Deliverable D2

SCENES European Transport Forecasting Model Specification

SCENES
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Executive Summary **1**

1. INTRODUCTION **3**

1.1 Overview **3**

1.2 Objectives **3**

1.3 Scope and Focus of European Area Strategic Transport Model **4**

1.4 Deliverable Structure **5**

2. TRANSPORT SUPPLY **7**

2.1 Introduction **7**

2.2 Model Enhancement **7**

2.2.1 Network overloading 7

2.2.2 Non-Road Capacity Issues 8

2.2.3 Other network issues 9

2.2.4 Network loading definitional issues 10

2.2.5 Review of fares / tariffs 12

2.2.6 Country specific value of time 13

2.2.8 Treatment of intra-zonal trips 14

2.3 Central and Eastern Europe Supply Side Specification. **14**

2.3.1 Network specification 14

2.3.2 Calibration and validation data 15

3. PASSENGER DEMAND **16**

3.1 Introduction **16**

3.2. Passenger Demand Model Enhancements **16**

3.2.1 Population segmentation 16

3.2.2 Car ownership 17

3.2.3 Trip rates 17

3.2.4 Model scope 18

3.3 Passenger Demand Model Expansion to CEEC Area **19**

3.3.1 Introduction 19

3.3.2 Demographic and socio-economic data 19

3.3.3 Car ownership 19

3.3.4 Trip rates and distribution 20

3.3.5 Calibration and validation demand model data requirements 20

4. FREIGHT DEMAND 22

4.1 Freight Demand Model Enhancements 22

4.1.1 Introduction 22

4.1.2 Use of revised I/O tables 22

4.1.3 Definition of transport flows 23

4.1.4 Use of volume to value conversion procedures 23

4.1.5 Modelling of intra-zonal freight trips 24

4.1.6 Freight value of time by flow 25

4.1.7 General calibration issues 25

4.2 Freight Demand Model Expansion 25

5. SPATIAL LOGISTICS APPENDED MODULE 27

5.1 Introduction 27

5.2 Appended modules: sub-modules 29

5.2.1 Introduction 29

5.2.2 Reconfiguration module and the use of Logistical Families 31

5.2.3 The chaining module 32

5.2.4 The logistic choice module 35

6. SUMMARY 40

Annex A - Methodology for spreading the assignment across sub-zones 41

Annex B - Air Capacity Issues 47

Annex C – Rail Capacity Issues 61

Executive Summary

The SCENES project builds closely on the work undertaken by the STREAMS and SCENARIOS consortia, which were earlier 4th Framework Transport RTD Programme research projects. These projects were concerned with strategic European level transport modelling, and the development of European transport scenarios respectively. This particular deliverable (D2) is the second deliverable from the SCENES consortium, following on from Deliverable D1 (CEEC Data and Method).

The STREAMS project successfully developed a strategic level model for forecasting transport throughout the EU. This model was subsequently applied within the DGVII Pilot Strategic Environmental Assessment (SEA) project, to provide traffic data as input to emissions software, for a range of European transport scenarios. The STREAMS model can therefore be seen as a successful prototype for the more extensive model to be developed within SCENES known as the 'European Area Strategic Transport Model'. This new model is broader in terms of its geographical scope, and more detailed in its treatment of the EU countries. In particular, the model is extended to cover countries in the CEEC area and includes an 'appended module', which incorporates aspects of freight logistics indirectly within the modelling framework.

This Deliverable therefore has two main objectives. The first is that of a 'taking stock' exercise, regarding the level of model development reached during the STREAMS project. This will take the form of a step-by-step consideration of the STREAMS modelling process, identifying areas of strengths and weakness.

Building upon this, the second purpose is to outline the areas of both model enhancement and expansion, which have already or will be undertaken as part of the SCENES project.

Model enhancement will take the shape of targeted network and more general supply and demand side improvements. In addition, enhancements will take the form of incorporating new sources of data that have become available since the specification of the original model. Other enhancements will involve more detailed treatment of supply and demand issues which were necessarily treated more simply in STREAMS.

Model expansion relates to the extension of the model to cover the bordering and near-neighbour central and eastern European countries. Extending the model to cover these rapidly changing countries presents difficulties with particular reference to the collection of certain types of data, which can often be problematic even among the EU countries. The criteria for the inclusion of countries were that they should either be bordering the existing EU, or be on the 'fast-track' for membership of the EU. The countries included are therefore the Czech Republic, Hungary, Poland, the Slovak Republic, Slovenia, and the three Baltic States - Latvia, Estonia, and Lithuania.

A further element of model enhancement / expansion within SCENES is the development of an 'appended module' which is designed to better reflect freight logistics considerations within the model distribution and assignment phase. The specification of this appended module is also reported in this deliverable.

1. INTRODUCTION

1.1 Overview

The SCENES project builds closely on the work undertaken by the STREAMS and SCENARIOS consortia, which were earlier 4th Framework Transport RTD Programme research projects. These projects were concerned with strategic European level transport modelling, and the development of European transport scenarios respectively. This particular deliverable (D2) is the second deliverable from the SCENES consortium, following on from Deliverable D1 (CEEC Data and Method). Deliverable D1 reported in detail the level and type of transport, socio-economic and economic data available in the central and eastern European countries (CEEC). The data contained in D1 will form a 'reference point' for all the work concerning the CEEC within the SCENES project, i.e., in all three work areas.

The 'Phase A' STREAMS project successfully developed a functioning strategic level model for forecasting transport throughout the EU. This model was subsequently applied within the DGVII Pilot Strategic Environmental Assessment (SEA) project, to provide traffic data as input to emissions software (developed within the COMMUTE project), for a range of European transport scenarios. The STREAMS model can therefore be seen as a successful prototype for the more extensive 'Phase B' model to be developed within SCENES known as the 'European Area Strategic Transport Model'. This new model is broader in terms of its geographical scope, and more detailed in its treatment of the EU countries. In particular, the model is extended to cover countries in the CEEC area and includes an 'appended module', which incorporates aspects of freight logistics indirectly within the modelling framework.

1.2 Objectives

Deliverable D2 therefore has two main objectives. The first is that of a 'taking stock' exercise, regarding the level of model development reached during the STREAMS project. This will take the form of a step-by-step consideration of the STREAMS modelling process, identifying areas of strengths and weakness.

Building upon this, the second purpose is to outline the areas of both model enhancement and expansion, which has already or will be undertaken as part of the SCENES project.

Firstly, the model enhancement will take the shape of both 'targeting' certain geographical areas for supply side improvements, and also introducing more general demand and supply side improvements, which will apply across the whole study area. In addition, enhancements will take the form of incorporating new sources of data which have become available since the specification of the original model, such as the publication of the latest UN / ECE 1995 Census of Motor Traffic on Arterial Routes. Other enhancements will involve more detailed treatment of supply and demand issues which were necessarily treated more simply in STREAMS.

Secondly, model expansion relates to the extension of the model to cover the bordering and near-neighbour central and eastern European countries. Extending the model to cover these rapidly changing countries presents difficulties with particular reference to the collection of certain types of data, which can often be problematic even among the EU countries.

A further element of model enhancement / expansion within SCENES is the development of an 'appended module' which is designed to better reflect freight logistics considerations within the model distribution and assignment phase. The specification of this appended module is also reported in this deliverable.

Although presented above as two objectives, in the following chapters they are treated together, with areas of model improvement being presented alongside identified areas of model weakness.

1.3 Scope and Focus of European Area Strategic Transport Model

The current STREAMS model treats all EU15 country zones as being 'internal' to the model – that is trips to, from, and between these zones are included in the scope of the model. Central and eastern European counties, in addition to non EU countries such as Switzerland and Norway, and the rest of the world are treated as 'external' to the model – that is only trips between the internal zones and the external zones are modelled. Trips between external zones are not modelled. Furthermore, for the passenger model in STREAMS, trips to and from external zones were excluded. Freight traffic between the internal zones and the rest of the world was however included.

In SCENES, a principal objective is the expansion of the model to central and eastern Europe. The criterion for the inclusion of countries were that they should either be bordering the existing EU, or be on the 'fast-track' for membership of the EU. Thus some of the STREAMS external zones will become internal to the SCENES. The model design will incorporate the countries shown below as being internal to the model. Also shown here are the number of zones in each country together with the zone name and zone centroid shown in parenthesis:

- **Czech Republic**, 8 zones, Praha, (Praha), Stredocesk_, (Kladno), Jihocesk_, (Ceske Budejovice), Zapadocesk_, (Plzen), Severocesk_, (Ústí nad Labem), V_chodocesk_, (Hradec Králové), Jihomoravsk_, (Brno), Severomoravsk_, (Ostrava)
- **Estonia**, 1 zone, (Tallin)
- **Hungary**, 7 zones, Kozep-Magyarország, (Budapest), Kozep-Dunantul, (Székesfehérvár), Nyugat-Dunantul, (Szombathely), Del-Dunantul, (Pécs), Eszak-Magyarország, (Miskolc), Eszak-Alfold, (Debrecen), Del-Alfold, (Szeged)
- **Latvia**, 1 zone, (Riga)
- **Lithuania**, 1 zone, (Villnius)
- **Poland**, 16 zones, Zachodniopomorskie, (Szczecin), Pomorskie, (Gdansk) Warminsko-Mazurskie, (Olsztyn), Kujawsko-Pomorskie, (Torun), Mazowieckie,

(Warszawa), Podlaskie, (Bialystok), Lubuskie, (Gorzów Wielkopolski), Wielkopolskie, (Poznan), Lodzkie, (Lódz), Lubelskie, (Lublin), Dolnoslaskie, (Wroclaw), Opolskie, (Opole), Slaskie, (Katowice), Swietokrzyskie, (Kielce), Malopolskie, (Kraków), Podkarpackie, (Rzeszów).

- **Slovakia**, 4 zones, Bratislavsk_, (Bratislava), Západne Slovensko, (Nitra), Stredne Slovensko, (Banská Bystrica), V_chodne Slovensko, (Kosice)
- **Slovenia**, 1 zone, **(**Ljubljana)

The remaining external zones within the STREAMS model design which are not affected by 'internalisation' will be carried forward into SCENES. The zoning system in the EU countries (NUTS2) will remain the same.

There is also a persuasive case for changing the base year from 1994 in the expanded SCENES model. By the conclusion of the project (Spring, 2000) the base year of 1994 will seem a long way back. Data permitting, there will be some benefit in at least moving to 1995 and perhaps even 1996. Given the lag-time in the publication of data, it is unlikely that any year after 1996 could be implemented. Eurostat data for population and car ownership have already been obtained for 1995.

Turning to the focus of the model, in STREAMS, much of the time was spent defining a rational and workable model structure for modelling at the very large strategic scale demanded by the project, particularly in the context of modelling passenger demand. Also, the inclusion of all trips within the model meant that a lot of time was spent developing methods to 'control' the very large number of short distance, intra-zonal trips. As a result of this, more time was spent looking at aggregate transport demand indicators by mode (generally by country) than at particular links or matrix type information, for model validation and calibration. As suggested above, the aggregate results produced by this detailed model structure were encouraging.

