised strategic model of this nature, and the potential differences in methodology used to estimate the 'observed' figures, the results seem reasonable.

4.3.4 International passenger tourism matrix results

Section 3.2.5 touched upon the procedure used within the model structure to 'match' a known matrix of international passenger trips. The sources were the World Tourism Organisations figures on tourism arrivals in European countries by country of origin, and other tourism arrivals data. This matrix therefore represents all trips by all purposes, which incorporate at least one overnight stay (this is the WTO definition of a tourism trip).

This residual disutility procedure comes after the traditional model calibration phase has been completed. There is a specific requirement for this approach in the context of international tourism trips, since the origin / destination patterns are determined to a lesser extent by factors traditionally used in distribution modelling (e.g., climate). The process works by aggregating the 15 EU countries and working from a fixed set of trip ends (i.e., the number of origins and destinations in each country). The 'observed' matrix is therefore slightly adjusted in proportion to 'match' these country trip ends, i.e., the trip ends produced by the model are not identical to the original 'observed' matrix. The procedure then adjusts the origin – destination pairs (the cells of the matrix) in accordance with the adjusted 'observed' zone pair (by adding or subtracting disutility). This program produces a matrix of disutilities which are then incorporated in the trip distribution procedure. The matrix of disutility is also carried forward into the forecast year trip distribution process – in effect to represent historical or non-transport related factors within the way in which persons choose destinations.

There is no equivalent data source for international trips not incorporating an overnight stay. This sector of the market comprises two distinct parts: longer distance business trips where the outward and return journeys are completed in one day, and shorter distance cross-border trips for both business and leisure. Neither of these types of trip are included in the tables below.

Table 4.5 shows the resulting modelled matrix of international tourism trips, which 'matches' the 'observed' matrix determined from the WTO data. The units are person trips per year. The directionality element has also been included in that outward and return trips appear in the table so the table is symmetrical. For the purposes of these matrices, Luxembourg is combined with Belgium.

It should be noted that the STREAMS model does not generate passenger trips to and from countries outside the EU.

Table 4.5: 1994 Modelled international passenger matrix of tourism trips (trips / year)

	Austria	Belgium	Denmark	Finland	France	Germany	Greece
Austria	-	386,535	149,103	88,148	1,207,785	12,729,375	441,650
Belgium	386,535	-	54,385	78,110	5,577,383	1,099,015	235,790
Denmark	149,103	54,385	-	75,008	709,560	1,308,160	272,838
Finland	88,148	78,110	75,008	-	250,938	609,185	457,893
France	1,207,785	5,577,383	709,560	250,938	-	13,310,820	623,785
Germany	12,729,375	1,099,015	1,308,160	609,185	13,310,820	-	3,044,648
Greece	441,650	235,790	272,838	457,893	623,785	3,044,648	-
Ireland	39,603	45,078	25,368	35,770	412,998	357,700	45,260
Italy	2,953,215	711,933	218,270	243,820	10,731,183	9,653,520	1,402,148
Netherlands	808,110	1,016,343	125,378	82,125	4,183,083	2,506,090	438,913
Portugal	65,883	187,793	103,478	157,680	918,523	955,570	21,353
Spain	234,695	590,023	119,720	132,860	4,584,218	11,093,810	91,615
Sweden	388,908	158,410	736,205	543,668	1,279,143	1,957,678	877,095
UK	714,670	1,201,580	290,358	303,863	11,981,855	3,803,483	2,061,520
EU15	**20,207,678**	**11,342,375**	**4,187,828**	**3,059,065**	**55,771,270**	**62,429,053**	**10,014,505**

	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK	EU15
Austria	39,603	2,953,215	808,110	65,883	234,695	388,908	714,670	**20,207,678**
Belgium	45,078	711,933	1,016,343	187,793	590,023	158,410	1,201,580	**11,342,375**
Denmark	25,368	218,270	125,378	103,478	119,720	736,205	290,358	**4,187,828**
Finland	35,770	243,820	82,125	157,680	132,860	543,668	303,863	**3,059,065**
France	412,998	10,731,183	4,183,083	918,523	4,584,218	1,279,143	11,981,855	**55,771,270**
Germany	357,700	9,653,520	2,506,090	955,570	11,093,810	1,957,678	3,803,483	**62,429,053**
Greece	45,260	1,402,148	438,913	21,353	91,615	877,095	2,061,520	**10,014,505**
Ireland	-	241,995	69,533	55,115	56,758	86,140	2,304,793	**3,776,108**
Italy	241,995	-	789,130	470,850	3,768,990	548,230	2,356,258	**34,089,540**
Netherlands	69,533	789,130	-	284,700	1,505,990	262,618	1,309,620	**13,381,630**
Portugal	55,115	470,850	284,700	-	1,836,498	191,078	1,030,395	**6,278,913**
Spain	56,758	3,768,990	1,505,990	1,836,498	-	430,700	6,403,013	**30,848,888**
Spain	86,140	548,230	262,618	191,078	430,700	-	945,533	**8,405,403**
UK	2,304,793	2,356,258	1,309,620	1,030,395	6,403,013	945,533	-	**34,706,938**
EU15	**3,776,108**	**34,089,540**	**13,381,630**	**6,278,913**	**30,848,888**	**8,405,403**	**34,706,938**	**298,499,190**

4.3.5 Back-casting with STREAMS

The final element of the passenger model calibration process was an experimental ‘back-casting’ exercise. Using derived population and socio-economic data from 1974, the model was run, and the results compared with aggregate transport demand statistics and modal split data also from 1974 or similar year. In general, given the necessarily limited scale of the exercise (e.g., using 1994 transport networks) and lack of appropriate data, the model performed well in reproducing the overall level of travel demand and modal split associated with 1974/75. For example the modelled passenger-kilometres by country compared well with those published by Eurostat for 1975, and modelled and UK observed modal split of trips were similar.

As stated above, the main objective of the back-casting exercise was to establish the broad stability of the model in producing transport output through time. The results show that this was achieved. They also pointed to the areas for which further development of the base year model was required.

4.4 Freight Demand Model: Base Year Calibration and Validation

There were three key steps involved in the calibration of the freight model:

- Assembling, analysing and processing the observed data for calibration and validation,
- calibrating the REM, volume to value ratios and intrazonal flows, and
- analysis of the modal split and average trip distances against observed data.

4.4.1 Assembling observed data

A considerable amount of work was required to convert official freight statistics into a consistent set of data, which could be used for calibrating and validating the freight model. Total freight flows were extracted from the Eurostat databases TREX and CoG for EU12 countries as follows:

- ‘CoG’ (*Carriage of Goods*) database: includes tables and trends of National and International transport in 12 EU countries by ‘land’ modes of transport (i.e., road, rail and inland waterway);

- ‘TREX’ (*External trade by mode of transport*) database: includes tables about trade among EU Member States and between them and all the other external countries.

National databases were used for the three more recent member states, namely Austria, Sweden, and Finland.

The TREX and CoG databases both have their strengths and weaknesses. The TREX database represents all international exchanges between EU countries, but it does not report any information on national traffic. TREX reports modal shares, but this data did not appear to be fully consistent with the definition of modes useful for the model. For example, multi-modal consignments are frequently registered under the first mode used (generally truck) instead of the main mode used for the larger part of the trip (e.g., ship). Although it covers only the ‘land modes’, the Carriage of Goods reports the national traffic of each country in a plausible way; e.g., data is obtained by national surveys (road transport) or by national statistics (for railway companies).

In essence, TREX was used as reference for the overall volume of international freight traffic, while CoG was used to assess the national traffic and the modal shares of ‘land modes’. Nevertheless, the TREX and CoG sources were not sufficient to define the complete reference data set and some additional terms or corrections were introduced.

The freight flows considered in the model are flows to, from and within EU15. However, the full pattern of freight traffic could not be reproduced because of the unavailability of some data for the three new member States: Finland, Sweden and Austria who joined the EU in 1995.

4.4.2 Calibrating the REM

Freight flows are based on the values of trades estimated by the Regional Economic Model (as discussed in Section 3.3). A key step in the calibration of the freight model was to ensure an accurate reproduction of the observed international trade matrix (derived from the data sources discussed above).

A residual disutility procedure was implemented in order to ensure a better reproduction of the observed trade matrix. For the STREAMS freight model the observed matrix was based on TREX trade values data, and hence was at a country to country level. There are no sources which provide a comprehensive description of international freight traffic at a regional level.

The residual disutility model performed well to reproduce the base matrix. For each country, a comparison was made between the overall modelled and observed value of its whole external trade (i.e., import plus export). For almost all trades and all countries the average difference between observed and modelled O-D trades was under 5% of the absolute values, with only pulp paper flows showing a greater discrepancy. However, paper represents about 1.5% of the total value traded and therefore the overall error is negligible.

4.4.3 1994 Modelled and observed flows

In this results section, figures are presented separately for national and international traffic both because the main sources of observed data present them separately, and because national and international traffic may have a significantly different modal share (as the average distances are very different).

Some factors should be taken into account when interpreting the results. Firstly, although the term ‘observed’ is often taken to refer to data which the model should always aim to match, the ‘observed’ data is itself often imperfect. This is most marked in the case of ‘other modes’ such as pipelines and air freight. Observed national statistics do not include ‘other modes’ because no valid statistics were available. In the international statistics, observed ‘other modes’ represent air freight, pipelines and other fixed installation and unknown modes. In the model, only pipelines and air freight are modelled, so the ‘other modes’ are generally underestimated.

Some observed data for ‘other modes’ are almost certainly wrong (over-estimated) and in some cases (e.g., traffic between Germany and The Netherlands) the observed share of such modes is quite significant, and therefore can affect the comparisons.

4.5 Base Year Freight Transport Model Validation & Results

This section reports the base year freight model results compared to the derived ‘observed’ data in a number of different ways[12]. The results are considered in three sections: total freight volume, national freight traffic, and international freight traffic.

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[12] Note that in the tables which follow with regard to petroleum products, crude petroleum, gaseous hydrocarbons (liquid or compressed) and non-fuel derivatives are not included.

4.5.1 Total freight traffic – national plus international

The first element of the freight transport model base year results considered is all the freight traffic in the model. Here a comparison of observed and modelled data by flow type and mode is reported, and in addition, the variation in modal split by distance is considered.

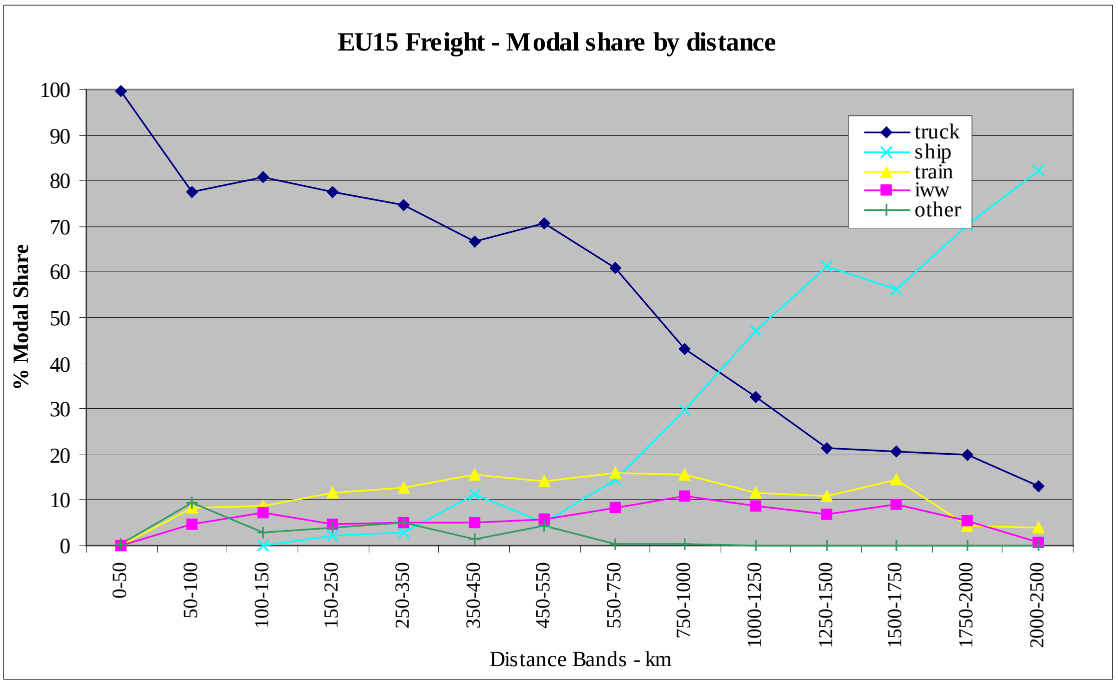
Table 4.6 below shows the total traffic in terms of tonnes per year by the ten flow types by mode. The derived 'observed' is also shown in the table. Overall, the levels of freight traffic compare well with the 'observed'.

Table 4.6: Total 1994 traffic (tonnes) to / from / between and within EU15 countries - Comparison between observed and modelled

		Observed data		Modelled data				Observed data		Modelled data	
Aggregated commodity flow	**Mode**	**Total annual volume (1000T)**	**Modal share (%)**	**Total annual volume (1000T)**	**Modal share (%)**	**Total annual volume (1000T)**	**Modal share (%)**	**Total annual volume (1000T)**	**Modal share (%)**	**Total annual volume (1000T)**	**Modal share (%)**
Agricultural and Food – bulk	Truck	947,591	89	978,364	91	**Paper pulp**	Truck	52,295	76	49,166	85
	Rail	43,797	4	33,476	3		Rail	6,820	10	3,324	6
	IWW	24,811	2	22,145	2		IWW	2,317	3	1,176	2
	Ship	49,315	5	43,337	4		Ship	6,327	9	4,362	7
	Other	3,699	0				Other	960	1		
	Total	**1,069,214**		**1,077,323**			**Total**	**68,720**		**58,027**	
Solid fuels and Ores	Truck	381,686	42	379,364	43	**Machinery and Miscellaneous articles**	Truck	1,687,852	90	1,718,233	91
	Rail	314,896	34	237,077	27		Rail	77,383	4	94,515	5
	IWW	111,134	12	141,182	16		IWW	3,882	0	9,512	1
	Ship	110,546	12	125,550	14		Ship	70,801	4	69,274	4
	Other	1,217	0				Other	33,244	2	297	0
	Total	**919,477**		**883,107**			**Total**	**1,873,161**		**1,891,534**	
Petroleum products	Truck	585,227	54	605,609	53	**Agricultural and Food – unitised**	Truck	1,205,861	93	1,182,780	93
	Rail	61,189	6	48,177	4		Rail	17,811	1	13,254	1
	IWW	89,783	8	34,776	3		IWW	13,557	1	24,280	2
	Ship	244,513	23	242,146	21		Ship	37,603	3	48,842	4
	Other	102,063	9	218,081	19		Other	16,235	1	59	0
	Total	**1,082,774**		**1,148,789**			**Total**	**1,291,067**		**1,269,155**	
Metal products	Truck	316,069	66	322,026	66	**Minerals and Building materials – unitised**	Truck	926,494	94	895,461	91
	Rail	111,752	23	109,538	22		Rail	22,889	2	43,377	4
	IWW	11,087	2	15,015	3		IWW	4,466	0	11,079	1
	Ship	36,093	8	43,108	9		Ship	35,360	4	37,189	4
	Other	1,904	0				Other	350	0		
	Total	**476,905**		**489,687**			**Total**	**989,560**		**987,106**	
Minerals and Building materials – bulk	Truck	4,020,419	95	4,253,416	97	**Fertilisers and Chemicals**	Truck	643,070	82	632,922	83
	Rail	67,152	2	33,780	1		Rail	35,353	5	22,987	3
	IWW	109,647	3	96,402	2		IWW	24,326	3	23,446	3
	Ship	52,875	1	21,742	1		Ship	76,744	10	81,408	11
	Other	2,798	0				Other	5,553	1	57	0
	Total	**4,252,890**		**4,405,340**			**Total**	**785,046**		**760,821**	
						Total	**Truck**	**10,766,563**	**84**	**11,017,275**	**85**
							Rail	**759,043**	**6**	**639,504**	**5**
							IWW	**395,008**	**3**	**379,013**	**3**
							Ship	**720,176**	**6**	**716,958**	**6**
							Other	**168,023**	**1**	**219,008**	**2**
							Total	**12,808,813**		**12,971,244**	

In Figure 4.3 below, the modal split by distance of total EU15 freight traffic (i.e., national plus international within the EU) is shown. There are no data to compare such results against, but the graph looks reasonable with 'truck' being largely dominant on shorter and medium distances and ship becoming the major mode over around 1,000 kilometres.

Figure 4.3: Total EU15 freight traffic – Modal split by distance range



This total volume of freight traffic in the system results in a total volume of tonne-km travelled by mode by EU country. Table 4.7 below, shows the tonne-km travelled in 1994 by road and rail, in terms of domestic and international traffic within each EU country. Also shown in Table 4.7 are the Eurostat Transport in Figures equivalent published figures.

Table 4.7: Total tonne-km moved by mode on EU member state territory (1994, tkm*10^9 pa)

	STREAMS	STREAMS	DGVII TIF	DGVII TIF	Ratio STR/TIF	
	Road	**Rail**	**Road**	**Rail**	**Road**	**Rail**
A	22.9	6.2	15	13	1.53	0.48
B	46.0	7.4	35	8	1.31	0.92
DK	6.2	6.9	14	2	0.44	3.47
FI	33.9	4.0	26	10	1.30	0.40
F	159.8	49.7	211	49	0.76	1.02
D	243.1	51.4	272	70	0.89	0.73
GR	21.1	2.5	13	0	1.63	-
IRE	10.5	0.5	5	1	2.09	0.46
I	113.9	60.9	187	21	0.61	2.90
L	2.1	0.1	2	1	1.04	0.14
NL	51.3	5.4	41	3	1.25	1.81
P	14.2	1.1	13	2	1.10	0.53
SP	77.6	22.2	92	9	0.84	2.47
SW	49.8	8.8	27	19	1.84	0.47
UK	156.7	20.1	144	13	1.09	1.55
EU15	**1,009.0**	**247.3**	**1097**	**221**	**0.92**	**1.12**

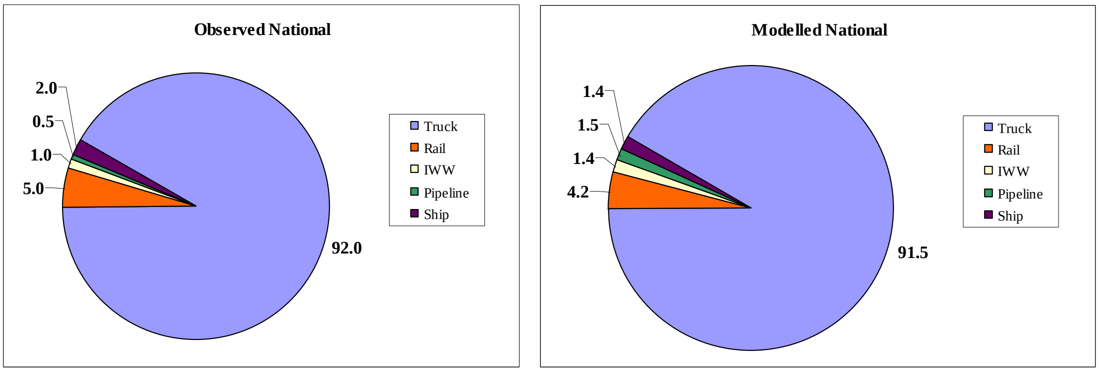
The overall modelled volume of tonne-km within the EU by road and rail modes is seen to match the observed data well. Looking at the major countries, there is also a reasonable match with the obsrerved data. Discrepancies are however apparent in the smaller countries, but it must be borne in mind that this level of country specific calibration is very difficult to reach.

4.5.2 EU15 national level traffic

National level freight traffic is the most important aspect of total flow in terms of tonne-kilometres of freight moved. The calibration considered the model outputs of national freight traffic in terms of the following: volume of freight moved by flow type, overall modal split, country level freight volumes by handling category, country level modal split, and national volumes in of tonne-kilometres travelled domestically, some of which are reported below.

The model matched the figures for national freight movements in terms of tonnes, for each EU country, by the flow categories of solid bulk, liquid bulk, general cargo, and unitised. Figure 4.4 shows the overall national modal split in terms of tonnes carried for national freight traffic in 1994. The modelled data compares well with the observed in this case.

Figure 4.4: EU15 National modal split (tonnes), modelled and observed (1994)



Looking at the volume of national freight in terms of tonne-km, Table 4.8 below gives the annual national tonne-km moved by EU country for 1994. The observed and modelled figures are shown.

Table 4.8: 1994 National EU15 tonne-km travelled, observed and modelled

Country	Annual Observed traffic (tkm $*10^6$ pa)	Annual Modelled traffic (tkm $*10^6$ pa)
Austria	12,855	15,788
Belgium and Lux.	22,145	26,884
Denmark	9,294	15,871
Finland	35,390	35,027
France	136,340	155,170
Germany	215,513	214,807
Greece	15,005	15,653
Ireland	4,694	4,787
Italy	129,635	147,980
The Netherlands	32,533	33,541
Portugal	12,586	12,509
Spain	83,778	96,053
Sweden	47,929	47,012
UK	152,294	166,454
All countries	**909,991**	**987,535**

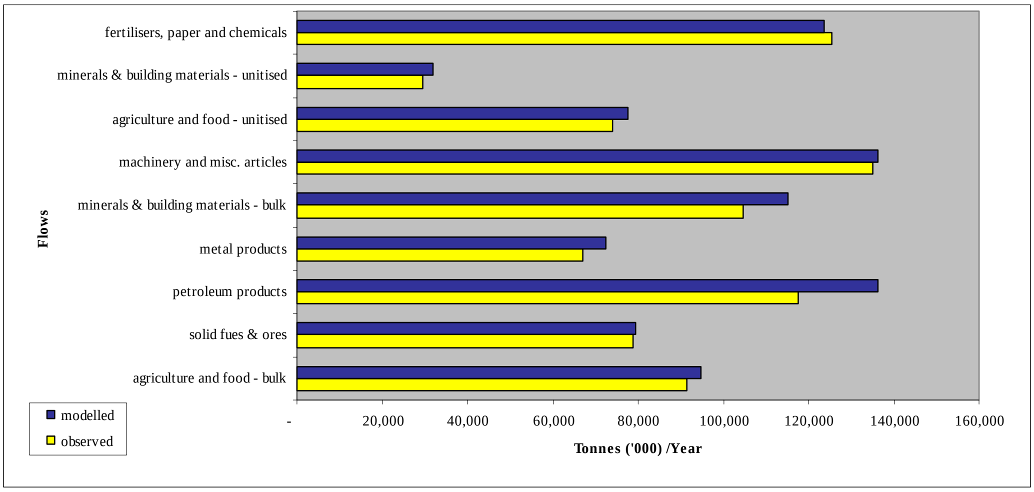
The modelled and the observed figures are therefore very similar. Regarding the overall data, national tonne-kilometres are slightly overestimated, although not dramatically so. The larger part of the overestimation is due to three countries: France, Italy, and UK.

4.5.3 International freight traffic

The international freight traffic which the model produces is compared against the (more limited) data on international freight in this section. The data is compared in terms of: volume of freight moved by flow type, overall modal split, volume of freight by handling category by country and modal split by country of origin. A summary table is then presented.

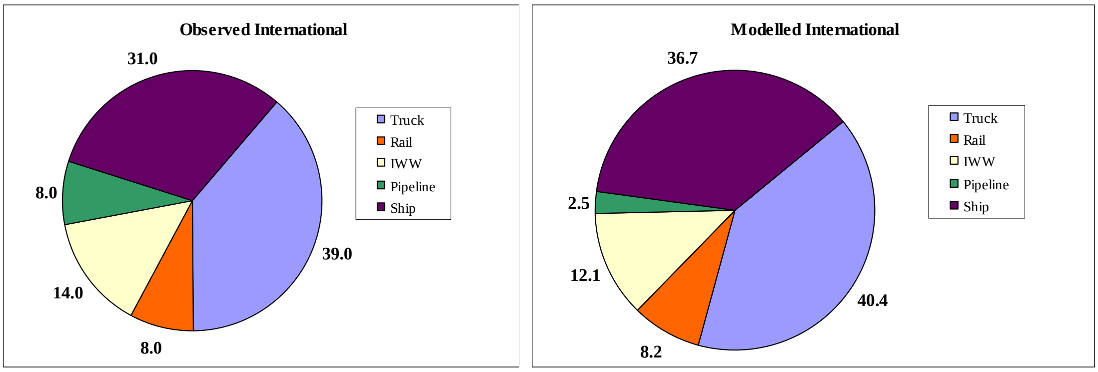
Figure 4.5 shows volumes of internal EU15 international freight traffic (tonnes) by flow type, aggregated across all modes compared to the derived 'observed' data. The modelled and observed data compare for all the flow types.

Figure 4.5: 1994 International EU15 freight, modelled and observed



The overall modal split for all internal EU15 international freight traffic in the model is shown in Figure 4.6. As with the national trips, the overall levels of modal split compare well with the observed, with shipping having a much higher share of international traffic.

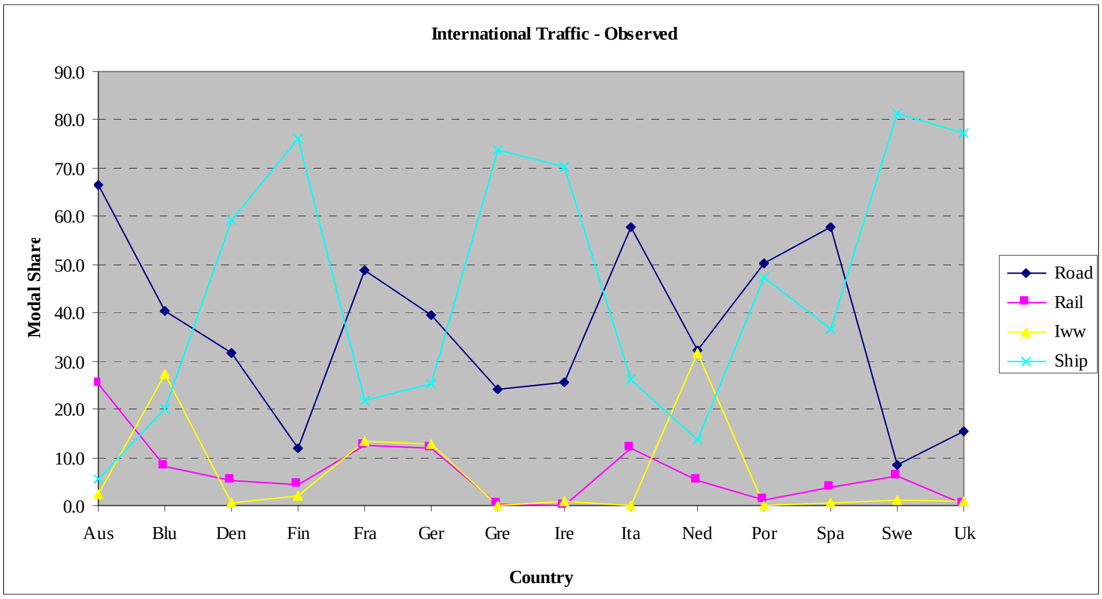
Figure 4.6: EU15 International mode split (tonnes), modelled and observed (%)



Figures 4.7 and 4.8 below compare the observed and modelled modal split (% of tonnes despatched) of EU15 international freight traffic at the country level. Even though the troublesome effect of 'other modes' is still present (although not shown in the figures) the observed and modelled data compare well. Ship is slightly overestimated overall and in particular for those countries where the actual modal share of ship is high, namely Italy, UK

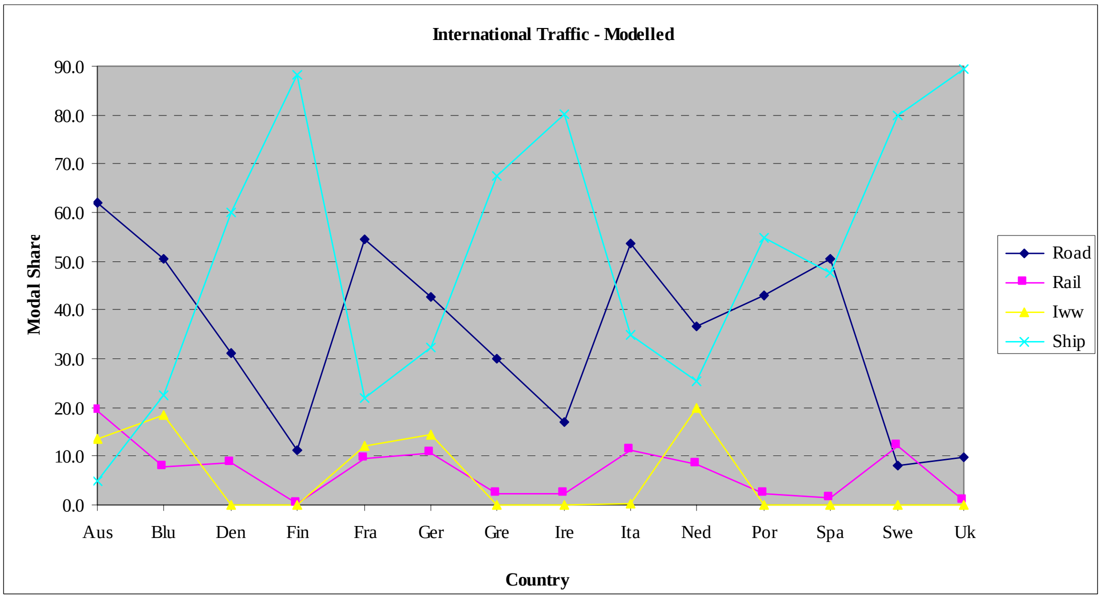
and Finland. In Austria, inland waterway traffic is overestimated, as a result of the extensive trades to and from France and the Benelux countries.