The focus of the SCENES Transport Forecasting Model will therefore perhaps be subtly shifted compared to that of the STREAMS model. Accepting the broad model structure put in place by STREAMS as being complete, and given that the levels of aggregate transport demand are broadly correct, more time can be spent looking at the characteristics of the longer distance trips in particular. More data will be collected relating to international movements, other matrix data, and tourism / business trip type information. Also, individual network links of strategic importance (and ideally where local traffic is minimal) will be monitored in terms of the model output to a much greater degree.

1.4 Deliverable Structure

The structure of this deliverable is to consider each of the elements of the model in turn: namely transport supply, passenger demand, and freight demand. Each of these elements has a chapter given over to it and within this chapter, strengths / weaknesses, enhancements to the model and the methodological approach to expanding the model to cover the CEEC area will be discussed. Some data issues are also touched upon in relation to the EU and CEEC countries, although detailed CEEC data issues are dealt with in Deliverable D1.

A separate chapter is then devoted to the specification of the freight logistics appended module. This is covered in some detail as the contents are entirely new in the context of STREAMS / SCENES.

2. TRANSPORT SUPPLY

2.1 Introduction

The supply side of the model can be thought to comprise the physical transport infrastructure and the charges faced by both passengers and the users of freight services. Included in consideration of the supply side is the use of 'distance band' zones to represent intra-zonal trips of different average distances.

The main strength of the STREAMS supply side specification was its comprehensive nature and its innovative treatment of the large numbers of intra-zonal trips. It is comprehensive in terms of both the modes covered (all modes) and the tariffs / fares applying to each mode (both fares / tariffs paid, and operating costs encountered). The inter-modal connections within the network structure are also extensively represented. Base year network link characteristics such as link standard (e.g., motorway / dual carriageway, conventional / high speed), speed, length etc., are also represented in detail. Also, a detailed set of all-day speed – flow relationships were developed (by road type) in order to reflect the gradual reduction in average daily speed associated with increasing traffic flows. The STREAMS network specifications thus proved a good tool for ensuring that zone to zone travel costs and times were broadly correct, principally for the purposes of propensity to travel and modal split calculations within the model. In STREAMS this was the main philosophical reason behind designing the networks in this way.

2.2 Model Enhancement

The main areas requiring development fall into three main categories – level of network detail, non-road capacity issues, and further development of costs / tariffs. The first of these areas, level of network detail, has been shown as a key area of model enhancement, particularly in the light of the Pilot SEA project where the emphasis was as much on link flows as overall aggregate results. Each of these three areas are discussed below.

2.2.1 Network overloading

Network overloading is a particular problem in areas of the model where the NUTS2 classification of zones leads to many small, densely packed zones. In these areas, such as the Benelux countries, many more of the total trips 'spill' out from the 'distance band' intra-zonal zones to the real modelled network and neighbouring zone centroids (since fewer of the distance band zones are attached in geographically small zones). This leads to overloading on the connecting links between adjacent zones and can occur for road and rail traffic. It is of importance for policy-orientated uses of the model in particular, that network overloading is minimised so measures to alleviate this situation are proposed in SCENES.

Overloading of the network of this nature was reduced with the introduction of the NUTS3 sub-zoning road assignment process, which formed an early part of the SCENES work. This procedure effectively increased the distribution of loading points on the network by using NUTS3 centroids and 'spread' the traffic to a greater degree across the network. This 'spread' is based on population and economic data at the NUTS3 level. Other approaches such as adjusting the internal STREAMS model 'spread' parameter to increase the number of routes taken between any two zone centroids have also been employed.

Despite these approaches taken during STREAMS, the Pilot SEA project still showed areas of significant network overloading. In order to address this, the following three measures will be taken in SCENES:

- Review the road network with a view to adding network detail in areas of dense zoning and other 'hotspots',
- adjust the number of attached distance band zones in areas where too many trips may be spilling onto the inter-zonal network, and
- introduce the NUTS3 sub-zone assignment procedure for the rail mode.

Road capacity is explicitly coded onto the network links as touched on above. In SCENES, as part of the network overloading review, the following additional steps will be taken:

- review road link capacity characteristics – some of the capacity characteristics (i.e., number of lanes) found from the data sources used (generally the IRF road database) were incorrect when checked for countries 'known' to the consortium members. Given the greater geographical coverage of the SCENES consortium a more extensive check can be made by the consortium, and,
- review general connectivity options for other modes in the model, such as shipping and the location of ports. Also, further ports will be added to lessen the concentration of traffic to too few ports which can distort freight flows in particular.

2.2.2 Non-Road Capacity Issues

A further main area of model enhancement outlined above relates to non-road modes capacity issues. In the STREAMS model, there are no capacity limits coded onto the rail, air and inland waterway networks, or indeed for the 'nodal' centres such as airports and seaports. There were good reasons for taking this approach in STREAMS, principally the simplifying assumption that capacity is not as significant an issue for these modes compared to the road modes. Indeed for some modes and at many sections of network in reality, capacity is not a restricting influence on the level of traffic found on a particular route or link, so within STREAMS it was considered a low priority issue.

In line with the capacity and network loading issues raised in 2.2.1 above, there may be a need to impose some simplified representation of capacity on these other modes, perhaps as a representation of known bottlenecks. Also, in STREAMS, the assumption for forecasting with the non-road modes was that all demand would be met by the operators of these modes. When forecasting as far ahead as 2020 however, this pure demand forecast may not be appropriate, given that railways and ultimately airports / air traffic control systems will have a finite capacity. In SCENES, the following capacity enhancements will be explored:

- consideration will be given to the coding of simple upper 'cap' type capacities to prevent extreme loading on rail links, based a review of track standards across the networks and published material regarding bottlenecks and typical track capacities,
- consideration will also be given to the coding of simple upper 'cap' type capacities for air terminals, by zone. This will again prevent extreme throughput of air passenger, particularly at the congested major hubs. In this way, passengers may be pushed out to the regional airports, reflecting the observed trends in air travel with low cost carriers. Other regional airports will be included in the network for 2020 where necessary, together with a greater connectivity between airports,
- these capacity 'caps' are implemented within the model software using a 'difficulty' function, a modelling construct designed for this purpose,
- the current STREAMS model outputs for sea and inland waterway port traffic will be compared to observed throughputs. If flows at certain ports are well in excess of the observed, a similar simple cap may be imposed. This is assumed to be an issues of lesser importance as there is less evidence of port capacity acting as a constraint on traffic, other than as a relatively short term effect.

Of greater significance for sea ports and inland waterway ports is the quality of the facilities and speed of turnaround etc. As suggested above, the capability to model this type of characteristic is contained in the STREAMS model network coding. There is however a need to distinguish to a greater extent the 'quality' of each of the port sites individually, and between different types of goods being moved. Therefore in SCENES:

- a review of inter-modal connections will be undertaken, in terms of capacity and other 'quality of service' characteristics, with a view to having a greater distinction between different inter-modal connections. There are many FPIV projects which have touched upon inter-modal networks and their experience could be drawn upon here.

2.2.3 Other network issues

There will be some other network orientated model enhancements as part of a general review process such as:

- better representation of rail speeds with particular regard to connectivity issues and times over longer distances. Rail trips which incorporate transfers could be better represented within the network structure, by re-coding the main rail terminals and incorporating a transfer link coded with explicit 'transfer' times. In this way the delay whilst waiting on connections could be better represented,
- shipping and inland waterway link speeds will be reviewed in the light of new data,

- greater use should be made of maritime passenger data, e.g., the Shippax material – the representation of the ferry network will be re-examined,
- greater use will be made of the available rail network flow data, which has been obtained from various reports, although this data is limited and often restricted by being expressed in 'trains' rather than 'persons / tonnes', and
- the number of freight sea ports will be increased.

There will be a more detailed treatment of the increasingly important shuttle train services for rail freight, which are currently coded with faster speeds than conventional rail freight. The most important other feature of these services is that they operate to a schedule. It would be useful to differentiate these scheduled serviced from conventional unitised rail services (where delays are much greater) by the use of 'transit line' style coding. In this way, each scheduled freight service is coded by its time-tabled characteristics. Therefore, the following issue will be examined:

- is it feasible in terms of time, resources and practicality to re-code scheduled freight services as 'transit line' style services?

Enhancements will also be made to the specification of the future year transport networks' characteristics. In particular, during the STREAMS project, the Commission produced a report on the likely future standard of the Trans European Networks ('Trans-European Transport Network – Report on the Implementation of the Guidelines'), based on network data received from the member states. This report gives more details on the standards of planned new and upgraded infrastructure together with the planned timing and level of implementation. This will imply a network which is less comprehensive than the all TEN network which was used in STREAMS. Therefore:

- the 2020 road and rail networks will be updated based on the Commission TENS status report and the incorporation of the 14 TEN Priority Projects.

2.2.4 Network loading definitional issues

As suggested in Chapter 1, the focus of the transport modelling in SCENES will be subtly shifted with a greater emphasis on calibrating / validating the model against more disaggregate data. As part of this, there will be a greater need to examine individual link flows, and this gives rise to a number of issues with specific reference to road links.

The first point is that the STREAMS road links are generally long, and will encompass a range of different flow levels along their length, typically increasing as large urban areas are approached. In STREAMS count data used in the model related to different points on links, given the limitations of data and the range of sources used. In SCENES, an explicit philosophical definition of 'link flow' is therefore required, given the greater priority being attached to link loading. Once defined, the nature of the modelled 'link flow' can be explicitly stated.

The second issue is the current methodology for dealing with intra-zonal traffic on inter-zonal road links, i.e., representing the (substantial) 'real world' effect of local traffic on inter-regional roads. The methodology used in STREAMS was to subtract a modelled link flow from the observed load on a link, and code it onto the link as an exogenous load (representing the local traffic element of total flow on the link). The flow on any particular road link is therefore a combination of exogenous load and modelled load. This exogenous load was increased in the forecast year in line with the growth in modelled intra-zonal trips.

There are a number of points which mean that this process should be refined for SCENES. The first point is that it depends upon where the 'observed' count has been taken on the link in question – often this is not known. The second point is the philosophical definition of which flow on the link is being represented. These issues are expanded upon below.

In summary the approach used in STREAMS is fundamentally sound, but requires some definitional clarification for application in SCENES. There seem to be a number of options to clarify the position:

- Work only with pure inter-zonal flows. This would have implications for both the flows which are reported on the links and the speed – flow relationships used. The advantage would be clarity of presentation and interpretation, the disadvantage being that the modelled link flow data could only match the observed in the very few places on the network where local trips are negligible,
- Continue with the current approach. There are two issues here – consistency and accuracy. The current approach is perhaps not consistent enough in that the 'observed' data set is not complete and the specific location of counts on the links is not known / specified. Arguably it is accurate in places, in that where the modelled inter-zonal flow is less than the 'observed' then an additional value is coded to make the total link flow the same as the coded 'observed'. In many other cases within STREAMS however, the modelled flow is greater than the 'observed' so no adjustment is made (although this problem should be reduced with the use of additional network detail at network 'hot-spots').
- Adapt the current approach. The current approach could be adapted to conform to a tighter definition. The clearest would be to say we are representing flows on links in terms of the flows at crossing points at zone boundaries. In this way we could say we are showing inter-regional flows as observed at NUTS2 zone boundaries, which would be a clear way forward given the nature of the model.