Figure 4.7: 1994 International EU15 freight traffic by mode, observed (%)



In Germany, 'other modes' are underestimated. As the modelled pipelines are used for national distribution, petroleum flows are considered part of the national traffic. However, in many cases, 'observed' data considers pipelines as the terminal mode of a multi-modal trip from abroad and therefore petroleum flows by pipeline are registered under the international statistics. Indeed, if the sum of national and international pipeline data is considered for Germany, the modelled flow is seen to be much less of an underestimate.

Figure 4.8: 1994 International EU15 freight traffic by mode, modelled (%)



Finally, the inland waterway modal share is underestimated for the Netherlands. Though the observed data was corrected as far as possible (by trying to exclude inland waterway 'feeder' traffic towards third countries, mainly Germany), the observed data may still be overestimated.

Comparisons of international tonne-kilometres travelled are not presented here. This is because in the first instance, the model produces international tonne-kilometres as the sum of international flows originating from a given country, regardless of the territory on which the shipment is made. The official statistics present international and national tonne-kilometres in a given country as the totality of the flow within the national boundaries only (i.e., including transit traffic). The two definitions therefore differ fundamentally. In addition, the model definition of 'mode' is based on an hierarchy, which again produces results which are not easily compatible with official figures.

However, the modelled total tonnes moved between the EU countries is in line with the observed, and the national tonne-km are in line, so the total volumes of freight flow in the base year model is satisfactory.

4.5.4 Summary of freight movements

The following summary table (Table 4.9) describes the main characteristics of national and international flows. This table compares the observed and the modelled outputs in terms of these key characteristics. In each of these key characteristics, the modelled and the observed values can be seen to compare well.

Table 4.9: 1994 Freight model validation – Summary table (1000T pa)

Characteristic	**Observed**	**Modelled**
National Flow	10,949,574	11,261,710
EU15-EU15 International Flow	823,269	852,838
Rest of World - EU15 International flows	727,680	597,580
EU15 – Rest of World Flows	305,947	259,116
All International Traffic	1,856,896	1,709,534
Total Volume Moved	**12,806,470**	**12,971,244**

5. STREAMS Software Development

5.1 Introduction

The STREAMS project included the production of three new pieces of software, the Network Tool, Scenario Manager, and the Presentation Tool. Each of these is described below.

5.2 Network tool

Most models that produce spatially detailed forecasts of transport patterns use link based networks as a key input. These model networks are often now extracted from a source GIS network, which may contain information irrelevant to modelling and also lack information which is necessary to modelling. The Network Tool is designed to create model networks from source ones and to then edit and manage the networks. In addition, once a model network has been created it will need to be checked.

The Network Tool works in MAPINFO and uses GIS network files as input. It performs four tasks:

Network management

- the tool allows users to build and modify networks on screen using a point and click interface;
- it gives a fast graphical view of the source and model networks and their properties, with efficient zooming and panning and related operations;
- it has a graphical point and click access to the link attributes and their geographical locations;
- links can be extracted from a source network to create a new model network. They can be extracted by either pointing and clicking on screen or based on their link attributes;
- new links and nodes can be added to the network and existing links can be modified and deleted;
- it allows link groups to be defined specifying a name and colour for each group of links; and
- STREAMS network files can be automatically generated from MAPINFO GIS files.

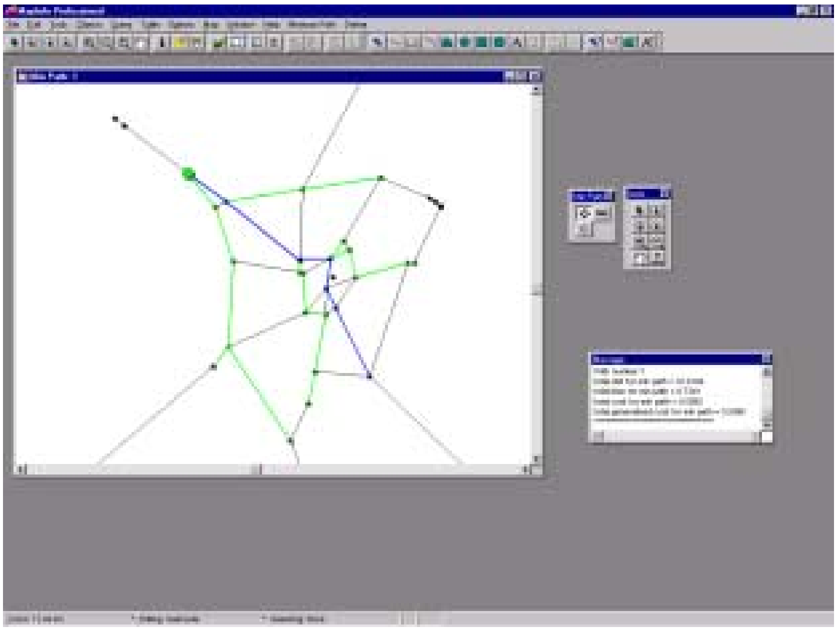
Minimum path calculation

- Minimum paths can be plotted based on distance, cost and time for network checking purposes. A single node can be selected from the base network and the path plotted from every other node to the selected node. Alternatively two nodes can be selected in the base network and the minimum path between them plotted. A simple example of the minimum path capability is shown in Figure 5.1 overleaf.

Consolidation

- The user can remove unnecessary links and nodes to obtain a smaller network without any loss of network information relevant to the transport model. Links in the source network can be aggregated in series (consolidation). This can be done link by link on screen or by consolidating all links of a specified type.

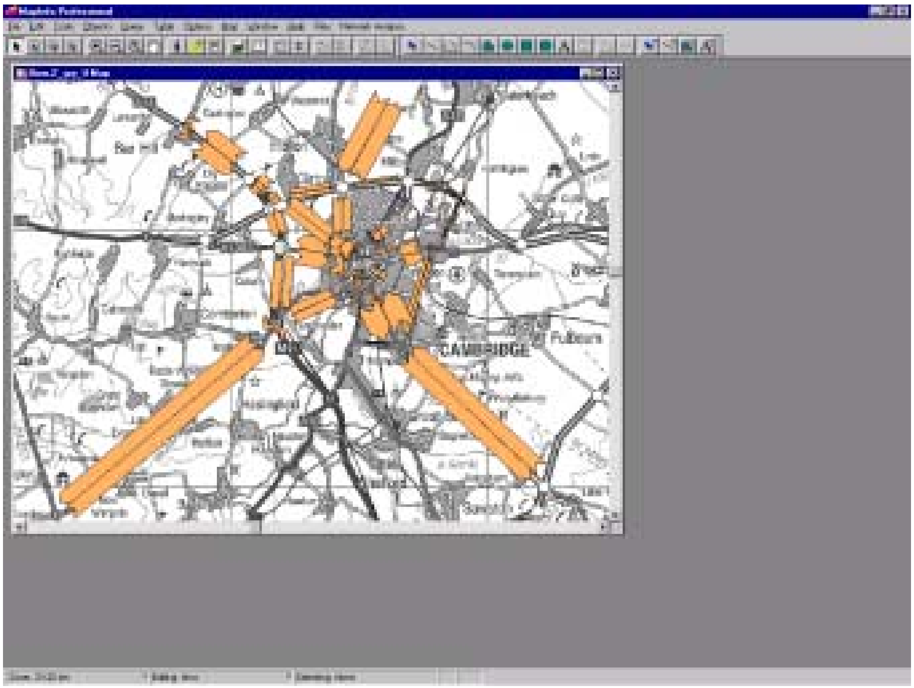
Figure 5.1: Example of minimum path calculation with the Network Tool



Results Presentation

- The final main area of functionality regards the presentation of loads on the network. This enables loaded networks (i.e., the output of a model run) to be analysed within the GIS environment. Link types can be grouped together in a way determined by the user and loads can be presented using numerical labels, or variable width arrows. An example ‘screenshot’ is shown in Figure 5.2 below, which shows the loaded network overlaying an actual map in GIS from.

Figure 5.2: Example of results presentation with the Network Tool



5.3 Scenario Manager

The Scenario Manager is a tool for automating and managing policy testing with the STREAMS model. The system allows policy tests to be quickly and easily defined by the application of constraints on the demand side, 'actions' and changes to the model transport network, 'schemes'. The system automates the running of policy tests by allowing a model run sequence, along with the appropriate program arguments, to be defined for each year being studied.

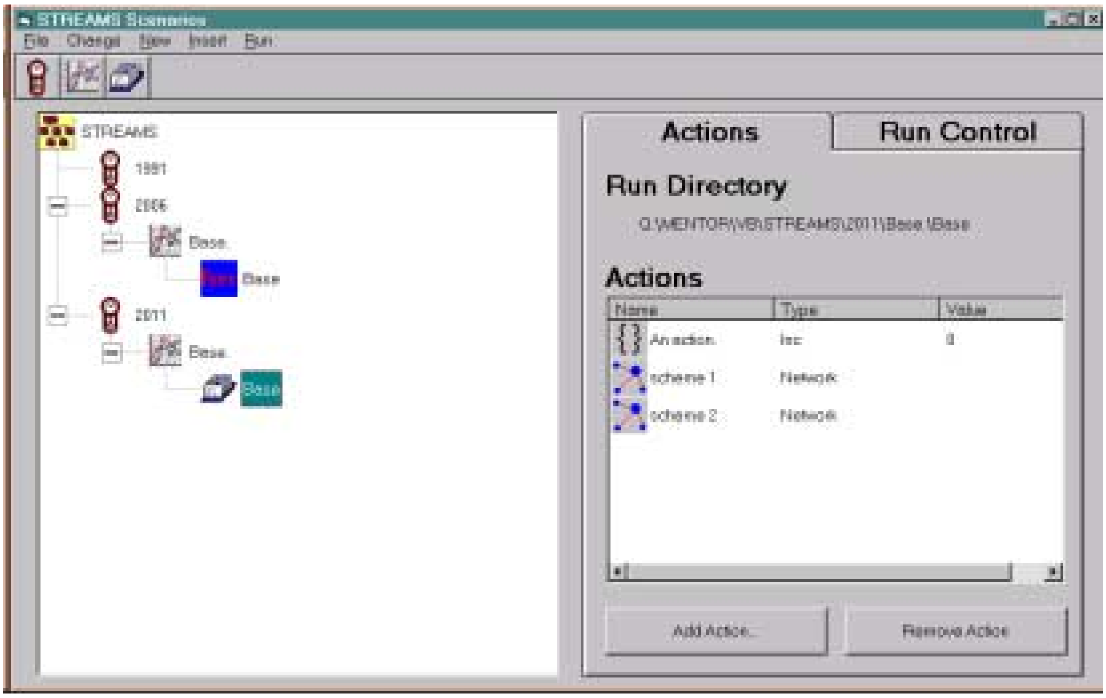
'Actions' can be applied zonally or over the whole study area. Actions whose values contradict each other in the same policy test are automatically detected. Actions can be defined as absolute values or as increments on the previous year.

Schemes are graphically defined in a GIS-based tool. Any number of schemes can be applied to a given policy test. Schemes can be linked with other schemes, called 'dependent schemes', where the existence of one scheme would be meaningless without the existence of its dependent scheme(s).

The system maintains a directory tree matching the years, scenarios and policies defined. Policy tests whose results are out of date with respect to their inputs are detected and displayed to the user.

Figure 5.3 below shows a sample of the Scenario Manager control panel.

Figure 5.3: Example of Scenario Manager software



5.4 Presentation tool

The purpose of the STREAMS Presentation Tool is to visualise the impacts of transport policies on travel times. Travel times are output of the STREAMS transport model, i.e., they take congestion on the road network into account. Different travel times in Europe can be presented as isochrone maps.

In order to map travel times continuously in space, the travel time calculation for the isochrone maps is based on the raster approach. For this purpose the area under consideration has to be 'rasterised', i.e. sub-divided into cells of equal size. Then, each cell can be considered as an origin cell for a trip to the selected destination and a travel time for this trip can be calculated as a combined travel time in raster and vector space.

The raster part of the travel time is the part of the trip from the origin cell onto the model network which can be calculated by mode and year specific average speeds. For each origin cell the nearest node or the next two or more nodes are identified by appropriate search routines. Then, the minimum total travel time is calculated by identifying that network node (origin node) out of the next nodes that results in the lowest total travel time between origin and destination by summing up the travel time from the origin cell to the origin node, and the network travel time from that origin node to the destination node as described before.

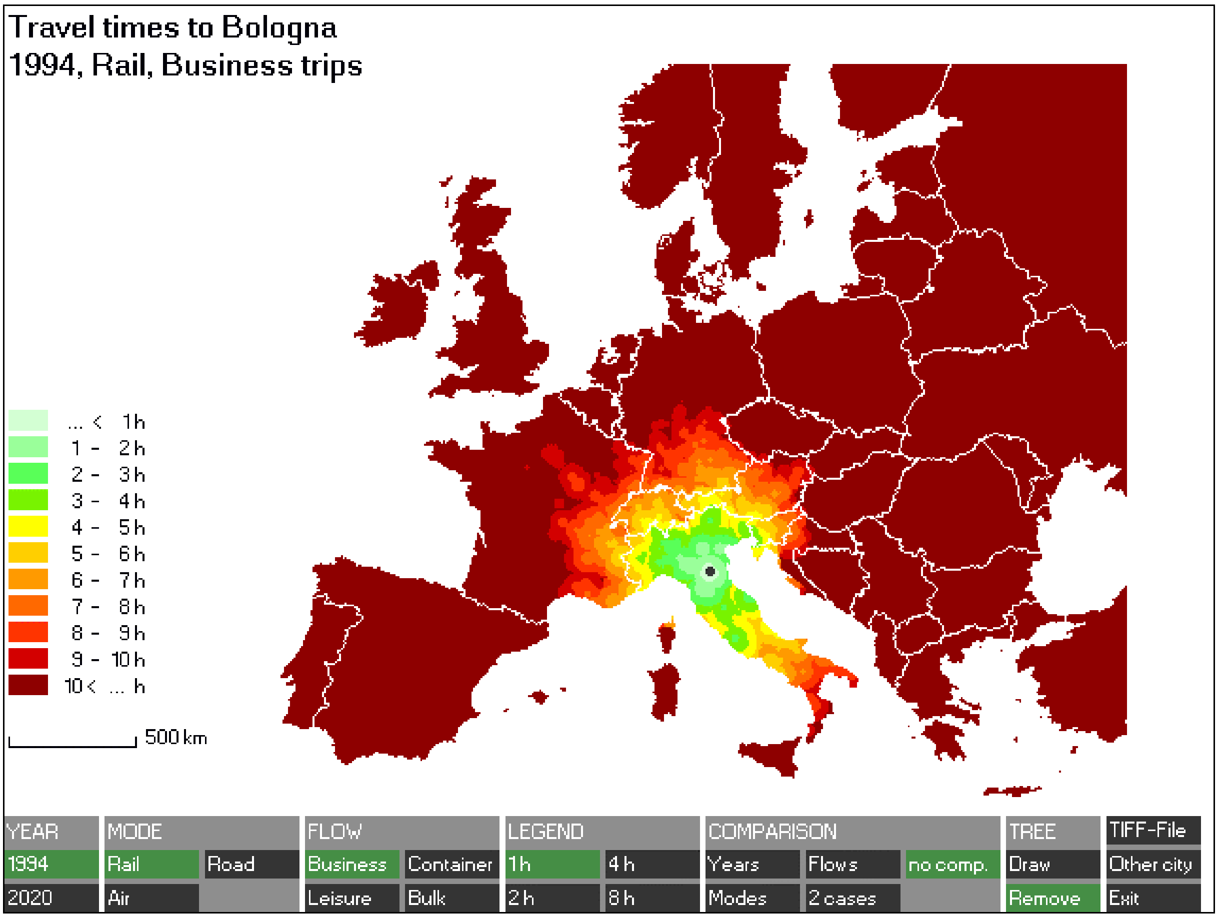
The STREAMS Presentation Tool consists of two different units: the destination selection via a map and the display unit with integrated option menus. For the selection of the destination city, i.e., the place for which the travel times will be displayed, the user is offered a European map showing the STREAMS zonal system. Moving the mouse over the map a zone touched by it will change colour and its zone name and its centroid name will be displayed until the mouse leaves that region. By clicking on a zone its centroid is selected as a destination and the programme proceeds to the map display unit.

After this selection the display unit starts and a first isochrone map for the destination city will be drawn on the screen (see Figure 5.4). Below the map, a menu will appear offering further options to the user. The map shown after first destination selection has been pre-defined: e.g., rail travel times of business travellers for 1994.

Then, the user might select among the options offered by clicking on the buttons. There are several different categories of button groups:

- Year – selection between the STREAMS Model base year 1994 or the forecast year 2020;
- Mode – selection among the available user modes rail (i.e., international rail, unitised rail, or bulk rail), road (i.e., car or truck) or air (i.e., business or independent travel);
- Flow – selection among the available flow types, business travel, leisure trips, container (i.e., unitised freight) and bulk (i.e., solid bulk); and,
- Legend – selection of different time intervals to be shown in the same colour on the map to reflect different travel time characteristics of the various flow types and user modes; available are one, two, four and eight hours intervals.

Figure 5.4: Screenshot of a typical isochrone map display screen with option menu



Note that further examples of the Presentation Tool are contained in Chapter 7.

6. Forecasting assumptions

6.1 Introduction

There are a number of assumptions required for the key data inputs for the demonstration STREAMS 2020 Reference Scenario. Some of the main assumptions made for the passenger and freight model sections are described below. Most of the assumptions were based on readily available material and were generally ‘neutral’ in nature. Obviously, in policy related work, considerably more effort would need to be put into the construction of the forecasting assumptions. This is discussed further in the Conclusions chapter.

6.2 Passenger demand model

The main input assumptions required for the passenger demand element of the model concern: population and car ownership, vehicle occupancy, the value of time, and trip rates.

Population forecasts were based on ‘baseline’ (medium growth) projections.[13] The projections for the car ownership levels in each member state in 2020 were based on official projections for four of the member states. These took the form of estimates of car stock or cars per thousand population. The countries and sources were Finland (FINNRA), France (INRETS), Germany (DIW), and the UK (DETR). The trend in car ownership was examined for these countries and the progression towards greater car ownership was used to estimate future levels in the remaining countries.

The growth in the value of time (an important proxy for income) has been estimated using the EU15 GDP growth rate of approximately 2.55% per annum. This figure was applied in the period 1994 - 2020 in the SCENARIOS project. This growth rate is applied to all flow types in the model.

Vehicle occupancy information was available from the EC DGXI Auto-Oil II Programme for a number of member states[14]. These data showed a slow but steady decrease in occupancy from 1994 to 2020. The 1994 occupancy rates were modified in line with the Auto-Oil II trends to provide the 2020 rates.

Future year trip rates were estimated using the growth in observed trip rates per person per annum from 1975 to 1994. The basis for this disaggregation of trip rates by population segment was unpublished UK National Travel Survey material received from the UK Department of Transport Environment and the Regions (DETR). Projected trip rates per person for 2020 are forecast to grow at similar rates to the observed trends. However, trip rates for different trip purposes have been projected to grow at different rates, reflecting the greater growth of personal and leisure trips than work related trips in the future. The growth in tourism trip rates is established separately. The basis for estimating growth in internal EU tourism was the figures produced by the World Tourism Organisation[15].

The overall modelled number of trips per person per year in 1994 was 1042, based on data published in National Travel Surveys for the member states. In 2020, this figure rises to 1122

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[13] See the Eurostat publication ‘Statistics in Focus: Population and social conditions 1997, no. 7’, entitled, ‘Beyond the predictable: demographic changes in the EU up to 2050’ (1997).
[14] Auto-Oil II Cost-effectiveness Study Base Case Report, September 1998.
[15] See the ‘Tourism 2020 Vision’ publication, WTO.

trips per person per year, in line with historical evidence. This increase is mainly down to increased car availability rather than increases in trip rates as such.

6.3 Freight demand model

The REM requires macro-economic projections to establish a setting of overall economic development up to 2020 in the EU15. The actual input-output demand and technical coefficients are necessarily assumed to remain constant. The following projections are therefore required from data sources external to the model: private consumption, public consumption, investment, exports to outside the EU, and imports from outside the EU.

The 1994 GDP, private consumption, public consumption, and investment are extracted from European Commission data (European Commission DGII, 1996). European Commission DG II Medium Term Projections (1997) form the basis of the macro-economic projections up to 2001 that have been implemented in the model.

Trend growth for the period 1985-1994 by broad industrial branches was available from published Eurostat figures and this was used in developing projections for the 33 STREAMS model factors for the period 2001-2020. The SCENARIOS project estimated GDP growth of 2.55% per annum from 1994 to 2020 was used as an overall check on future growth of private consumption, public consumption, and investment when projections for the period 2001-2020 were developed for the study.

6.4 Transport supply

The two main constituents of the supply model are the networks and modal costs.

The main sources for determining the 2020 road and rail networks were the future plans from Community guidelines for the development of Trans-European Networks (TEN-T) (Official Journal of the European Communities, 1996). These plans were assumed to have been implemented in full by 2020.

The 2020 road network is based on the TEN-T plans and information in the International Road Federation database on national plans for network upgrading. The 2020 rail network is also based on the TEN-T plans, which for passenger lines includes building new high-speed rail lines, upgrading conventional rail track for high-speed use and building some new conventional rail links. This results in a very significantly expanded rail network. Only a small number of changes were made to the other networks for 2020: air and shipping networks were unchanged but the inland waterways network was upgraded to reflect major planned changes in connectivity.

A neutral view was taken on the changes in passenger tariffs and costs. Car operating costs and tolls were estimated to increase at 2% per annum based on projections in the SCENARIOS project Reference Scenario (SCENARIOS, 1998). All rail tariffs, local bus and long distance coach tariffs were also assumed to grow at 2% per annum. For air, different cost functions were used for leisure, business, and charter flights. Air tariffs were assumed to decrease at approximately 0.5% per annum in line with recent trends. All these changes are set against a projected GDP increase of 2.55% per annum, thus the real cost of transport is decreasing for the Reference Scenario, in line with recent trends.

Assumptions for the freight modes affect both costs and operating conditions. Deregulation will promote further competition within the road haulage industry. Lorries are assumed to have higher load factors to represent the reduction of empty back flows, especially for unitised goods. For rail, a partial convergence of tariffs towards the EU average was assumed. Improved port efficiency is reflected through a reduction of costs and loading / unloading times at sea ports and inland ports.

7. STREAMS model results

7.1 Introduction

The results of the demonstration 2020 Reference Scenario STREAMS model run are reported in this chapter, based on the assumptions described in Chapter 6. The passenger model results are discussed first followed by the freight section. The combined network assignment outputs are then reported for the road network.

It should be emphasised that the results are crucially dependent on the assumptions made, which were discussed in Chapter 6. No attempt was made to produce an 'official' EU scenario at this stage. The aim of producing a reference forecast was to demonstrate that the model development work had achieved its objectives and to highlight issues for further research work.

7.2 Passenger Model Results – 2020 Reference Scenario

The 2020 passenger model results can of course be reported in many different ways. The following sections illustrate the type of results which have been produced, showing the total number of trips and distribution of trips by distance and then modal split and passenger-kilometres at the EU level.

7.2.1 Overall number of trips

In order to understand the changes in the model between 1994 and 2020 it is useful to start by looking at the changes in actual numbers of trips by the STREAMS passenger flow groups. Table 7.1 compares the 1994 and 2020 figures and shows the growth or decline in each category. The figures relate to all EU15 countries and the units are thousands of trips per day.

Table 7.1 therefore clearly shows the decline in trips associated with the population segments which are reducing in size, i.e., the no and part car available groups, compared to the 1994 base. The total number of trips has increased by 12% overall, and the single biggest area of growth is in international independent holidays taken by those with partial or full car availability. By far the largest individual passenger flow type in both 1994 and 2020 is the group which incorporates shopping, personal business, education, visiting friends and relatives and day trips (all of less than 40km), made by persons with partial car availability.

These results confirm that most of the overall increase in travel demand can be attributed to increases in journey distances rather than large increases in the number of trips. This point is developed further later in this Chapter.

Table 7.1: Number of passenger trips ('000 per day) by flow type, 1994 and 2020

Flow Group	1994	2020	% change
Short trips			
Commuting and business trips, no car available	21,230.0	7,730.4	*-63.6*
Commuting and business trips, part car available	76,777.8	50,136.6	*-34.7*
Commuting and business trips, full car available	110,683.0	165,050.5	*49.1*
Children, all trips, all car availability levels	104,460.9	98,552.5	*-5.7*
Shopping, personal business, education, VFR[16], day trip – no car available	142,215.5	71,061.1	*-50.0*
Shopping, personal business, education, VFR, day trip – part car available	427,094.3	525,188.1	*23.0*
Shopping, personal business, education, VFR, day trip – full car available	132,146.7	214,369.5	*62.2*
Long trips			
VFR, day trip – no car available	5,030.9	2,476.1	*-50.8*
VFR, day trip – part & full car available	20,803.9	27,624.4	*32.8*
Charter holiday	86.7	91.1	*5.1*
Business and commuting – all car availability levels	15,259.1	16,298.4	*6.8*
International independent holiday – no car available	74.4	70.9	*-4.8*
International independent holiday - part & full car available	656.7	1,708.0	*160.1*
Domestic holiday – no car available	359.1	339.8	*-5.4*
Domestic holiday – part & full car available	2,532.3	6,167.6	*143.6*
TOTAL	**1,059,411.3**	**1,186,865.0**	***12.0***

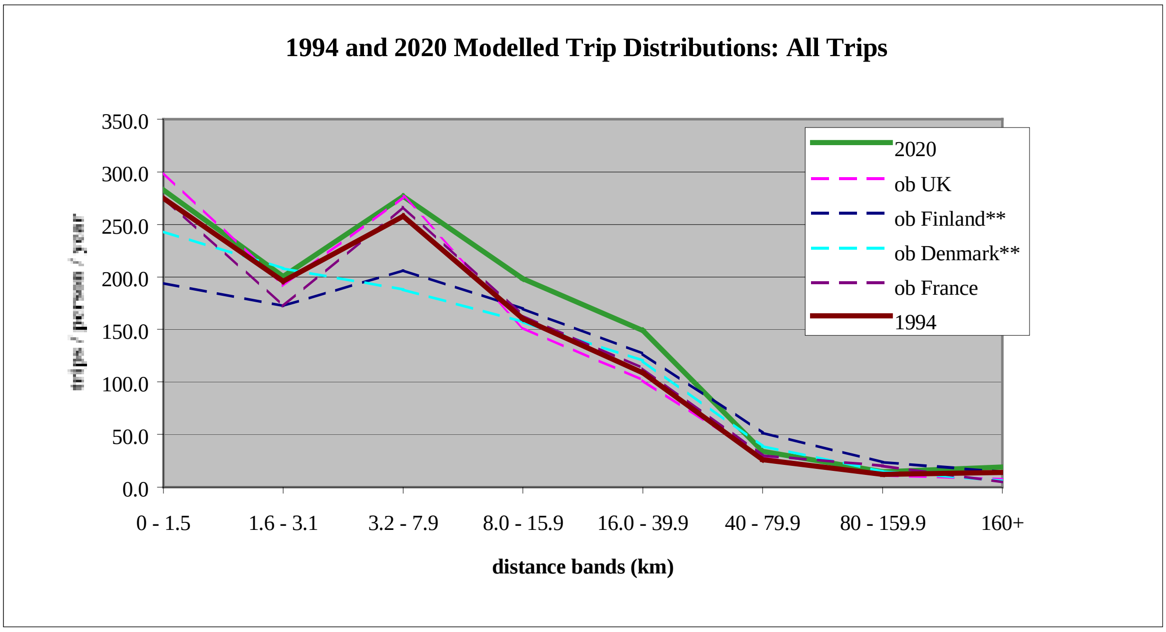
7.2.2 Distribution of trips by distance

Figure 7.1 below shows the new distribution of number of trips per person per year by distance band associated with the 2020 Reference Scenario. Also shown for comparison are the 1994 modelled and selected EU NTS results.