The latter approach is probably preferable. Following this latter approach, a good observed data set, such as the '1995 UN Census of Motor Traffic on Main International Traffic Arteries'[1], could be used as a base (supplemented with national data where necessary / available) to pick off the observed flows on the roads at the approximate

[1] The UN Census for 1995 has been obtained in 'test' form in an electronic format.

crossing points on boundaries between zones. These values could then be used as a de-facto maximum 'cap' for the assignment in the base year, for the true inter-zonals. Given that the UN Census includes the main international and strategic links, the other inter-zonal links in any locale not covered by UN are unlikely to have a greater flow in most cases than on the main route, so the 'cap' could be used as a guideline for surrounding routes. [This process would not however be included within the model mechanism].

At this end point, (once all links are loaded to a realistic level) the exogenous load could be re-calculated (observed minus modelled), so that the base year modelled link flow value is near to the true 'observed' values at the zone boundary across the whole link. This could be done at the end of the process in the same manner as is currently the case. The exogenous load would therefore represent short distance traffic on the network links at the crossing points between zones.

There is certainly a need in SCENES to clearly define exactly which flows are being represented on links. This point was emphasised in the Pilot SEA project where much more attention was paid to link flow information. Given the time available in SCENES and a degree of patience, there is no reason why a set of base year link flows bearing a good resemblance to e.g., the UN Census data cannot be achieved. This would have the added benefit of making the model much more attractive for policy use.

These link flow representation issues do not affect the aggregate statistics for person and vehicle kilometres however as these are already modelled through a combination of the dummy zone network and the real network. The aggregate statistics are therefore not affected because the exogenous loads are not added into the aggregate transport results – they only manifest themselves if looking at individual link flows.

2.2.5 Review of fares / tariffs

As discussed above the STREAMS model incorporates travel fares, tariffs and operating cost functions for all modes for passengers and freight within the model. Some of these functions were necessarily simplified due to the plethora of ticket types available in particular for rail and air passenger modes. The functions used in STREAMS came from a wide range of sources. The costs paid by users of freight services are also difficult to specify consistently in a functional form. Therefore the following actions will be taken:

- re-define passenger coach and rail cost functions based on a more consistent and detailed data set. The data contained in the 'Lonely Planet' and other similar travel guides (usually country specific) is ideal for some countries for the specification of simple and consistent functions for rail and coach fares. However, these guides do not follow the same format for all countries so will be supplemented by Internet based data (e.g., most countries' rail services are now given in detail on websites, and some of these contain fare data),
- re-define passenger air fare functions. A wider literature search for consistent air fares is required,

- revise freight cost functions in consultation with other SCENES partners, e.g., NEA, and,
- new cost functions will be developed specifically for long distance truck trips, based on a non-linear formulation.

2.2.6 Country specific value of time

One of the main outcomes of the STREAMS work was the requirement to allow greater flexibility in the internal modelling parameters with regard to dealing with country specific characteristics. The greatest need is to be able to adjust the values of time which are applied to each country – the STREAMS model worked on a universal value of time in combination with other indirect measures to represent national differences. The ability to specify country specific values of time is of particular relevance to the modal split calculations within the model, and would allow greater differentiation between the behavioural characteristics of relatively poor and rich countries. This is now a greater requirement given the inclusion of the CEEC area where the transport infrastructure and economic situations are very different from those found in the EU.

Indeed it can be argued that this model enhancement is essential from a philosophical viewpoint given that the supply side characteristics, i.e., the tariffs, operating costs and fares reflect the national differences. For example, German rail fares are more expensive than Greek fares in the model, yet there is currently no only an indirect capability to differentiate the ability to pay (based on national levels of car availability). As suggested above, when dealing with EU countries this set up (universal value of time) can be made to work – for the more diverse situation across the CEEC area however, it would be a far less attractive option.

There are probably two options to address this problem. The first option involves some considerable software changes being implemented by ME&P – these would allow specific values of time (proxies of national income levels) to be attached to different groups of zones, in this case countries, groups of countries or perhaps even certain zones (metropolitan areas for example). The second option, which would be quicker to implement in the short term as it would not require programming work, would be to establish additional journey purposes within the model set-up, e.g., shopping trips in poorer countries and shopping trips in richer countries. These would then use different modes, i.e., car in richer countries and car in poorer countries. In this way, different values of time and distribution parameters could be applied. However, this approach would be inelegant and somewhat cumbersome, and would also add significantly to the dimensional structure of the model set up. It would also be a very ‘short-term’ solution to this long-standing issue.

It is therefore concluded that without the software changes, it is likely to prove very difficult to get a model of the EU and CEEC area to function in an acceptable behavioural manner. Therefore:

- internal software changes to allow greater specification of country specific factors will be implemented.

2.2.8 Treatment of intra-zonal trips

The methodology for the treatment of passenger intra-zonal trips in SCENES will not change fundamentally from STREAMS. The main enhancement could come in the form of a greater categorisation of zones types, increasing from the current six zone types. This would allow a greater flexibility for the treatment of intra-zonal trips' characteristics, i.e., speed and modal availability. Within the context of a general model 'audit', the modal split characteristics of all 200 zones (plus the CEEC area zones) will be examined in greater detail than was possible within STREAMS, and adjustments made accordingly. Greatest attention within this 'audit' would be given to the zones which include a large population (some zones comprise 5 million persons or more).

A further aspect of the zone classification which could be examined is the level of urbanisation within each zone. This could then be related to the average traffic speeds in each individual zone type in some simple fashion. This issue was raised firstly in the context of the Pilot SEA project, where intra-zonal traffic speeds are an important factor. The level of urbanisation would be a good guide towards the typical speeds for each zone. It would also help determine the proportion of 'urban' as opposed to 'intra-zonal' trips – again this would have been a useful distinction to make within the Pilot SEA project when considering traffic emissions.

This methodology for the treatment of intrazonal passenger trips will also be adapted and extended to the freight sector (see Section 4.1.5).

2.3 Central and Eastern Europe Supply Side Specification.

2.3.1 Network specification

The specification of transport networks for the CEEC countries requires a similar set of characteristics to be defined as to those for the EU. Given the lack of a 'base' network for CEEC of the type which was available for the EU (i.e., the TEN-T networks) the national hierarchies need to be used to a greater extent for defining the road networks. Defining the links to be included in the rail networks is also less clear than was the case for the EU. The local knowledge of the CEEC consortium members is therefore used to identify a correct core network for both the road and rail networks, taking into account the zoning system in each case to ensure that the main inter-regional links are included. There will also be a requirement for input on the basic characteristics such as road standards and number of lanes. The inland waterway network will be specified using the same source maps as for the EU, in addition to the data contained in D1. The main air connections will also be specified using the ICAO survey material used in defining the EU air network.

Perhaps more difficult is the specification of the network characteristics. There is a need to ensure that the different network characteristics, in terms of standard of physical infrastructure, traffic composition (e.g., the presence of slow, ageing trucks) and service provision, are reflected in the specification. This will involve particular consideration of free-flow road speeds and rail link speeds. A further requirement is the specification of airports, seaports, inter-modal terminals, inland waterway ports, product pipelines and also border delays which are likely to be a much more significant factor (particularly although not exclusively for freight traffic).

The final aspect of CEEC supply specification is the development of passenger public transport fares and car operating cost functions, and freight tariffs functions for ship / barge / rail together with truck operating costs. Some public transport tariffs and fuel costs in all countries are reported in Deliverable D1.

The specification of 2020 forecast year passenger and freight networks required data to be collected by the CEEC partners regarding the national plans of the newly included countries, and this is also documented in Deliverable D1. Detailed data is available for Poland regarding road and rail network plans for 2015. A smaller and less detailed amount of infrastructure planning data is available for Czech Republic, Hungary and Slovakia. There are also network data which may be made available via the TINA programme, subject to its availability.

2.3.2 Calibration and validation data

The main requirements in this case are for CEEC traffic flow data on the defined strategic network for road and rail modes. Other data for example airport and seaport throughput and freight flows on inland waterways are also ideally required.

Again, Poland is well covered on the main links for road and rail modes, are the Baltic States. For the other countries the UN 1995 Census provides the observed data (together with the proportion of HGVs) at a reasonable level of detail for the road modes. Observed flow data for other modes and countries appears to be far less comprehensive.

The other main calibration issue for the CEEC networks is minimum path calculations, and typical city to city journey distances and costs. The same publications which were used to validate the STREAMS EU networks (for city pair travel times and distances) will be consulted for their coverage of the CEEC area.

Minimum path plots for road and rail modes will be checked for validity with the CEEC partners.

3. PASSENGER DEMAND

3.1 Introduction

It was remarked in STREAMS Deliverable D8/D10 that the basic structure of the passenger demand element of the SCENES model would not change significantly from the STREAMS methodology. There are however areas in which the passenger demand model could be enhanced, and these are mainly centred upon some of the necessary simplifying assumptions, which had to be made in STREAMS. Many of the detailed structural assumptions regarding the population segmentation in STREAMS were through necessity initially derived from UK sources. During STREAMS it was possible to make various checks on the applicability of using these structures in other EU countries, for instance in the field of trip rates.

Some of these assumptions can be re-visited in SCENES and tested in the light of their application to the CEEC area.

3.2. Passenger Demand Model Enhancements

3.2.1 Population segmentation

The highly segmented approach used in STREAMS, which splits each zone's population into 20 sub-group based on age, employment and car availability was a strength of the modelling approach. This segmentation was used as a basis for generating trips in STREAMS, and is repeated below.

Age and employment disaggregation:

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

Each of these (P1 to P5) were further disaggregated as follows for car availability:

- persons living in a household with 1 or more adults and no car (C1),
- persons living in a household with 2 or more adults and 1 car (C2),
- persons living in a household with 1 adult and 1 or more cars (C3), and
- persons living in a household with 2 or more adults and 2 or more cars (C4).

Using readily available data and relatively few assumptions, it was possible to specify P1 to P5 for 1994 at the NUTS2 level for all EU countries. Of more difficulty was the disaggregation of P1 to P5, into C1 to C4. UK Census based data were used in the first instance in conjunction with a logit based choice function and a zonal car stock constraint to estimate the C1 to C4 split for each zone. The main requirement within SCENES is to ensure that this methodology can equally be applied to the CEEC area. Ideally, some comparable census data should be obtained from another EU or CEE country, and compared with the C1 to C4 / P1 to P5 split found in the UK. This may prove difficult to obtain however given the detailed nature of the data requirement. An alternative is to carry on with the current methodology and have a close look at the model output for a wide range of zones, particularly in the CEEC context, to ensure that a plausible segmentation is being achieved.

Similar considerations apply to zonal population characteristics for the 2020 forecast year. A simplifying assumption was made in STREAMS starting from the national growth rates for P1 to P5 segments which were established from Eurostat and other sources. These national growth rates were applied uniformly to all zones, i.e., there was no regional variation in growth rates within a country. This assumption could be revised in SCENES using perhaps some of the SCENARIOS / SCENES material on regional clustering, or using projections from other sources.

3.2.2 Car ownership

A generalised car ownership forecasting process was developed in STREAMS based on 'official' forecasts for four countries, Finland, UK, France, and Germany. A linear relationship was developed where countries starting from a lower base of car ownership accelerated towards an EU 'converged' level faster than countries with a higher initial car ownership. This process will be reviewed in the light of the very low levels of car ownership expected for the CEEC. The feasibility of developing a simple 'S' shaped trend relationship towards saturation (e.g., Gompertz style function) will be examined in this context. In this way differential growth rates at the zonal level would be inferred, as each zone would start from a different point on the curve. This methodology would also be applied in the EU context, where in STREAMS, all zones in a given country were allowed to grow at the same rate in terms of vehicle stock. Other IV Framework projects such as MEET have also produced car ownership projections – these will also be consulted in this context.