The effects of increasing prosperity and car ownership can clearly be seen with the increase in the number of the longer trips. There is a significant increase in the number of trips between 8 - 16 kilometres, and 16 – 40 kilometres in particular. There is also clear evidence of growth in the >160 kilometre category, reflecting increases in long business and tourism trips. At the shorter distances, the increase in the number of trips is more modest.

[16] VFR – visiting friends and relatives

Figure 7.1: Distribution of trips by distance – 1994 / 2020 modelled, and EU NTS

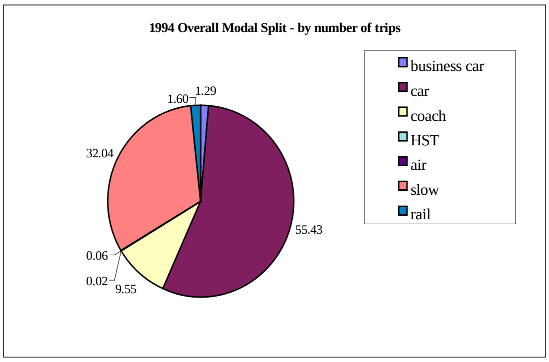


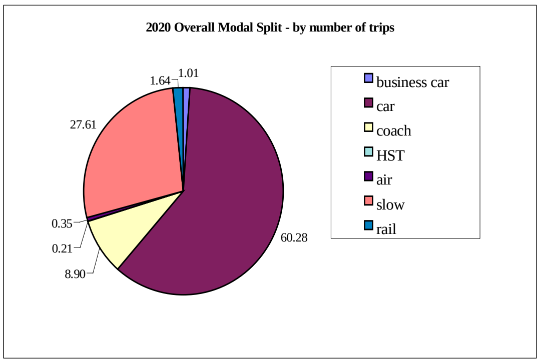
7.2.3 EU15 modal split

This section considers the main modal split characteristics of the 2020 Reference Scenario model run, for the EU15 as a whole. The results are considered in total, then disaggregated by distance.

Figure 7.2 shows the overall modal split for both 1994 and 2020, expressed in terms of a percentage of the number of all trips.

Figure 7.2: 1994 and 2020 Overall modal split (all trips, %)

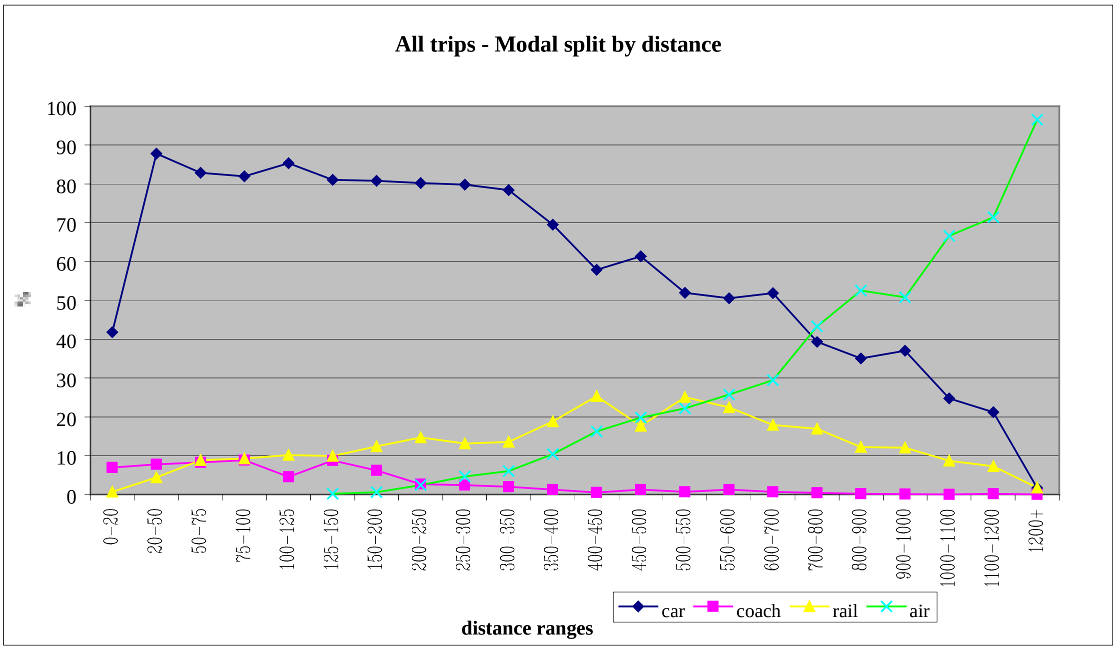




The main modal shifts are therefore seen to be away from slow mode towards the car. The car's share overall goes up from around 55% to just over 60%. Other significant results are the increase in high-speed rail from 0.02% to 0.21% of all trips, with conventional rail also gaining slightly. The share of the market held by bus / coach remains broadly constant. Air's share is also seen to rise significantly from 0.06% to 0.35% - this can be attributed mainly to the lowering of air fares relative to other modes.

The 2020 modal split is also considered by distance. Figure 7.3 below shows this in the same format as the 1994 results were shown in Figure 4.1.

Figure 7.3: 2020 modal split by distance (km), all trips (%)



There are therefore some significant modal shifts apparent in the 2020 run compared to the 1994 base case. Most significant is that air becomes a viable proposition at a much shorter distance than in the base case. As stated above, this is because air fares are reducing significantly compared to the other modes. The share of rail in the 300 – 900 kilometre range is also much greater than in the base, reflecting the extensive high quality high-speed rail infrastructure now in place. Over 1200km, the air mode takes virtually all the trips, again reflecting the low cost of this option in the Reference Scenario.

7.2.4 EU15 Passenger-kilometres travelled

Having considered the total number of trips and the overall modal share, the total volume of travel with the EU is now reported. Table 7.2 shows the EU aggregate results for passenger-kilometres by mode together with the 1994 base and the implied per annum growth rate between the two. The units are thousands of passenger-kilometres per day, and passenger travel to or from outside the EU is not included.

The overall level of growth in passenger travel is therefore 1.5% per annum[17]. Passenger-kilometres travelled by car increases by just under 1% per annum – however, since car occupancy levels reduce in the future, the increase in car kilometres will be slightly greater than this figure. The largest growth is for air travel. This is due to the reduction in air fares which make air travel very cheap by 2020, compared to other modes. This level of growth should be taken to reflect the maximum unconstrained demand – in the model there are no air capacity considerations, so this growth is unchecked. Overall, the rail mode also shows a significant per annum growth rate when considered in terms of passenger-kilometres – again reflecting the substantially increased infrastructure planned to be in place by 2020.

[17] Figures from DGTREN of the European Commission (Transport in Figures), indicate that between 1970 and 1990, the rate of growth for mechanised modes (car, train & bus) was 3.2% per annum. This slowed to 1.8% between 1990 and 1997.

Table 7.2: EU15 Passenger-kilometres travelled by mode ('000 / day)

Mode	1994 p-km	2020 p-km	*% per annum growth*
Air	664,444	4,090,654	*7.3*
Car	10,639,159	12,989,902	*0.8*
Bus / Coach	1,061,237	1,147,265	*0.3*
Slow	725,000	684,215	*-0.2*
Train	781,364	1,584,596	*2.8*
Total	**13,871,204**	**20,505,632**	***1.5***

The overall increase in passenger-kilometres is therefore from 13.8 billion passenger-kilometres per day to 20.5 billion, an increase of approximately 50%. It was seen from Table 7.1 that the number of trips made had increased by only 12%. These figures therefore give some indication as to the order of magnitude of the two sources of growth in passenger travel – increased trip distance, and more passenger trips, the former demonstrating its larger influence.

This growth in passenger-km is a combination of more trips being made, but more importantly of an increase in average trip distance. The overall average trip length is predicted to rise from 13.1 kilometres in 1994 to 17.3 kilometres in 2020 (including international trips). This growth is in line with historical trends.

7.2.5 Country specific results

This section reports the 2020 passenger model results at the member state level.

The growth in passenger-km can also be viewed at the national level. Table 7.3 shows the forecast passenger-km travelled by origin country per day, together with the total per annum increase by country.

Table 7.3: 2020 Passenger-kilometres by mode by country ('000 / day)

Origin Country	Air	Car	Coach	Slow	Train	Total	*% p.a. growth*
Austria	112,383	249,603	35,801	12,955	45,613	**456,355**	*1.43*
Belgium	91,552	343,918	62,141	17,791	35,585	**550,987**	*1.40*
Denmark	96,388	208,882	15,323	8,187	19,105	**347,885**	*2.13*
Finland	120,515	192,115	22,050	7,240	11,957	**353,877**	*1.98*
France	538,036	2,143,315	159,868	104,199	408,980	**3,354,398**	*1.47*
Germany	977,927	2,847,783	271,270	151,327	265,151	**4,513,458**	*1.49*
Greece	31,557	409,646	20,419	22,218	10,022	**493,862**	*1.62*
Ireland	50,565	131,442	6,693	4,960	4,766	**198,426**	*2.15*
Italy	554,888	1,688,898	196,715	103,717	407,558	**2,951,776**	*1.20*
Luxembourg	2,412	18,123	2,151	521	2,873	**26,080**	*1.69*
Netherlands	190,834	567,114	55,870	39,135	81,366	**934,319**	*1.82*
Portugal	102,976	332,412	33,709	14,394	21,457	**504,948**	*1.65*
Spain	222,924	1,483,738	90,071	82,682	118,416	**1,997,831**	*1.58*
Sweden	285,807	297,390	33,855	14,278	29,969	**661,299**	*2.26*
UK	711,890	2,084,523	141,329	100,611	121,778	**3,160,131**	*1.48*
EU15 Total	**4,090,654**	**12,998,902**	**1,147,265**	**684,215**	**1,584,596**	**20,505,632**	***1.52***

Table 7.4 shows the modal split proportions by country, in terms of percentages of number of trips.

Table 7.4: 2020 Modal split by country (% trips)

Origin Country	Air	Car	Coach	Slow	Train
Austria	0.41	59.8	12.4	24.4	3.0
Belgium	0.27	57.4	13.1	27.8	1.3
Denmark	0.49	69.7	7.9	19.9	2.0
Finland	0.45	68.3	10.4	19.6	1.2
France	0.43	64.9	7.3	25.9	1.6
Germany	0.31	56.7	10.6	30.0	2.5
Greece	0.09	62.7	6.9	30.1	0.3
Ireland	0.48	74.0	6.2	18.4	0.9
Italy	0.33	57.1	10.7	29.2	2.8
Luxembourg	0.14	69.5	12.7	16.4	1.2
Netherlands	0.26	59.8	6.9	31.4	1.7
Portugal	0.30	63.7	13.5	20.7	1.7
Spain	0.28	60.1	6.1	32.4	1.1
Sweden	0.73	62.2	11.9	23.2	2.0
UK	0.39	66.5	7.3	24.6	1.3
EU15	**0.35**	**61.3**	**8.9**	**27.6**	**1.8**

From this table, the countries experiencing the greatest growth in the proportion of rail travel such as Germany and Italy are those with the greatest investment in new infrastructure over the period. The poor state of Greek railways is reflected in their continuing low proportion of trips. The country which sees the greatest increase in the proportion of car trips is Greece, since this started from a low base of car ownership. Ireland also sees a big rise, although the proportion in the base was already high due to the rural nature of the country. In general the pattern is consistent in that those countries which started with a higher level of car ownership see less of a rise in this proportion.

Looking at slow mode, although the Netherlands sees a reduction for this mode, it is still towards the top compared to other countries, despite its high levels of car ownership. The more peripheral countries in the EU such as Ireland, Finland, Denmark and Sweden see the greatest proportion of trips by air of any of the countries.

7.3 Freight Model Results – 2020 Reference Scenario

7.3.1 Introduction

This section reports some examples of the demonstration 2020 Reference Scenario results in terms of the total volume of freight in the system, the modal share of these freight, the tonne-km of freight moved, and an examination of the different constituents of the overall freight moved.[18]

7.3.2 Total freight moved – national plus international (tonnes)

The first main measure for the 2020 Reference Scenario is the total number of tonnes in the system. The total number of tonnes (national, intra EU international, and EU / rest of World exports / imports) increases from 12.9 billion tonnes per annum in 1994 to 20.7 billion tonnes per annum, a per annum increase of 1.8%. This overall figure conceals differences between

[18] Note that the results shown in this section differ slightly from those contained in STREAMS Deliverable D8 / D10. These changes were the result of further analysis carried out in the light of the application of the STREAMS model in the 'Forecasts of EU/TEN-T transport and emissions: a pilot study' project.

the main elements of the freight moved however. Table 7.5, below shows the proportions of the total traffic by type. Also shown is the per annum changes in tonnes moved by these different types of movement.

Table 7.5: Total STREAMS freight traffic by type of movement (tonnes)

Type of Movement	1994 Base (%)	2020 Reference Scenario (%)	*% pa change 1994 – 2020*
EU National	86.8	80.9	*1.5*
International EU15	6.6	6.7	*1.9*
ROW to EU15	4.6	10.3	*5.0*
EU15 to ROW	2.0	2.1	*1.9*

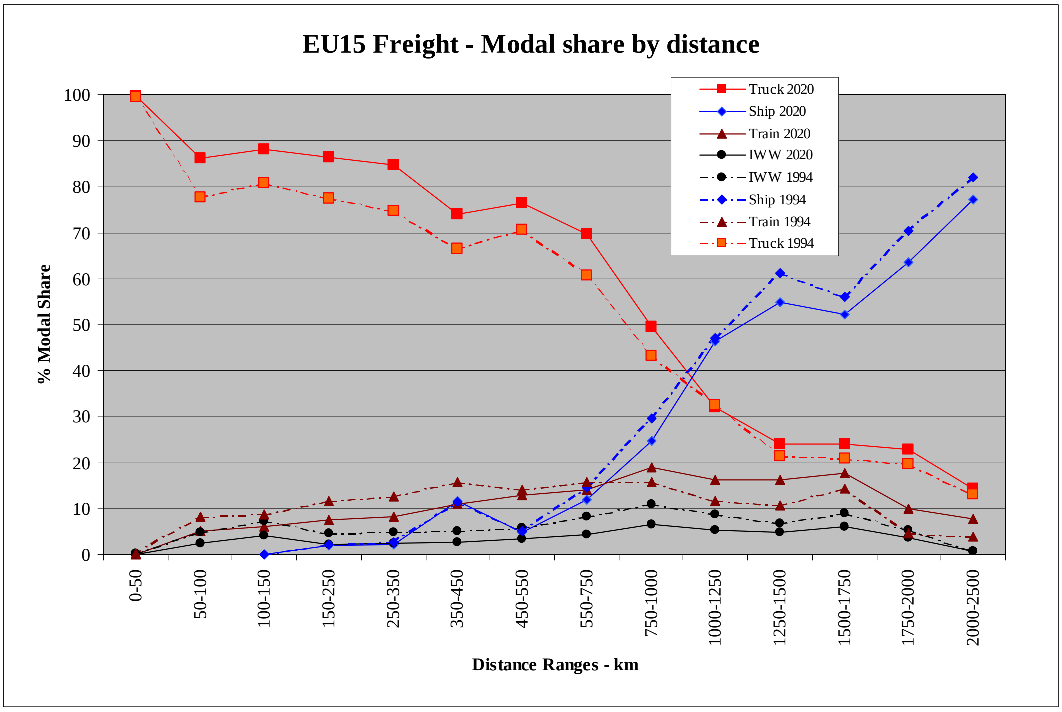
It can be seen from Table 7.5 that in 2020, the national movements therefore account for a smaller proportion of the tonnes moved than in 1994. The biggest growth in terms of the proportion of tonnes moved is in imports to the EU15 from the rest of the world. The per annum growth rates also illustrate that international freight will increase at a greater rate than domestic freight, since domestic freight tonnes is seen to be growing at a rate of only 1.5% per annum.

The changing nature of the types of goods moved is illustrated by the fact that, looking at international freight traffic for example, unitised goods (at 1.3% per annum) grows faster than semi-bulk, or general cargo (0.5% per annum).

7.3.3 Modal split

Turning to modal split, Figure 7.4 below shows the modal split by distance for all national and international freight traffic within the EU. The modelled values for 1994 (dotted lines) and 2020 (solid lines) are both shown for comparison. Note that in this Figure, all freight movements are included, i.e., trips to and from the rest of the world are included (up to 2500km).

Figure 7.4: Total EU15 freight traffic – Modal split by distance range (%)



It is therefore clear when viewed in this way that there are some significant shifts in modal share taking place between 1994 and 2020. In general, the share of truck traffic increases although this effect lessens as the distance increases. Beyond around 700km, the share of rail starts to increase in 2020 relative to 1994, whilst inland waterway loses modal share at all distances. The increase seen by rail is at the expense of all the other modes – where rail takes market share from ship, this is due in part to the completion of fixed link infrastructure in the future year network relative to the base. Much of the increased rail traffic will however be due to the significantly extended infrastructure – particularly the freight freeways.

There are some significant modal shifts for national and international EU15 freight flows. The 1994 results are repeated below in Table 7.6 together with the 2020 results.

Table 7.6: 1994 / 2020 modal split - national and EU15 international freight (% tonnes)[19]

	1994 National	**2020 National**		**1994 International**	**2020 International**
Truck	91.5	93.1		40.4	34.2
Rail	4.2	3.3		8.2	12.4
Inland waterway	1.4	1.1		12.1	8.2
Pipe	1.5	1.2		2.5	2.1
Ship	1.4	1.4		36.7	43.2

When looking at international trips between the EU15 countries it is clear that the truck mode actually loses out between 1994 and 2020, mainly at the expense of coastal shipping and rail. At the national level, the share of truck increases.

Rail gains international market share through the considerably enhanced infrastructure in 2020, although this is not enough to prevent a reduction in national rail freight, where the shorter average length of haul makes rail less competitive. The share of inland waterway drops significantly to a level of almost half that of 1994 for international trips. Pipelines share of the market is also seen to decrease. Some care is needed in interpreting these results however, given the modal definitions used in this case.

7.3.4 Total freight transport (tonne-km)

In addition to looking at volumes of tonnes moved, its also possible to look at the forecasts in terms of tonne-km by mode. The modelled 1994 Base situation and the 2020 Reference Scenario, are shown in Table 7.7 below. In this case, the figures refer to tonne-km travelled on the transport network within the territory of the EU15, regardless of the origin and destination of the shipment. In other words, traffic from or to external countries travelling into or away from the EU are included in these figures. Also shown in the Table are the 1994 'official' figures, for comparison.

[19] Note that the mode which is attributed to a shipment is based on an hierarchy of modes as follows – (1) truck, (2) railway, (3) inland waterway, (4) ship, and (5) air freight / pipeline. Where several modes are used in the course of an origin – destination shipment, the mode which is attributed to the OD pair is the mode used which is highest in the hierarchy. It therefore follows that a trip is defined as using 'truck' only if no other mode is used.

Table 7.7: 1994 and 2020 freight transport (tonne-km (10^6)/ annum)

	Road	**Rail**	**IWW**	**Coastal Shipping**	**Pipeline**	**EU15**
DGTREN[20] 1994	1,091,600	218,800	111,900	1,012,400	83,900	2,518,600
STREAMS 1994	1,026,531	276,692	157,493	1,091,552	45,975	2,608,023
STREAMS 2020	1,704,337	705,356	363,212	2,690,384	60,854	5,463,423
1994-2020 % pa growth	*1.97*	*3.66*	*3.27*	*3.53*	*1.08*	*2.88*

The overall volume of tonne-km travelled on EU territory is therefore comparable, and the match is particularly good for the coastal shipping and road modes. Looking at the 2020 Reference Scenario situation, there is an increase of 2.8% per annum in terms of tonne-km. The increasingly international nature of trade is demonstrated by the large increase in coastal shipping traffic. The dramatic increase in rail infrastructure, coupled with neutral pricing in relation to road and increased road congestion, means that the rail mode sees a higher rate of growth than the road mode.

These figures in isolation do not tell the complete picture however. The total figures contain three distinct elements which the STREAMS structure allows us to look at in isolation – namely national traffic, international traffic between EU countries and international traffic formed by exports and imports from / to the EU.

Table 7.8 below shows these aspects of the model results for 1994 and 2020.

Table 7.8: 1994 and 2020 freight flows by type (tonne-km (10^6) / annum)

	National	**EU international**	**Total EU**	**Import / Export International**
STREAMS 1994 Base	1,127,065 (43.2%)	1,082,268 (41.50%)	2,209,334	398,689 (15.3%)
STREAMS 2020 Reference Scenario	1,686,373 (30.9%)	1,741,121 (31.9%)	3,427,493	2,035,929 (37.3%)
% pa growth	*1.56*	*1.85*	*1.70*	*6.47*

The overall rate of growth is therefore seen to be heavily influenced by the big rise in export / import traffic to and from the EU. In STREAMS, forecasts were made of the value of exports and imports to / from different parts of Europe and the rest of the world using what limited forecast data were available (mainly short term forecasts from DGII). These values were typically in the region of 5% per annum growth. Using these assumptions, the proportion of traffic coming from or going to the rest of the world from the EU rises from 15.3% in the base year to 37.3% in the reference scenario. This aspect also explains the fact that the increases are greater for the non-road modes.

If only freight with origins and destinations within the EU only are considered however, the overall growth rate of tonne-km is a more modest 1.7% per annum.

In summary then, the overall growth in tonne-km is highly sensitive to issues such as to what extent trade increases between the current EU and other countries such as the accession

[20] EU Transport in Figures – Statistical Pocket Book, January 2000, EC DGTREN / Eurostat

countries to the EU. Looking between modes, the model is also sensitive to transport cost changes and the level of infrastructure in the networks.

7.4 Network Loading

This section considers the results of the 1994 base and demonstration 2020 Reference Scenario in terms of the loading of the road network in each year. The road network (excluding intra-zonal links) is considered by type of road, and here the flow to capacity ratio found on the links aggregated by road type is reported. Table 7.9 shows the results for the base year and Reference Scenario tests at the EU15 level.

Each network link in the STREAMS model is represented by a link type and a capacity, which reflect both the road standard and number of lanes. The capacity is a theoretical design capacity, and is used in conjunction with capacity restraint functions (developed within the project) to determine average daily speeds on road links during the traffic assignment phase of the model run. The assignment is multi-iteration, until convergence on path building (i.e., route choice) is reached. The final assigned road network load is then compared to the design capacity and the ratio between the two is determined for each link. This value therefore gives an indication of the prevalence of congested links found in each run of the model. The flow units are passenger car units (pcus) which is a weighted combination of cars, goods vehicles and buses / coaches.

Table 7.9 below presents the results at the aggregate EU level, for each of the road types - 'tolled motorway', 'motorway', 'dual carriageway' and 'other road'. In this definition, 'other road' is a road with one lane in each direction – the other categories are multi-lane roads. The table shows the percentage of each road type's total network length (km) which falls in each of the flow / capacity ratio groups (by direction).

The straight flow / capacity ratios output by the model were however adjusted to a more meaningful indicator as follows. The capacity coded on to the road networks represents a 24-hour capacity. This was necessary since the capacity restraint functions were formulated from 24-hour capacity figures, where the functions were adjusted in line with the hourly profile of traffic throughout the day. In order to produce a more meaningful flow / capacity ratio, analysis of traffic data indicated that approximately 90% of traffic flow occurs within the period 0600 – 2200 hours. The 24-hour link flow and capacity data were therefore adjusted accordingly and new flow / capacity ratios determined. It is these 'adjusted' figures which appear in Table 7.9.

Table 7.9: EU15 Modelled road network km by flow / capacity ratios and type

Test / Road Type	**Flow / Capacity 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	28.8	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**
2020 Reference Scenario						
Toll Motorway	33.5	35.5	18.6	7.6	4.8	**41,842**
Motorway	20.0	25.3	24.4	15.2	15.1	**64,354**
Dual Carriageway	53.4	22.4	14.1	6.1	4.1	**30,515**
Other Road	49.2	21.4	16.4	4.3	8.8	**53,403**
Total	**36.5**	**26.0**	**19.2**	**9.0**	**9.3**	**190,113**

This table can be interpreted as follows – e.g., in the base year model, there is 47,342km of motorway (by direction) and 14.5% of this length has an adjusted flow / capacity ratio of between 0.75 and 1.0. The figures for the 2020 Reference Scenario show that there is slightly more road network (reflecting new links) and many upgraded links, for example the total length of motorway in the EU increases from 77,000km to 106,000km between 1994 and 2020.

Considering the kilometres of all congested links (flow / capacity ratio > 1), the proportion more than doubles between 1994 and 2020 from 4.4% to 9.3%, reflecting a significant increase in indicative congestion on the network. These results give an indication of the likely increase in congestion throughout the EU, although these figures cannot be seen as definitive at this stage.

7.5 Presentation tool results

The Presentation Tool provides an alternative way of presenting the STREAMS model results, focussing on travel time changes. Some sample output is presented below.

Figures 7.5 and 7.6 show travel times to Paris by rail for leisure trips. The map in Figure 7.5 displays the situation in 1994. Clearly visible are the corridors of the existing high-speed rail network in France which lead then to lower travel times to Paris than outside those corridors. Figure 7.6 shows travel times for 2020. Now, the impacts of the trans-European rail network assumed in this model output become visible. The area of low travel times for leisure trips towards Paris is clearly expanded. New high-speed rail corridors in Spain, Italy and Germany appear as well. As a further example, Figures 7.7 and 7.8 respectively show the road and air travel times relating to business travellers in 2020.

The maps displayed in Figure 7.9 and 7.10 have been created by using one of the comparison options of the STREAMS Presentation Tool. Shown are business trips to Brussels for different user modes for the year 1994. Not surprisingly, Brussels is served by very good air connections to all European agglomerations leading to low travel times from there. Rail and road travel times from European destinations are in the same range as air for areas close to Brussels, because travellers that would use air, actually use road or rail here, and are much higher for areas further apart.