Historical trends for the EU countries will be used to develop a relationship for the likely future year increases in CEEC as their economies expand.

3.2.3 Trip rates

Passenger trip rates are the foundation of the passenger transport demand model. Within STREAMS, all available EU member states' national travel surveys (NTS) were obtained and analysed – namely Denmark, France, Sweden, Finland, UK, the Netherlands, and Germany. It was not possible to incorporate the published figures from these NTS within STREAMS directly because the level of disaggregation required by the model was much too great compared to than that found in the published material. Instead, the rates which were used in STREAMS were derived from very detailed unpublished UK NTS data, obtained by the consortium by special request.

From this data source it was possible to obtain trip rates for the 20 population segments discussed above (i.e., P1 to P5, split by C1 to C4), and the nine trip purposes defined within the project (U1 to U9[2]). These rates were initially applied throughout the EU in the model. In this way, the overall trip rates (all trips per person per year) which were inferred by the use of UK figures could be established for each of the EU countries. This figure was then compared against either the relevant overall figure from the published NTS for countries where this was available, or the general range of values expected from other countries' NTS. Where these figures looked out of line all the trip rates applying in the relevant country were adjusted in proportion e.g., increased or decreased by 10%. However, the relative proportion of trips by purpose and population group were held at the UK NTS level in the absence of any viable alternative course of action, or evidence to suggest that such an assumption was overly misrepresentative.

Within SCENES, the model will be enhanced by obtaining further NTS data relating to countries for which data was not obtained in STREAMS (which has either now become available or relates to sub-national areas). Also some trip rate data will be collected for large urban or regional studies for countries where no national figures are available. However, it is unlikely that any new data will be obtained which would allow changes to be made to the relative proportions of the trip rates by purpose and population segment on a consistent and systematic basis. The best use will however be made of the available data to compare this relative split with the UK where possible. In the light of this, it may be possible to make some minor adjustments.

More data will also be sought with respect to longer distance and international business trips. Business trips which comprise an overnight stay are included within the WTO 'tourism' trips definition, so are known to some extent. Same day trips however do not appear in these statistics. There may be some value in re-specifying business trips within the model to treat international and domestic trips as different trip purposes. Alternatively, same day and overnight stay business trips could be treated as different journey purposes. Either of these distinctions would help particularly in modal split although care is required since the relationship between the two will be affected by supply side characteristics. These distinctions are also of particular relevance in international travel, and also in terms of untangling the published statistical data.

A further trip rate related factor refers to the specification of tourism trip rates. This is expanded upon in the next section.

3.2.4 Model scope

It was pointed out in the introduction that the STREAMS passenger model element was restricted to movement within and between EU countries. This will be expanded to

[2] The purposes are as follows: commuting & business – short [U1], shopping, personal business and education – short [U2], visiting friends and relatives, entertainment and day trip – short [U3], visiting friends and relatives, entertainment – long [U4], day trip, shopping, personal business and education – long [U5], business & commuting – long [U6], domestic holiday [U7], inclusive international holiday [U8], and, other international holiday [U9].

include traffic to and from the rest of the World within SCENES. By necessity, trips to and from the CEEC area will be included in any case.

The inclusion of trips to / from the rest of the World has particular relevance for tourism trips. Country specific tourism trip rates for EU residents were established from tourism data obtained from the World Tourism Organisation (WTO) and a Euro-Barometer survey of holiday making characteristics by EU country. These rates will require revision in SCENES as trips to non-EU countries will now be included, thus altering the actual number of trips and therefore the trip rates specified within the model.

WTO published data should be of sufficient detail to specify the trips to / from the rest of the World given that these external zones are based on a continental spatial scale.

3.3 Passenger Demand Model Expansion to CEEC Area

3.3.1 Introduction

As previously suggested the passenger demand model design will not change fundamentally for the modelling of the CEEC area. The major obstacles are in this case all data related – most notably the absence of any official National Travel Survey type data, and poor calibration / validation data. The main areas of model development are considered below.

3.3.2 Demographic and socio-economic data

The most promising area for obtaining good data for the modelling of the CEEC area is demographic data. Sufficient data looks to be available to estimate the P1, (P2 / P3 / P4) combined and P5 population groups for the base year at the zonal level. There will be some fringe difficulties attached to this however. In some cases for example, the level of disaggregation between published data and model zones is different due to the re-drawing of administrative boundaries. In other instances, only national level data is likely to be available. Splitting the P2 / P3 / P4 groups will be more difficult however, since no single data set (using consistent definitions) has so far been established.

Methodologies will have to be developed to estimate these demographic and socio-economic model inputs (at the zonal level) where necessary. Assumptions of this nature can be checked with CEEC / Nordic partners for general plausibility.

External sources will be used to provide population forecasts (segmented as far as possible).

3.3.3 Car ownership

Zonal car stock data is required to establish the C1 to C4 disaggregation of the P1 to P5 groups discussed above. Looking at the currently available car stock figures, zonal level data should be available in Poland and Hungary – the situation for other countries is less clear. A further factor to be considered in the model specification is the age and condition of the car fleet. Initial data would suggest that the average CEEC area car covers a significantly lesser annual mileage than its western European counterpart. In combination with the older fleet and poorer infrastructure, these factors will all have a limiting effect on the propensity to travel, which will have to be reflected in the model parameters.

Limited forecasts of car ownership appear to be available. The methodology discussed above in Section 3.2.2 will therefore be employed to determine future year levels of car stock and thus availability for the project.

3.3.4 Trip rates and distribution

As pointed out above, the lack of any comprehensive NTS data for any part of the CEEC area means that there will be an element of judgement involved in setting up this part of the demand model. There is some survey information available for Poland – however this applies to longer trips, and looks to exclude slow mode trips. The data will though, be of some use in the calibration of the longer trips, although it applies only to trips defined as 'tourism' trips by the World Tourism Organisation (i.e., trips that involve at least one overnight). There is also some partial data of this nature available for Hungary.

There may also be some regional or larger urban studies which have involved the collection of 'travel diary' style data within the CEEC. The Phare office and other relevant organisations could be contacted to investigate this further. Also CEEC partners will be asked if they know of any such studies.

The method which will be used initially will be to specify the trip rates as for the original UK rates, and see what the resulting implied overall trip rate is for each country. These rates should be low since the levels of car availability will be low. If this figure is still high, then the actual rates will be adjusted down, on a country by country basis, perhaps also altering the proportional trip rates between groups.

It is at this point that the capability to specify other country specific factors looks to be essential in the model. A parameter within the model adjusts the propensity to travel, i.e., the 'spread' of trips, and thus the average trip distance associated with that journey purpose. Given the large differences in person kilometres travelled per year in the CEEC compared to the EU, there is a need for this parameter to take on a different value from the EU for the CEEC area. The poor quality of the infrastructure (reflected in journey times and hence disutility) will promote this effect to some extent but is unlikely to be sufficiently strong to achieve the necessary effect, so some calibration of the model parameters will be required.

3.3.5 Calibration and validation demand model data requirements

Passenger model validation data will also be very partial for the CEEC area. Key parameters such as person kilometres travelled by mode, average journey distance by mode (incorporating all trips, including walk and slow mode) and modal split by distance are unlikely to be available in their entirety for all or indeed any of the newly included countries. The least reliable data is likely to concern the private car. The data for the public transport modes is more widely available, especially rail and bus. In particular, the rail and bus person-kilometre data looks to be available for all countries. Other data, such as the distribution of trips by distance and average trip distance by mode is likely to be elusive.

The lack of NTS data is also a major handicap as this type of study is the best source of observed modal split data disaggregated by type of journey and person type. The lack of any data of this type is problematic.

Matrix data is also valuable in the model calibration. There is no data of this type however for the CEEC area, although good matrix data is rare even in the EU countries. International level matrix data will be inferred from the WTO statistics – although these figures refer to trips incorporating an overnight stay, so are only applicable to certain journey purposes.

Overall the picture on data availability regarding the CEEC area model calibration and validation is at best patchy. Best use will have to be made of what is available and in this case, the UN road network flows (which are reliable and consistent) look the most valuable source of data.

The overall approach is therefore to assemble all the relevant items of passenger demand data that exist and to use these as a set of controls to be met by adjusting the values of the model parameters that were originally derived from EU data sources.

4. FREIGHT DEMAND

4.1 Freight Demand Model Enhancements

4.1.1 Introduction

The freight demand modelling element of the STREAMS / SCENES transport models is significantly more elaborate than the methodology used for the modelling of passenger trips. In summary, the freight demand model uses a combination of Leontief input-output (I/O) structures in conjunction with a spatial allocation procedure and a matrix of transport disutilities to produce a matrix of trade in terms of value. This process is known collectively in this context as a Regional Economic Model (REM).

Other routines within the model convert these values to volumes (by commodity type and origin-destination pair), and this matrix of tonnes is then assigned to the transport networks in a more 'conventional' fashion. Modal split and route choice are then determined in the transport assignment module based on the characteristics of the flow type (e.g., bulk or unitised). A full explanation of the freight demand model methodology can be found in the STREAMS Deliverable D8/D10, Section 3.2.

Given the complexity of the freight demand model set-up and the fairly heavy data demands which the methodology has, there are several possible areas of model enhancement which could be addressed in SCENES. The main areas of enhancement planned for SCENES are the incorporation of new I/O tables and changes to the definition of transport flow groups, the volume to value procedures and the modelling of intra-zonal trips.

4.1.2 Use of revised I/O tables

The STREAMS REM was based on an incomplete set of official EU Input / Output tables. At the time, tables were only available for 7 of the 15 EU countries, although this 7 represented the vast majority of the EU in terms of population and economic activity. Also the tables used were originally specified for 1985. The tables were estimated and updated to 1994 within the STREAMS project, primarily using national accounting data. Each country which was not specifically covered by its own I/O table was attributed the table from the country which it most closely resembled. Although sufficient for the STREAMS project, new data has now become available and a new approach can therefore be taken.

There now exists a full EU15 set of I/O tables fully revised for 1995 available from Eurostat, and these have been obtained. These tables will form a much better basis for the model. However, given the increase in dimensions of the model resulting from the incorporation of the CEEC area (i.e., additional internal zones), it may be necessary and advisable to use a more aggregated industry classification in the REM. Currently, there are 33 factors fully incorporated in the REM structure (itself based on an aggregation of the NACE / CLIO R59 classification), and there could be other benefits from reducing this number when it comes to translating these trades into transport flows. The number of factors will be reduced to 28.

4.1.3 Definition of transport flows

There are currently ten STREAMS freight model flow groups, i.e., the aggregations of trades into units for assignment to the network. These ten groups are aggregations of the NST/R 2-digit classification as used in the Eurostat TREX database and in other applications.

A full version of the 1995 TREX database (3-digit classification) has been obtained by the consortium, and it is intended to review the composition of the freight flows in the light of this new data. The aim is to have a better decomposition of freights with respect to their modal choice and handling category characteristics. This is also advisable to guarantee a suitable correspondence with the logistics families defined in the appended module (see Chapter 5).

In particular the split between bulk, general cargo and unitised goods could be re-defined as a result of this more detailed classification now available. The current flow ‘paper pulp’ will be merged with another flow or enriched with other flows and re-named, as this flow has been very small in volume in STREAMS and has proved difficult to deal with. A further example is that the current flow ‘machinery and miscellaneous articles’ currently comprises NST/R Chapter 9 and is defined as a ‘unitised’ flow in STREAMS. In reality, part of NST/R Chapter 9 defined goods are transported as ‘general cargo’. This flow group could therefore be split into two groups, one unitised and one general cargo.

These are some examples of how the model could be enhanced in terms of the definition of transport flow groups, by using new data and building upon the lessons learned in STREAMS. Other examples may emerge as the data is examined further.

4.1.4 Use of volume to value conversion procedures

The relationship between trades (value, aggregations of NACE/CLIO 59) and flows (volume, aggregations of NST/R) are defined within the model as part of the value to volume conversion procedure. Currently, there is a limitation in that one trade can only give rise to one flow within this process. Known internally as TRIMLAT, this procedure is used to define specific O-D volume to value ratios.

An enhanced version of TRIMLAT will allow this limitation to be relaxed. Therefore a more sophisticated trade-flow relationship could be developed in conjunction with the more detailed NACE-CLIO and NST/R data now available.

The TRIMLAT procedure fundamentally performed well in STREAMS, but some undesired effects were produced due to some discrepancies between O-D data of values and volumes, which led to the use of large multipliers in some cases. The new, more detailed data should allow a revision of the procedure of estimation of O-D values from

TREX values in order to reduce the number of very large multipliers, which can sometimes produce bias in the magnitude of volumes.

4.1.5 Modelling of intra-zonal freight trips

A further area of model enhancement is in the field of the modelling of intra-zonal freight traffic. In STREAMS the rather more sophisticated approach used in the passenger modelling was not used for freight traffic. Instead, a more conventional approach was adopted and each zone centroid had one intra-zonal link to represent intra-zonal freight trips entirely within the zone. The length of the link was broadly related to the size of the zone.

Within SCENES, two enhancements will be made. The first is the possible limited introduction of other modes as intra-zonal options. It was the experience within STREAMS that for instance, it was difficult to get the tonne-kilometres by mode to match the national totals for all countries. In some cases (e.g., inland waterway traffic in the Netherlands), this may have been due to the lack of intra-zonal mode options. The introduction of other modes will therefore be examined, although it is not envisaged that this would be widespread, since in most cases, virtually all traffic which is defined as intra-zonal will be undertaken by truck, given that it is short distance.

The second enhancement will be widespread and that is the adoption of the passenger model style distance band zone system, in order to represent intra-zonal freight trips of different distances. This would have another advantage in that it would allow the same ‘spill out’ and ‘spill in’ effects which occur in the passenger model at the trip distribution stage. These changes occur as a result of changes in the quality and cost of inter-zonal transport.

In order to implement this latter enhancement, new data would be required as to the modal split of freight trips by detailed distance band over shorter distances. Some information on this should be available from the UK NTS publications (at least in terms of person trips by van by distance) although this data source may not be comprehensive.

The implementation of the ‘distance band’ zone methodology for freight would have a further benefit in that it could allow the use of a new ‘short van’ mode. During the Pilot SEA project, some difficulties were encountered in terms of the definitions of freight traffic. There was some debate over exactly what the ‘short truck’ and ‘long truck’ modes were representing, and over the average tonnes carried by each mode. These definitional issues created difficulty when interfacing with the COMMUTE software for calculating vehicle emissions. The use of a ‘short van’ mode would allow a much better representation of shorter distance (not just intra-zonal) freight movements.

Overall, there are undoubtedly difficulties relating to data and definitions when considering the use of ‘van’ types modes in the model. There is however a need to incorporate this mode in some way in order to improve the truck kilometres figures in particular, which are produced by the model.

4.1.6 Freight value of time by flow

The VOT values used in the STREAMS freight model did not differentiate in a significant way by type of flow; the only difference being between unitised and non unitised flows. On the basis of a review of literature data now available, the freight value of time will be better assessed and differences among flows, also in the light of the new flow definitions discussed in Section 4.1.3 - will be introduced in the model.

4.1.7 General calibration issues

A number of definitional issues have arisen as a result of the discussion and analysis of the STREAMS model results and more particularly SEA model results, with regard to the freight model outputs. As a result, there would be considerable benefit in widening the scope of the freight model calibration. This will include looking specifically at freight tonne-km movements by mode by country, in terms of national and international trips made *within national boundaries* (i.e., in line with the definition used in publications such as DGVII's Transport in Figures). The comparison used in the calibration of the STREAMS model was to examine freight movement by country of origin, in line with observed data derived at length from the TREX and Carriage of Goods sources. There is a strong case for using both types of data as the key validation statistics.

Most of the validation statistics were also reported in terms of tonnes. More attention however was given to the tonne-km data when the results were reported. It would therefore be useful to consider re-visiting the data which were derived from TREX and CoG to compile a definitive set of tonne-km data by country of origin by mode (including international trips) and use this as an additional validation measure for the land modes. The non-road mode freight flows will also be calibrated to a greater degree of detail than was possible in STREAMS. Other sources such as the NEAC database will be consulted for use in the calibration of the model.

4.2 Freight Demand Model Expansion

It was touched upon earlier in this Deliverable that data limitations were the main problem likely to be encountered for modelling the CEEC area. This is particularly the case for freight demand modelling given the complex set-up of the model for the EU. Several approaches were examined as to the best broad approach to be taken for extending the model to the CEEC area.

Initially, it was thought that there were obvious disadvantages to using the same method that had been used for the EU area. The most obvious drawback was the lack of any known usable Input / Output tables for the relevant countries. Other approaches were therefore considered.

Given the limitations of the alternatives however, all of the alternative options proved unattractive. An additional complication would arise if an alternative approach were used – in that the combination of two different types of REM structure within one overarching modelling framework would have been awkward and time consuming to implement. It would also create complications, which would have been a poor use of the project's resources.

It was therefore decided to use an adapted Input / Output style approach, in combination with trade data, for freight demand modelling in the CEEC, given that a full Polish I/O table has recently become available to the project. This I/O table can be used as a basis for the CEEC study area and adapted for use in other counties. This adaptation procedure was previously used for EU countries which were without their own I/O tables as discussed above.

The basic structure of the model will be the same as that used for the EU. Considerable work will be required however on the I/O table element of the process. A similar procedure to the one used in STREAMS to update the 1985 I/O tables with national accounts data could be used, with the Polish table being used as a base for the other CEEC. This will ensure that the combination of population based demand coefficients and technical coefficients reproduce the national accounts data. This aggregate national accounts data should be readily available as its at the national level (e.g., European Bank for Reconstruction and Development, Transition Reports).

The other elements of the CEEC REM such as investment (including change in stocks), private consumption, public consumption, exports to outside the EU, and imports from outside the EU will come from published sources. The main problem for these data sources will be obtaining data at the zonal level. Assumptions will most likely have to be made in some cases, and again these assumptions could be checked with the CEEC partners.

On the data side, there has been a large quantity of economic data collated within the SCENES D1 Deliverable. This should form a good basis, in terms of the economic aggregates, for the freight model of the CEEC area.

5. SPATIAL LOGISTICS APPENDED MODULE

5.1 Introduction

This chapter describes the draft design of the appended module to be developed within the Scenes project. The appended module will be developed as a separate module, closely linked, but not part of the main SCENES European Area Strategic Forecasting Model. The document gives an outline of the draft model specification by describing the main computations, data-flows and data-needs for the module.

The appended module of the SCENES model transfers the intermediate outcome of the model, an O/D-table consisting trade volume between regions (zones), into O/D transport flows, by incorporating the usage of alternative distribution chains. A 'chain' here is defined as a series of distribution centers (DCs) and transport relationships for a trade flow at the O/D level. The main reasons to include these modules in the general model are that:

- Estimates of trade between regions will not be accurate if based on the costs of bridging the geographic distance, without including the cost of logistic organization, such as inventory and holding costs, and,

- Due to the use of warehouses, freight flows will be spatially reorganized. For example, each O\D relation of a trade may become a chain of multiple origin-destinations, each using different inventory chains.

Within the appended module, alternative distribution chains are specified for the trade volumes between the regions and then assigned to the network. The logistic module does not yet specify the modality choice in a chain, but identifies typical distribution structures for chains, based on the characteristics of the region, products and the network. In this way it transforms 'trade' flows to 'transport' flows (although both are in terms of tonnes). The appended module calculates the number and the location of DCs throughout Europe. Figure 5.1 gives an overview of the scope of the appended module.

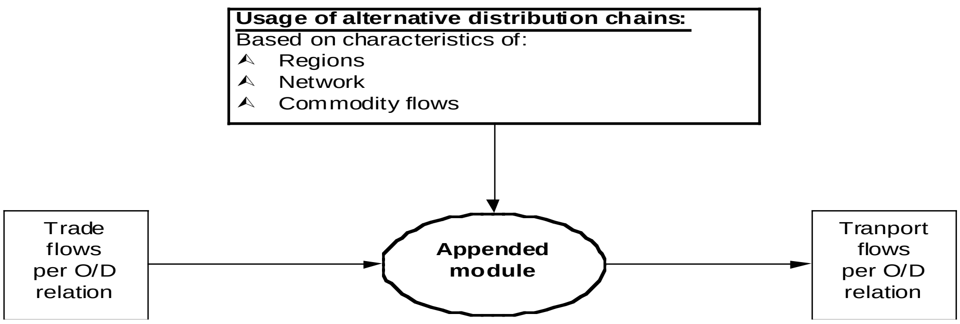


Figure 5.1: Input / output relations for the appended module

Figure 5.1 indicates that instead of considering individual products or companies, alternative distribution chains are specified based on aggregates of freight flow by:

- **Origin \ Destination**: the module uses NUTS2 regions to aggregate freight flows between individual companies or DC's. Note that in a model of interregional freight transport, changes will only be noticeable if warehouses connect different regions, and not only locations within one region. This implies that distribution structures should primarily be considered at national and continental scale if we define regions at the sub-national level. Table 5.1 gives an overview of the alternative distribution structures or chain types, which are distinguished in the model. Per chain type, several alternative chains using different DCs' locations are possible. For example the flows of goods X, between region A and B is distributed as 25% direct and 75 % uses a NDC as chain type. Form this 75%, 50% uses a warehouse in C as alternative chain and 25% warehouses in D and E.

Table 5.1: Chain types

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

- **Commodity flows**: within the STREAMS model 10 types of goods (commodity flows) are distinguished, which will be reconfigured within the appended module to 'Logistical Families'. Logistical Families (LF) are groups of products with homogenous logistical characteristics and requirements (i.e., shipment-size, value, order frequency, etc.) and therefore they will have comparable distribution structures. The main reason to reconfigure the transport flows is that they are created by identifying homogenous segments for modal split, and not for the logistic choice processes, which determine the distribution structure of goods. The criteria used to model logistics choice behaviour differs by incorporation of costs for logistics organisation (like inventory and handling costs), and alternative distribution chains.