In order to look at the differences between cases in more detail the option for direct comparison has to be used. One example for this is presented in Figure 7.10 in which future travel time differences between rail and air are mapped. The destination is Cambridge, the flow type is business travel. The map shows in red colours from which areas rail is faster than travelling by air and in blue colour where the air mode is beneficial in terms of travel time. Grey colours indicate the areas in which no significant travel time differences exist between the two modes. Travel time advantages for rail are mainly visible along the high-speed rail link from the European continent through the Channel Tunnel. Despite the fact that Cambridge will not directly be served by high-speed rail it can take advantage of infrastructure developments elsewhere. Then, in a nearly ring-shaped area up to 800km no significant differences in travel time exist. Beyond that, air travel is faster. However, the shape of the light red areas showing a travel time advantage of one hour for air indicate future high-speed rail corridors through Germany and France.

Figure 7.5: Travel times to Paris, rail, leisure trips, 1994.

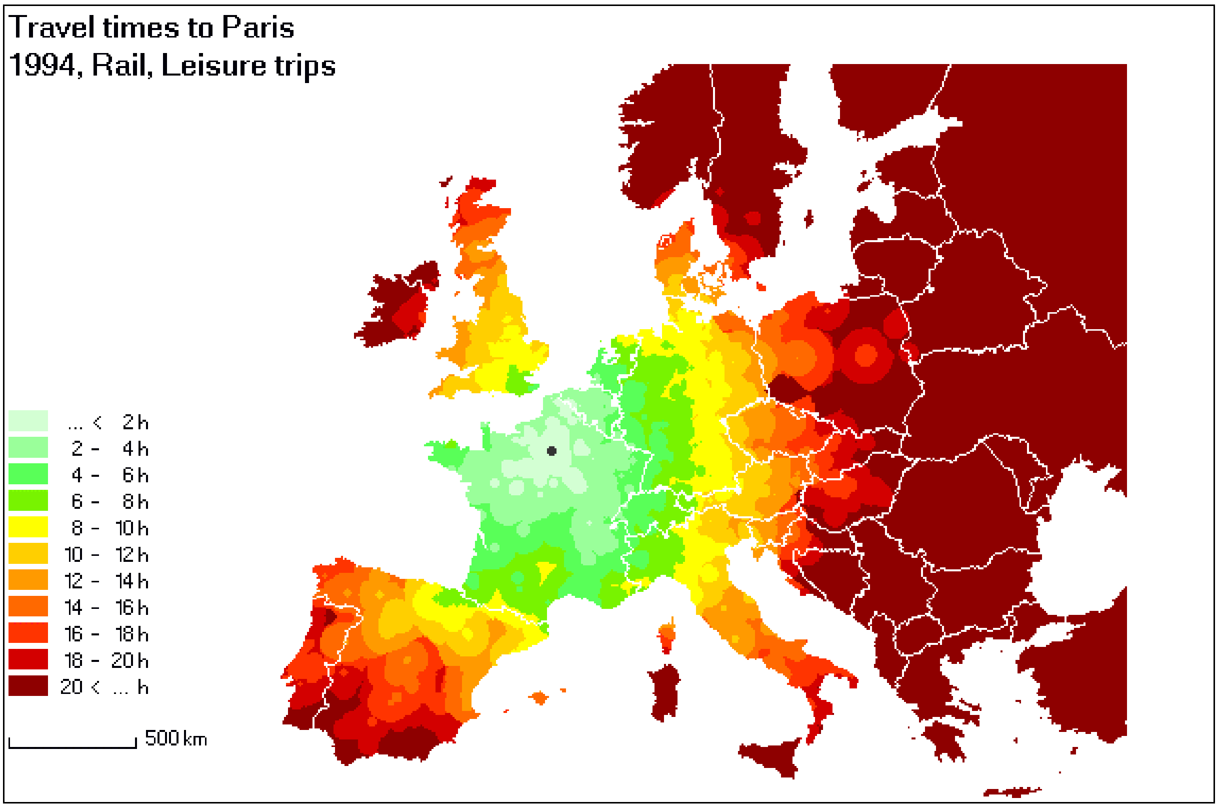


Figure 7.6: Travel times to Paris, rail, leisure trips, 2020.