5.2 Appended modules: sub-modules

5.2.1 Introduction

The main objective of the appended module work-package is to design and build a model for the analysis of long-term changes in physical distribution structures at the European level. The model will produce information that describes the number and the location of distribution centers between supplier and customer, taking into account the effects of the choice between alternative distribution structures in the STREAMS / SCENES model.

The appended module consists of three main sub-modules:

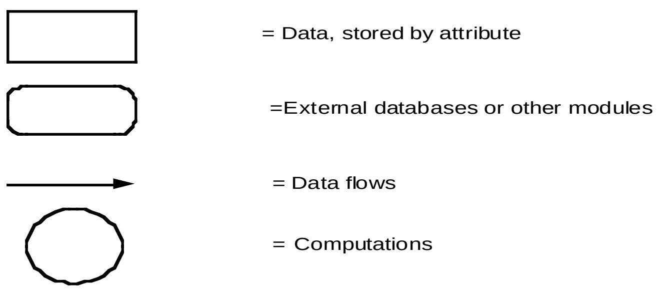
- **Reconfiguration module**: this module reconfigures the input and output to /from the appended modules to the transport flow definitions as used by the STREAMS / SCENES model. This module is explained in paragraph 5.2.2.

- **Chaining module**: this module calculates the possible DC locations per alternative chain and the probability of the using an alternative distribution chain. This module is explained in paragraph 5.2.3

- **Logistic choice module**: this module assigns (percentages) volumes of the total commodity flow for an O/D-relation to chain types (see Table 5.1), using alternative DC-locations. This module is explained in paragraph 5.2.4.

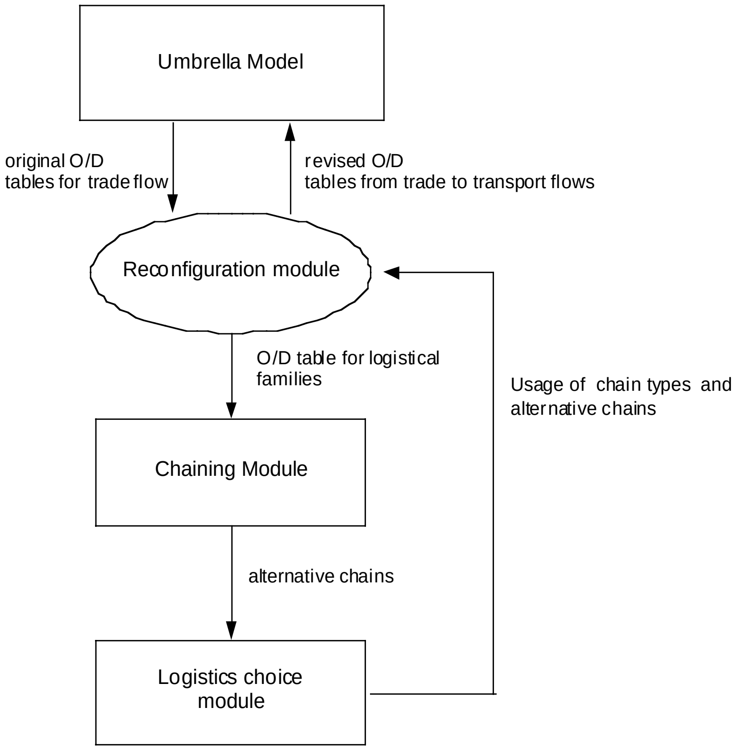
The appended modules will be developed as separate modules, closely linked, but not a part of the main model. The remaining sub-paragraphs describe the computations and data flows within the modules.

The following symbols are used in the figures of the sub-paragraphs:



The interaction between the three modules and the relation with the SCENES model are shown in Figure 5.2.

Figure 5.2: Relationships between modules and umbrella model



5.2.2 Reconfiguration module and the use of Logistical Families

This section discusses the reconfiguration module, which recalculates the input and output of the appended module in such a way that it matches the level of detail of the SCENES transport model. The extent of using this module depends on the prospects for adapting both the STREAMS transport flow groups and flows of Logistical Families as TNO use within the Dutch model. The reconfiguration will be based on the composition of both flows at NSTR 2 digit level. Within the SCENES project it is possible that the STREAMS transport flow groups will use a new definition, as described in Section 4.1.3. The objective is to adapt both flows in such a way that a new general classification for both SCENES and the appended module could be developed within the project. It is currently assumed that this will not be possible and a reconfiguration will have to be applied.

The module will be used at two points in the appended module:

- to reconfigure the input of the chaining module: the 10 transport flows of the SCENES model will be translated into approximately 10-15 flows for Logistical Families for every O/D pair, and

- to reconfigure the output of the logistic choice module: 10-15 flows of Logistical Families will be translated into a revised O/D table using the original 10 transport flows of the SCENES model.

The revised O/D tables for the 10 transport flows is in fact a translation of the original O/D table for trade flows into O/D tables representing transport routes, indicating the share of different alternatives for the distribution of goods on each O/D pair. The basis for the reconfiguration is the development of a 'Logistical Family' database. As described before, Logistical Families are product groups with homogenous logistical characteristics and requirements. Therefore it is reasonable to assume that their logistic behavior is homogenous. The development of this database will involve the extension of the principles applied in an existing and operational logistic choice model for the Netherlands. For the construction of the database, literature studies and interviews among logistics experts have been executed. In more detail, Logistical Families will be distinguished using for example the following product and market characteristics:

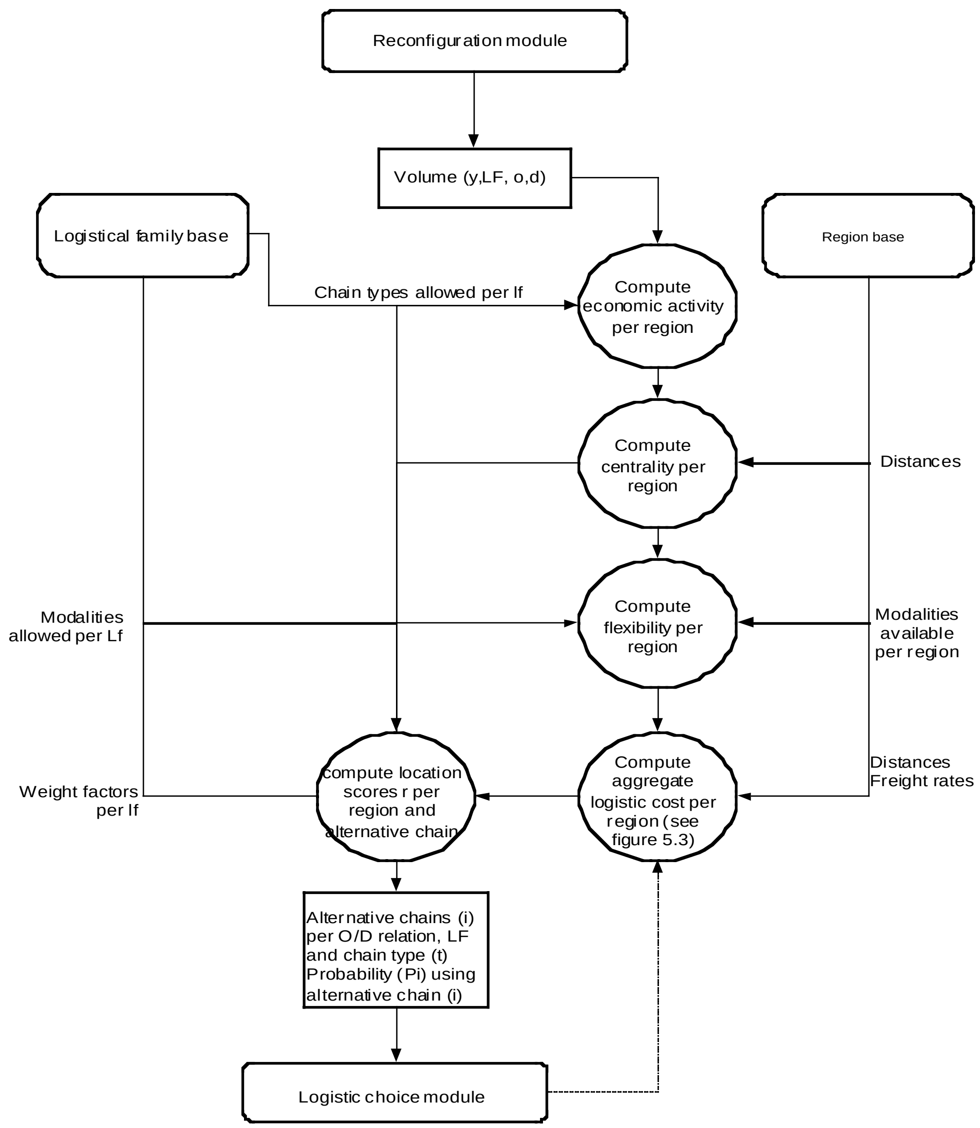
- Delivery strategy,
- Value density (value of products per m^3),
- Shipment size (in tons),
- Perishability (the period which a product is technically/economically usable), and,
- Packing density (the number of coli per m^3).

For each of these Logistical Families, typical alternative distribution chains will be specified. The actual usage of a specific chain type and geographic assignment to commodity flows on an O/D relation will be explained in the following paragraphs.

5.2.3 The chaining module

The chaining module computes different regions for the possible location of a DC per commodity flow LF and O/D relation. Figure 5.3 gives an overview of the data flows and computations of this module.

Figure 5.3: Overview of the chaining module



The basis for the use of an alternative chain per chain type and commodity flow is the ranking of the attractiveness of a region as DC location by considering the logistic costs (transport, handling and inventory) and non-financial aspects. As Figure 5.3 indicates, the probability P(i) of using an alternative chain is an indicator for this attractivity.

Within the chaining module the logistics cost for a region are computed by the sum of the total logistics costs for every possible alternative chain using this region. Section 5.2.4 contains a detailed description of the computation of the logistics cost for a chain.

The use of non-financial aspects, like economic activity and accessibility reflects the incorporation of regional characteristics in the decision process for determining a DC-location. Indicators for non-financial aspects are:

A. **Economic activity -** can be computed by the total volume of production and attraction of goods from a region.

[Production and attraction data (trade volumes (tonnes)) for every region will be needed from the SCENES model].

B. **Centrality -** can be computed by several indicators. One example is a centrality index for every region, by computing a weighted reciprocal of the distance of a possible DC location to other destinations, shown below:

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

B_l	= centrality index for other destinations form location *l*
X_{ij}	= volume of commodity flow per LF between origin *i* destination *j*
d_{ij}	= distance between location *l* and destination *j*
i	= origin
j	= destination
l	= region of the DC-location

C. **Flexibility -** can be computed by a simple access index, using the availability of infrastructure within a region for the different modalities form surrounding regions. This dimensionless factor has a maximum value of 100%, if a region can be accessed by all modes (modes that are allowed for every logistical family) form all surrounding regions.

[Data on network connectivity (for all modes rail, inland waterway, pipeline, air, road, coastal and deep-sea shipping) per region will be needed from the SCENES model.]