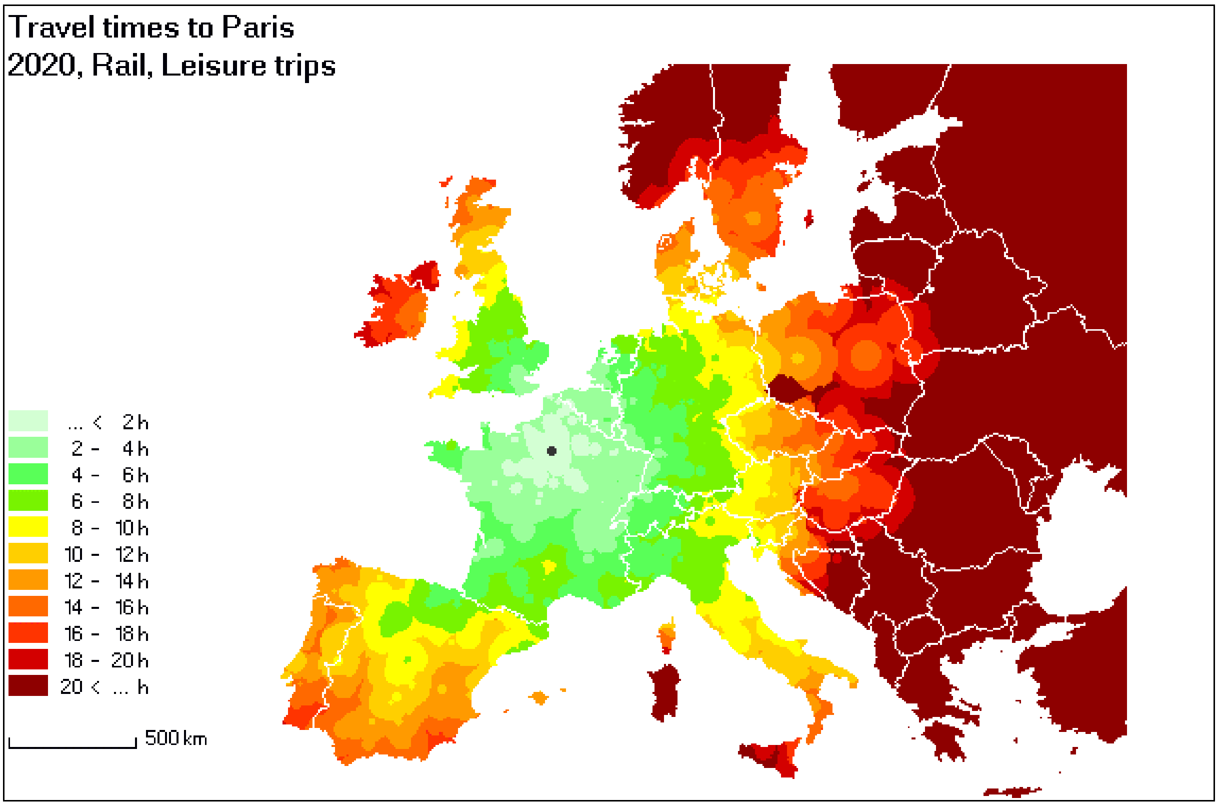


Figure 7.7: Travel times to Naples, Road, business trips, 2020

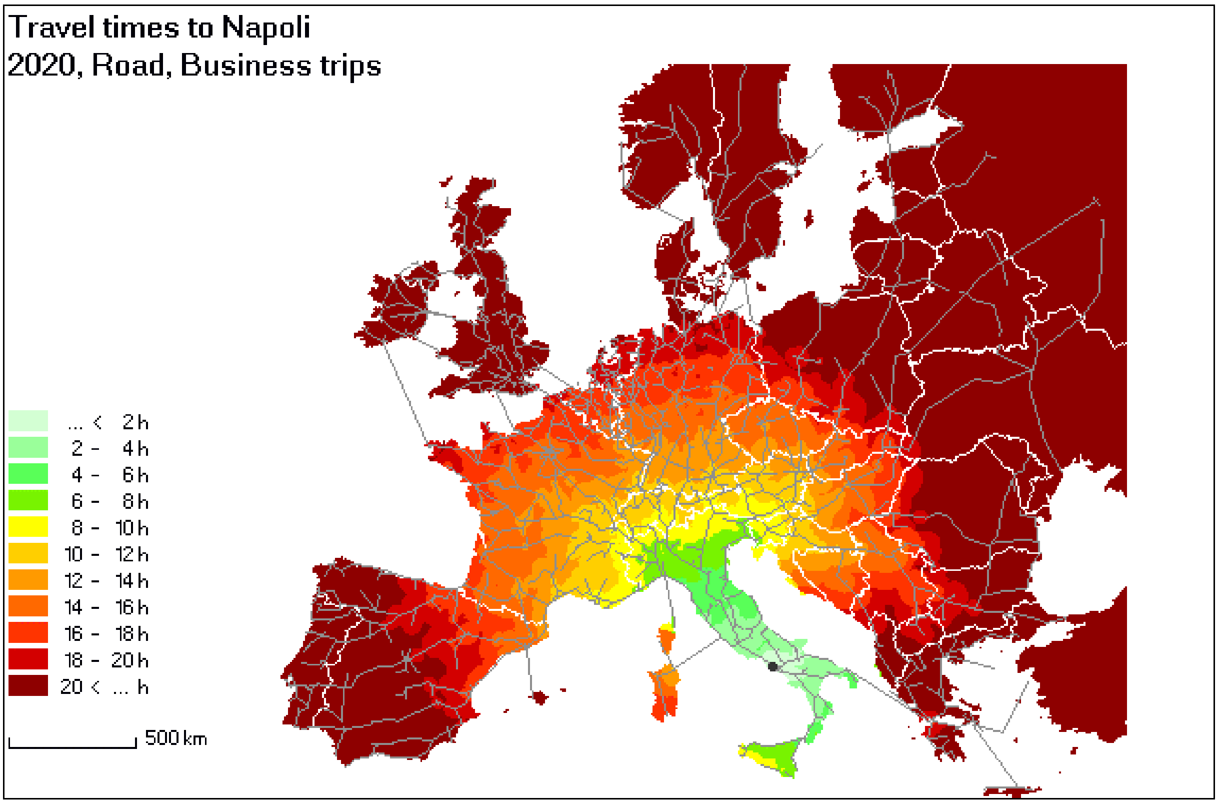


Figure 7.8: Travel times to Naples, Air - business trips, 2020

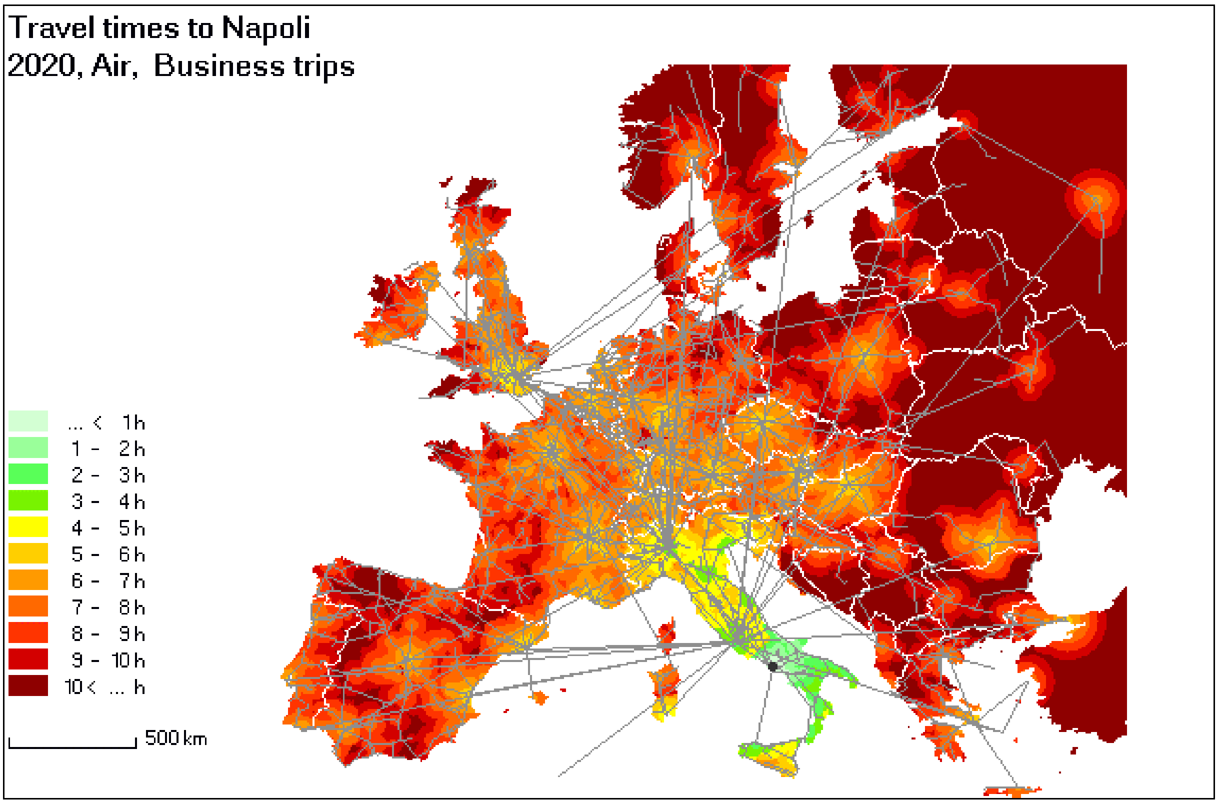


Figure 7.9: Travel times to Brussels, All modes- business trips, 1994

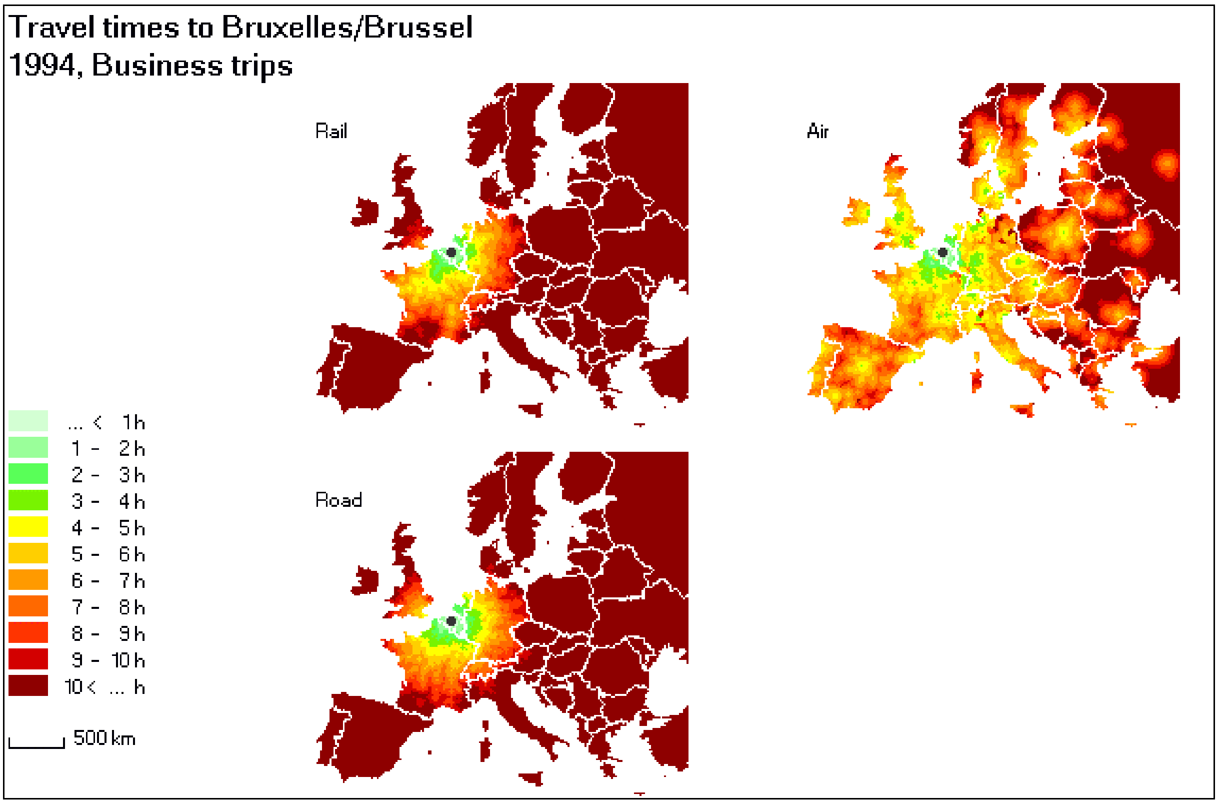
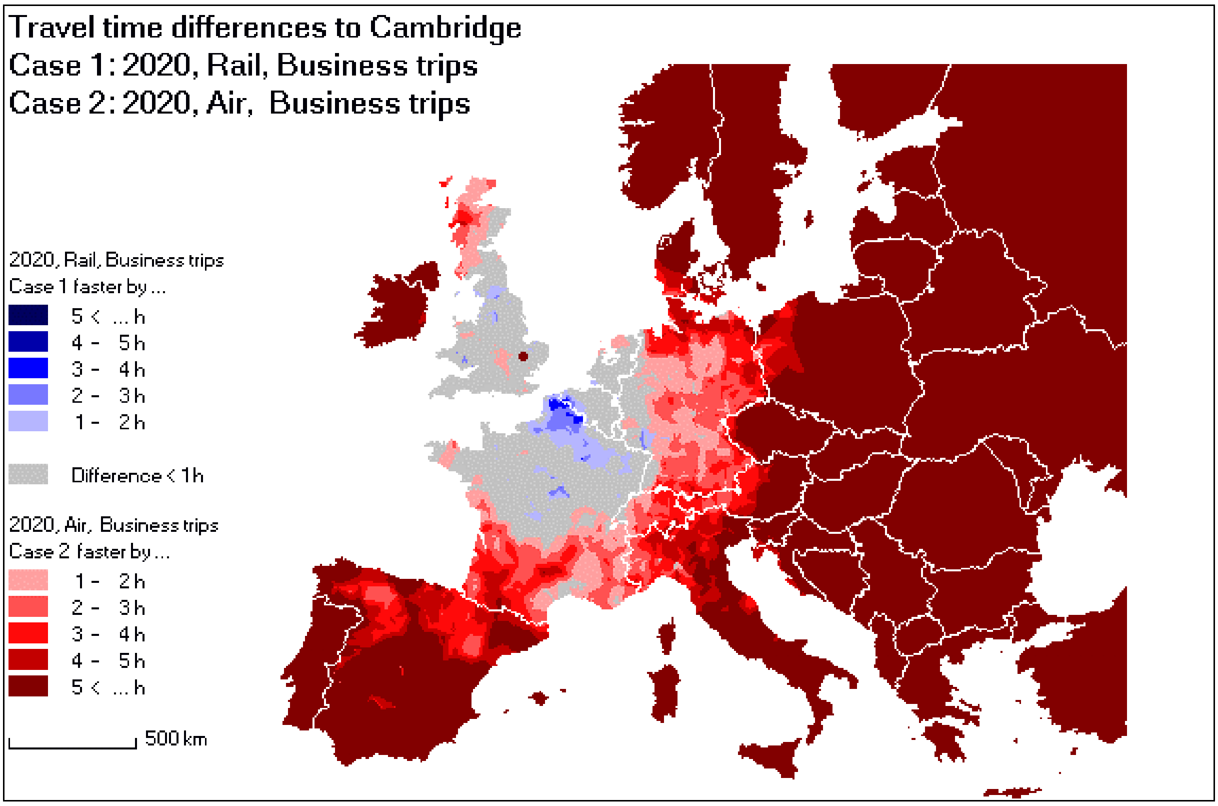


Figure 7.10: Travel time comparison to Cambridge, Rail versus Air - business trips, 2020



8. Conclusions

8.1 Review of the model

The central objective of the STREAMS project was to create a prototype multi-modal strategic transport and transport demand model for the EU, and to use it to produce an initial, demonstration 'Reference Scenario' forecast for EU transport in 2020. The model forecasts of passenger and freight transport demand and changes in modal share over time are reasonable compared to similar smaller scale models over the equivalent time period, or indeed independent modal forecasts, and so the central objective has clearly been achieved.

The considerable research work undertaken during the model development regarding the demand model structure and segmentation in particular, have proved to be a good platform for medium and longer term forecasting. This was a second objective of the STREAMS project. Indeed the successor model to STREAMS, the SCENES European Transport Forecasting model builds very closely on the STREAMS structure, and no fundamental changes to the model structure are envisaged.

It is clear that a model of this nature has however to be used carefully, given its strategic nature. The type of applications to which STREAMS is best suited are those which require an overview forecast of the levels of all transport demand by mode for passenger and freight traffic throughout the EU taken as a whole. At a level beneath this, the model can also provide similar output at the national level – incorporating as it does the key characteristics of the transport system in each member state.

The model is well suited to estimating modal shifts and changes in transport demand associated with transport cost changes in particular. Given the spatial scale of the model, it is less well suited for instance to assessing the effect of a particular piece of infrastructure, unless it is of major strategic importance. In this respect, a strategic model can be no substitute for more detailed local models, in that at this stage of model development, STREAMS does not accurately reflect detailed flows at the individual link level.

The model is also well suited to testing 'demand' scenarios in terms of their effects on the overall level of transport demand. Variations on population, employment and car availability on the passenger side, and production, and growth by sector on the freight side can be tested using the STREAMS model structure. Combinations of these 'demand' and 'transport policy' scenarios can also be run.

The model results of the demonstration 2020 Reference Scenario discussed in Chapter 7, have demonstrated that the main model causal mechanisms are functioning correctly and that the model is sensitive to the main determinants of transport demand. It is of course possible to analyse and present the model results in a far greater level of detail (geographical and sectoral) than has been presented in the STREAMS project. The main focus in STREAMS was however on the model structure and underlying data and as such, the model outputs have not been produced and presented at the micro-level. These issues are explored in the Phase B project, discussed below.

The assumptions which were used for the demonstration Reference Scenario were fairly broad in nature. This is mainly since the purpose of the exercise was to demonstrate the model in forecasting mode rather than to provide definitive forecasts as such. If a model of this nature were to be used in earnest for forecasting (for example for policy analysis and development), more detailed work would be required in terms of specifying the nature of the 'scenarios' to be tested. Assumptions regarding economic growth, changing industrial structure, growth in transport costs by mode, car availability and infrastructure provision are only a few of the factors which can be incorporated in a typical 'scenario' specification. There are many ways in which different facets of policy or the socio-economic environment could be represented in a forecast scenario. In addition, these factors could all be dealt with at a national rather than an EU wide level within the model structure.

8.2 Further development of the model

Given the prototype nature of this 'Phase-A' project, consideration has been given throughout the STREAMS project's duration to areas of possible model development in Phase B (i.e., the SCENES project). The basic design of the model has been seen to handle the main causal mechanisms on the transport demand side well. The fundamental structure of the demand model will not therefore change in SCENES. Instead, a series of carefully considered more detailed model improvements will be implemented, targeted in particular at the potential needs of the policymaker. These cover four main areas, and are additional to the geographical extension of the SCENES model to Central and Eastern Europe (CEE):

- Further development of the multi-modal networks;
- Refinement of the passenger demand model and passenger transport supply data;
- Updating and development of Regional Economic Model (REM) for freight demand, and freight transport supply data; and
- Development and assimilation of freight logistics - the 'Appended Module'.

Each of these main areas of model development work are considered in brief below.

8.2.1 Development of multi-modal networks

The three main areas of development here are:

- 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 'distance band' zones representing short distance trips).

The purpose of the EU road capacity work is firstly, to address the problems of overloading hot-spots identified in particular during the 'Forecasts of EU / TEN-T Transport and Emissions: A Pilot Study' and, secondly, to facilitate a better representation of transport flows on individual strategic network links.

8.2.2 Development of passenger demand model and passenger transport modal supply data

There are several main aspects of this 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 more detailed international tourism trip making characteristics (including external countries) in order to establish international trip rates for use in the model. Some adjustments will be made to the definition of trip types and zonal attractors. On the 'supply' side, better value of time data, car operating cost data, rail and coach tariffs, and local public transport tariffs are all required at the country level.

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

Considerable work will be required to update the STREAMS REM. This will incorporate the use of 1995 official input – output tables for all EU countries, which will replace the updated 1985 tables which covered only part of the EU and were adapted for other countries, used in STREAMS. The volume to value ratios used in the model will also be revised, together with a large number of minor improvements to the freight transport model.

8.2.4 Development and assimilation of freight logistics 'Appended Module'

The aim of the appended module will be to incorporate long term changes in distribution trends to the STREAMS modelling framework.

As a result of these improvements to the STREAMS model, the basis for forecasting at the macro, or EU level will be enhanced. In addition, the greater level of network detail in the model will make it suitable for use at a smaller geographical level.

Appendices

Appendix 1

Conferences, publications, presentations and dissemination

There has been considerable interest in the STREAMS work throughout the duration of the project. Below are some of the main dissemination activities which have been undertaken, both for the STREAMS model, and the additional work involved in the additional 'Forecasts of EU/TEN-T transport and emissions: A pilot study' element of the STREAMS project:

- In July 1998, ME&P presented a paper at the World Conference of Transport Research, in Antwerp, Belgium, entitled – 'Developing an Operational Strategic Transport Model for the European Union'. This forum was chosen to focus dissemination on a wider audience than the Fourth Framework researchers.

- A version of this paper was also presented to the Concerted Action Committee (CAC) on Information Systems in October 1998 in Brussels. STREAMS/SEA/SCENES were presented at this workshop where the focus was on the European Transport Information System. The workshop was attended by representatives from the Member States.

- In the summer of 1998, ME&P presented a paper on the STREAMS model to a conference of European construction industrialists, at the Asphalt '98 conference, Berlin.

- In November 1998, the 'Forecasts of EU/TEN-T transport and emissions: A pilot study' approach was presented to the Member States at meeting of the TEN-T Committee, hosted by the Commission in Brussels.

- A joint seminar was held of the STREAMS, SCENES, and EUROMOSS projects where the results of STREAMS were presented to Commission officials. This took place in Brussels in April 1999.

- The final results of the 'Forecasts of EU/TEN-T transport and emissions: A pilot study', were also presented to a wide range of Commission officials at a seminar in May 1999, in Brussels. The purpose of this seminar was to present the study results and discuss policy implications together with raising awareness amongst senior Commission policy officials of the STREAMS modelling approach.

- In September 1999, ME&P presented a paper entitled 'European Transport Forecasts for 2020: The STREAMS Model Results' to the European Transport Conference – Pan European Transport Policy, Cambridge.

- A version of this paper was subsequently presented at the Transport Research Conference – 'Paving the way for Sustainable Mobility', in Lille, France, November 1999. The results of the 'Forecasts of EU/TEN-T transport and emissions: A pilot study', element of the STREAMS work were also included in this presentation.

- The project co-ordinator has established a web page for the project, linked to the company's website, at http://fpiv.meap.co.uk/fpiv/streams3.htm. During the course of the project various papers and Deliverables have been available for download from this site. Details of the 'Forecasts of EU/TEN-T transport and emissions: A pilot study' extension to STREAMS have also been posted at http://fpiv.meap.co.uk/fpiv/Environ.htm.

In addition to these formal dissemination activities there have been many ad hoc requests for information regarding the model and the results Deliverables. It can be said that the

Deliverable D8 / D10 – 'STREAMS Model Structure and Results' in particular has received a wide circulation.

It is intended that the dissemination of the STREAMS work continues within the remit of its successor project, SCENES. Again there is considerable interest in this work, particularly with the added capability of SCENES to deal with more issues which are of potential interest to policymakers.

Project Deliverables

- D1 – Outline Model Specification, November 1996
- D3 (incorporation D2) – The STREAMS Model, December 1996
- D4 – The STREAMS Pass 1 Model, May 1997
- D5 – Scenario Management Tool, May 1998
- D6 – TEN Strategic Tool, December 1997
- D7 – The STREAMS Research Report, July 1997
- D8 / D10 - STREAMS Model Structure and Results, September 1999
- D9 – STREAMS Presentation Tool, March 2000

Project Deliverables can be obtained directly from ME&P at:

ME&P, 49-51 High Street, Trumpington, Cambridge, CB2 2HZ, UK, or

by email from - admin@meap.co.uk

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