The final location choice is done by multi-criteria analysis incorporating the logistics costs and the non-financial factors. Regions will be ranked according to their locations scores (see Figure 5.3), and weighting factors based on the presence of transport and distribution activities within a region. This ranking are used to calculate the probability P(i) of using the alternative chain, by the formula:

$$P(i) = \frac{\exp\{r_i\}}{\sum_n \exp(r_i)} \qquad \text{Where } i \in D_{n,f}$$

Variables:

P(i) = probability of using alternative chain i

r = location score

i..n = alternative locations

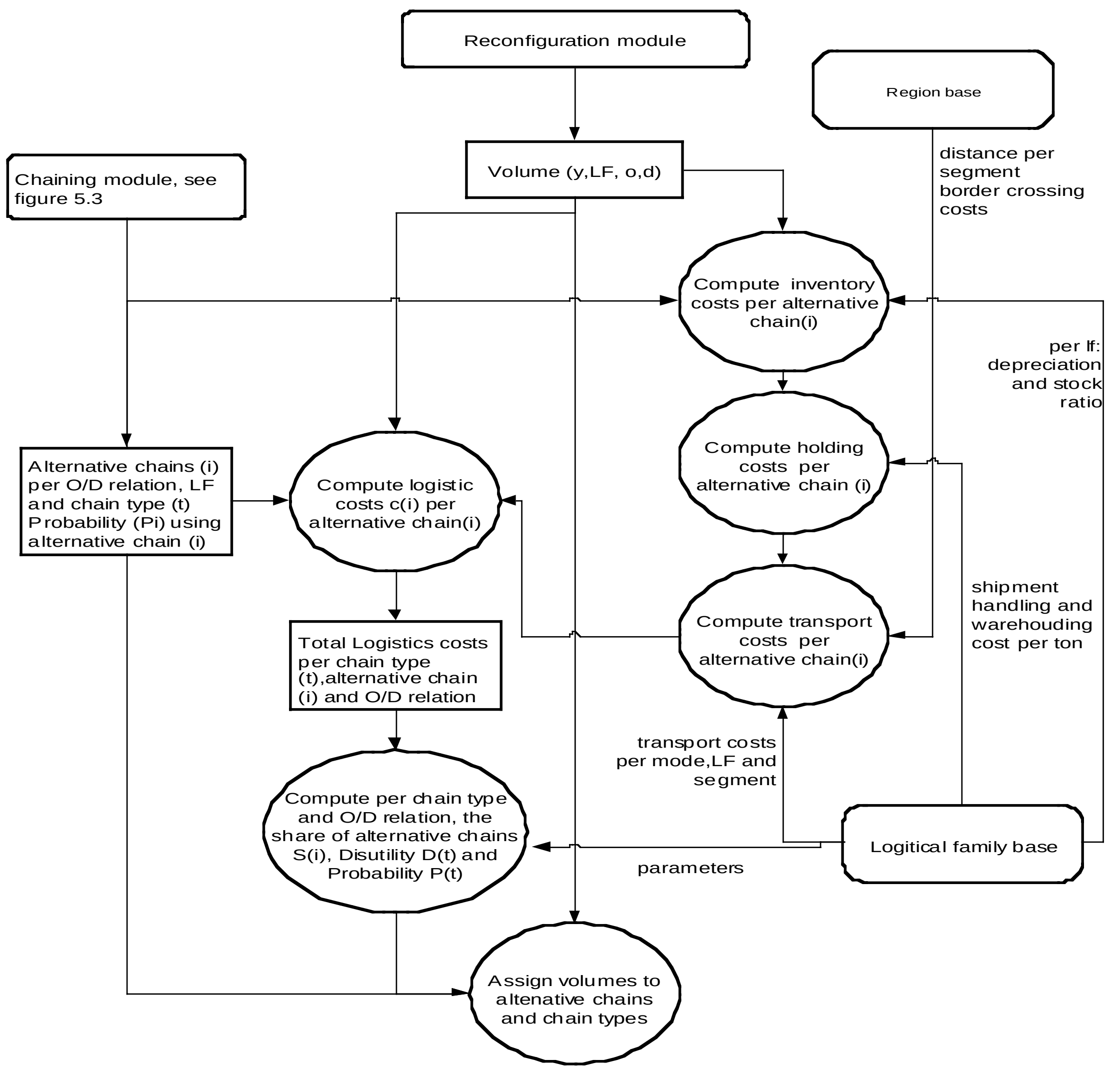
H = collection of alternative chains per LF and O/D relation

lf = logistical family

5.2.4 The logistic choice module

To describe the logistic choice module (LCM), Figure 5.4 gives an overview of data flows and computations within the logistical module.

Figure 5.4: Overview of the Logistics choice module



This module calculates the assignment of (percentages) volumes to alternative chains and chain types. Figure 5.4 shows how the probability of using a specific alternative distribution chain is computed. The remainder of this chapter describes the most important features of this module.

As the probability of using an alternative chain per O/D relation, chain type and LF –flow is calculated within the chaining module, the logistic choice module assigns the volumes to chain types and the underlying alternative chains in three steps:

1. Compute the logistic costs per alternative chain and chain type
2. Assignment of volume to alternative chains per chain type
3. Assignment of volume to chain types

Ad.1) Compute the logistic costs per alternative chain and chain type

The total logistic costs per alternative chain and per Logistical Family have three components:

$$c_i = c_i^t + c_i^v + c_i^h$$

Variables:

c_i = total logistic costs alternative chain

c^t = transport costs

c^v = inventory costs

c^h = holding costs

The sum of the total logistics cost for all possible chains per region is also used within the chaining module, as described in Section 5.2.3.

Inventory costs are specified for every Logistical Family and contain the inventory costs fort he actual stock necessary for the demand over a period, and both the safety and season's stock:

$$c_i^v = X_{ij} S_{lf} (D_{lf+} + F_{lf})$$

Variables;

c^v = inventory costs

X_{ij} = commodity flow per LF (volume) between origin i and destination *j*

S_{lf} = stock ratio per LF

D_{lf} = depreciation ratio per LF

F_{lf} = fixed costs per ton

Holding costs are independent from the product and are divided into handling and holding costs:

$$c_i^h = X_{ij}(A + S_{lf}O)$$

Variables;

c^h = holding costs

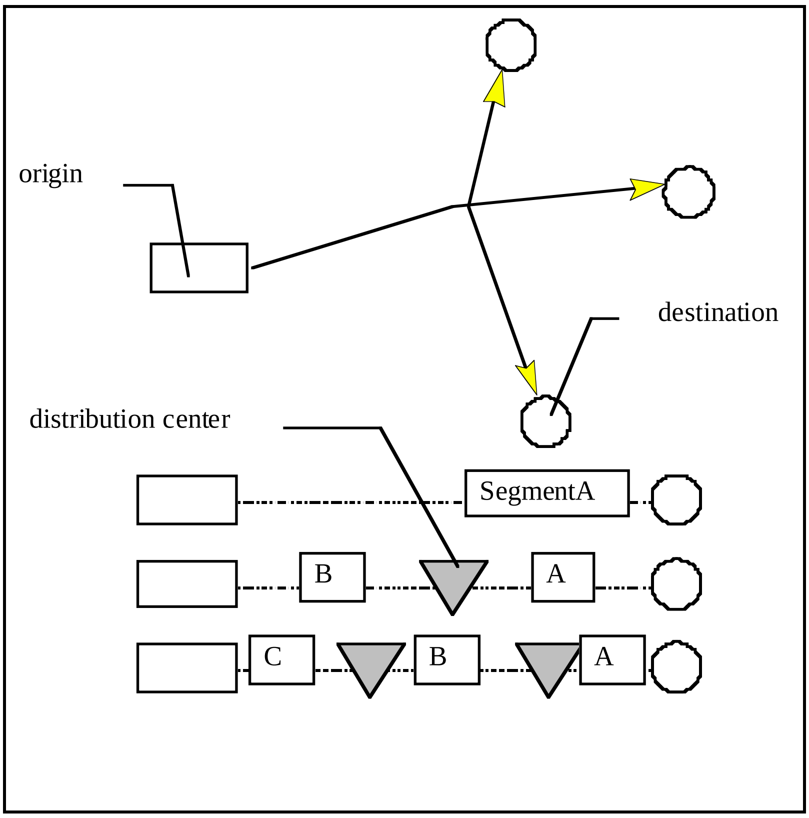
X_{ij} = total commodity flow on O/D-relation

O = warehousing costs per ton

A = shipment handling cost per ton

Transport cost for a chain are calculated by using the cost per tonne-km and per segment of a chain. The segmentation is based on the freight rate per modality, the value of time and the shipment size. Figure 5.5 contains the segments per chain type.

Figure 5.5: Segments per chain type



The tariffs per tonne-km and segment increases from segment C to A for every commodity flow. Segment A represents the last stage of the distribution chain, the transport to the end-consumer. In this segment the shipment-sizes are smaller, value of time higher, and as a consequence the tariff per tonne-km increases.

The formula used to compute the transport costs is:

$$c_i^t = X_{ij} \sum_s T_s d_{ij,s}$$

Variables:

T_s = tariff per segment per LF

$d_{ij,s}$ = distance per segment in km between origin i and destination j

s = Segments per chain type and LF

Ad.2) Assignment of volume to alternative chain per chain type

This assignment is calculated by using:

- the probabilities of possible locations per alternative chain as computed in the chaining module
- the total logistic costs for every alternative chain per O/D relation from step1. These costs are used to compute the 'weighted' costs for all alternatives within one type of chain, by using the formula :

$$S(i) = \frac{\exp\{\alpha, c_i\}}{\sum_n \exp(\alpha, c_i)} \qquad \text{Where } i \in H_{n,lf}$$

Variables:

S (i) = share of alternative chain i in the total volume per chain type

c(i) = total logistics costs for alternative i

i…n = alternative chains i per chain type and O/D relation

α = parameter indicating sensitivity of LF-flow x for logistics costs

H = collection of alternative distribution chains per LF and O/D relation

The S(i) provides the division of the volume over alternatives per chain type, by using a Logit-model. Parameter α gives an indication of the sensitivity of a Logistical Family for logistic costs, when making the choice for a specific chain. In this way the model includes the relevance of other non-financial factors in the choice behavior. By using restrictions for specific (non-realistic) relation types and Logistical Families, the set of alternative chains is limited.

Ad 3) Assignment of volume to chain types

Using a disutility function, the volumes are assigned to chain types. Computing the disutility of a chain type, relative to each other does this. The total disutility of a chain type per O/D relation and LF is the sum of the disutilities of the individual alternative chains per chain type.

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

Variables

D = disutility per chain type

t = chain type

λ = parameter per LF

ci = total logistics cost per alternative chain and location i

i.. n = all alternative chains per chain type and O/D relation

CT = chain types allowed per LF

The weighted outcomes of the disutility functions per chain type is used to compute the probability of using of a chain type, by using formula

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

Variables:

P = probability of using chain type per O/D relation

D = disutility per chain type

i = all alternative chain types per O/D relation

μ = parameter per LF

f = logistical family

CT = chain types allowed per LF

The final assignment of the total flow of a Logistical Family per O/D relationship is computed by multiplying the probability of using a chain type P(t) with total volume X per LF and O/D relation.

6. SUMMARY

This Deliverable has outlined in some detail the enhancement and expansion of the STREAMS model which will be undertaken within the SCENES project. The end result will be a more detailed model of the EU, expanded and using the same methodological approach to cover the countries of Central and Eastern Europe. Many of the activities referred to in the text are already completed (e.g., work on the assignment NUTS3 sub-zoning procedure, see Annex A for the original specification) or under way (e.g. work on air and rail capacity, see Annexes B and C for more detail).

Other activities not strictly part of a model 'specification' but which are crucial to the actual model implementation have also been completed. For example, a 'matrix tool' has been developed. This tool has two main functions, namely matrix aggregation and matrix trimming. In combination with the aggregating facility is a limited algebraic functionality allowing the establishment of weighted averages in aggregation. This aggregating tool has been used within SCENES as part of the comparison exercise which is being undertaken between the STREAMS model and Dutch consultants NEA's NEAC freight database within the SCENES project. The tool has allowed the STREAMS model results to be aggregated such that the zoning system, the definition of flows, and the definition of modes can all be compared on a common footing.

This work is part of a wider ongoing exercise to review the STREAMS model results and structure in relation to other relevant studies and databases, particularly the Phare forecasting study, DGVII's 2020 forecast consultancy study and EUFRANET. The consultants involved in these projects are also represented in the SCENES consortium which facilitates this process. The work may lead to further adjustments to the SCENES model structure and calibration process.

Annex A - Methodology for spreading the assignment across sub-zones

INTRODUCTION

This Annex provides a specification of how to increase the number of zones between which trips are assigned within STREAMS / SCENES, without enormously increasing the computational burden. This is required in order to make the assignment of trips to the road network spread more fully over the primary road network in any model that uses large zones.

Background to the problem

When the STREAMS model has been run for the whole of Europe with 202 zones defined at the NUTS 2 level, it has been found that the trips are insufficiently spread over the major roads on the model network due to the large size of each of the model zones.

For example, East Anglia in the UK is a single zone which has a centroid in Cambridge. The large flows originating in East Anglia and ending in London and the South East of England are therefore almost all concentrated in the main corridor between Cambridge and London that connects the two zones. In reality, the travel demand should be spread between all of the major centres of activity within the zone, such as Ipswich, Norwich, and Peterborough, rather than just being all located at the centroid in Cambridge. This would ensure that the regional traffic flow is spread more evenly over the set of regional centres and thus primary roads within the zone.

The correct solution to this problem is simply to increase the number of zones that are included within the model, by say moving from a NUTS2 to a NUTS3 level of zoning. However this is not a feasible solution because of the burdens that it places on computer storage and computation. The resources required to run either the regional economic or transport models increase as the *square* of the number of zones, rather than merely being a linear function of the number of zones. Accordingly, a fourfold increase in the number of zones would cause the model to take 16 times as long to run and would increase storage requirements by a similar amount. Given the current model size and the computing resources available on even the most powerful PCs, this is not feasible.

The challenge is to find a method of increasing the level of detail provided at the road assignment stage, but without a major corresponding increase in the overall size and computational burden in the model. The rest of this Annex provides a specification of such a method. Firstly it explains the theoretical approach. Then it explains how to implement it within the assignment program (TASA). Then, the details of the required changes to the software are described.

THEORY

The approach to be adopted is to subdivide each main zone I into a number of sub-zones $i \in I$ so that at the assignment stage the trips are assigned between all pairs of sub-zones as T_{ij}, instead of just between all pairs of main zones as T_{IJ}. The challenge is to approximate this extra spatial detail with the minimum extra consumption of computer resources.

To guide the subdivision of zones we use measures of the relative size of each sub-zone i within its main zone I, denoting the size by O_i for trip origins, and by D_j for trip destinations.

The distribution of trips among the sub-zones is not determined primarily by the disutility of travel from this sub-zone to the destination zone, but this disutility will have an important secondary influence. The size term will be the primary determinant since it is to represent the overall spread of origins or destinations throughout the main zone. The local accessibility effects are expected to be of lesser importance than the relative size of the sub-zones in reality in determining the spread of the longer distance trips considered in the STREAMS/SCENES model.

Splitting origin zones

The standard output from the path building procedure in TASA is the travel disutility u_{IJ} between every pair of main zones. Using the approach that will be described later in this note, it will be possible to extend the program to also calculate the travel disutility u_{iJ} from each origin sub-zone to each destination main zone, without a major increase in calculations. Unfortunately, the programme structure cannot easily be extended to calculate the reverse travel disutility u_{Ij}, from an origin main zone to a destination sub-zone, without a comparable increase in computational resources.

At the origin zone end it is necessary to code the connecting link between the main zone centroid and every one of its sub-zone centroids with an identical very large travel disutility. The purpose of this large disutility is to force the creation of a range of 'feasible paths' in the sense of Dial's algorithm, so that every sub-zone centroid of each main zone centroid is part of a path to the specified destination zone. A feasible multi-path is one which at no node moves the traveller further away from the destination zone than the disutility at his current node. This rule is to avoid infinite circular loops in the paths. When actually carrying out the modal split and calculating the disutility of travel for the path, the value of the disutility is set to zero for these connecting links between the sub-zones and the main zone centroid. Its only use is at the stage of creating valid paths between origin and destination sub-zones.

The separation of the trips among the origin sub-zones is based on a combination of the size of the zone and of its relative accessibility. The following formula is used at the origin end of the trip

$$T_{iJ} = T_{IJ} \frac{O_i e^{(-\lambda u_{iJ})}}{\sum_{i' \in I} O_{i'} e^{(-\lambda u_{i'J})}} \qquad (1)$$

Here the value chosen for the distribution spread parameter λ is based on that which has been used in the land use / demand program (LUSA) for the trade(s) which comprise the flow type that is being assigned. This will ensure that the spread of origins among the sub-zones is broadly equivalent to that which would have been created by running at the level of sub-zones rather than at the main zone level.

Provided that the transport disutilities are measured throughout in units of:

- generalised time per person trip for passengers
- generalised cost per tonne for freight,

then the values of the parameter λ that have been used in LUSA may perhaps be used without any transformations here TASA. However, there may be some need for transformations due to the use of the path building based, rather than the modal split based, travel disutilities in the calculation of the spread of trips. This issue is discussed in more detail below.

The variable which is chosen for the origin zone size term O_i should be selected to be representative of the main influences governing the allocation to zones of the corresponding trades in LUSA. Whether it should be based on the production zone (TotProd) or the consumption zone (TotCons) terms in LUSA will be governed by the direction in which the constituent trades and the flow type are related in the model interface file UFP. Since the size term O_i is only used to subdivide the trips of a main zone into its constituent sub-zones, the units in which it is measured do not necessarily have to be identical between one main zone and another, they only need to be consistent across every sub-zone for the main zone.

The current TASA assignment loads the trip volume T_{IJ} at each origin main zone centroid I and assigns it to the destination main zone J. The proposed method loads instead the values T_{iJ} as calculated by equation (2) at each origin sub-zone centroid i. This is a cheap and relatively simple variant on the existing assignment methodology. This initially allocates these loads from all origin zones to their respective centroid nodes and then starting at the most distant node from the destination, cumulatively assigns the traffic along the links towards the destination. It picks up any traffic that has been loaded at intermediate zones as it progresses gradually ever closer to the destination zone. The resources associated with processing the extra origin sub-zone loads will be very minor in the overall context of the assignment, provided that the overall number of links on the network does not increase significantly.

Splitting destination zones

There are two potential approaches to this task, each of which is discussed below.

Refining the algorithm

As explained previously the calculation of the travel disutility u_{Ij} from an origin main zone to a destination sub-zone, would require some creativity within the current algorithmic structure. This is because the program calculates paths from *all* origin nodes to the *single* destination node corresponding to the zone centroid for the main zone *J*. Accordingly under the current structure, for any specific origin zone *I* there is no guarantee that its set of feasible paths to the destination zone *J* will pass through more than one of the required sub-zone centroids of this destination main zone.

At the origin zone end the connecting links between all of the sub-zone centroid nodes and the main zone centroid node are set to a large and identical disutility as explained above, to encourage the path building algorithm to produce feasible paths via all of the origin sub-zone centroids. However, the structure of the algorithm implies that although it is likely to be successful in this task at the origin zone end, at best only partial success is likely at the destination zone end.

Ideally what is required is that the destination sub-zone centroid connectors in some sense cancel out the geographic advantages of arriving from a specific origin zone. This would guarantee the creation of a complete set of paths via all destination sub-zone centroids. However, at present other than the use of access connectors to the main destination zone which have uniformly large disutilities, it is not clear what other means could be effective. Accordingly an alternative approach is required.

Increasing the computation

On the assumption that the feasible paths problem above will not be easily cracked at the destination zone end, an alternative (but computationally much more intensive) solution is to assign trips separately to each of the destination sub-zone centroids where required. This is basically a continuation of the current approach. However, it may be possible to avoid substantial duplication of path building with some inspection of the calculations already carried out.

The outcome from the path building procedure, assuming that the origin zone enhancements have been implemented, will be a set of travel disutilities u_{ij} between all pairs of sub-zones from *i* to *j*. The approach in equation (1) above to divide up the trips among sub-zones at the origin could be adopted in an analogous fashion at the destination end as follows:

$$T_{ij} = T_{iJ} \frac{D_j e^{\left(-\lambda u_{ij}\right)}}{\sum_{j' \in J} D_{j'} e^{\left(-\lambda u_{ij'}\right)}} \qquad (2)$$

The equations (1) and (2) can be adapted and then combined in two slightly different ways to give

$$T_{ij} = T_{IJ} \frac{O_i e^{(-\lambda u_{iJ})}}{\sum_{i' \in I} O_{i'} e^{(-\lambda u_{i'J})}} \frac{D_j e^{(-\lambda u_{ij})}}{\sum_{j' \in J} D_{j'} e^{(-\lambda u_{ij'})}} \qquad (3)$$

which respects the constraint $T_{iJ} = \sum_{j \in J} T_{ij}$ or

$$T_{ij} = T_{IJ} \frac{O_i e^{(-\lambda u_{ij})}}{\sum_{i' \in I} O_{i'} e^{(-\lambda u_{i'j})}} \frac{D_j e^{(-\lambda u_{Ij})}}{\sum_{j' \in J} D_{j'} e^{(-\lambda u_{Ij'})}} \qquad (4)$$

which respects the constraint $T_{Ij} = \sum_{i \in I} T_{ij}$. They both can be shown to respect the constraint $T_{IJ} = \sum_{j \in J} \sum_{i \in I} T_{ij}$ which ensures that the set of trips when summed at both the origin and the destination across the set of sub-zones, will match the original total number of trips for the main zone pair. It also implies that the zonal size terms need to adopt consistent units among the sub-zones within a main zone, but not necessarily between main zones. For reasons of convenience in the software coding within the existing program structure, the equation (4) has been selected rather than (3), for the implementation of the zone splitting.

The trips T_{ij} are loaded onto the origin sub-zones i in order to be assigned to the destination sub-zone j. This is then repeated for each destination sub-zone j in turn. This method would increase the computation and the storage of paths by a factor approximately proportional to the increase in the number of sub-zones, rather than to the square of this number, provided that the size of the network is not increased.

ALTERNATIVE APPROACHES

A number of alternative approaches to that described above have been considered. These are approaches that could be implemented without requiring changes to the TASA software. These are briefly reviewed here to explain why they have been rejected as possible solutions to the large zone assignment problem.

Pure assignment

Here the approach is that each of the sub-zone centroids is connected to the main zone centroid, but that the main zone centroid is not otherwise connected to the road network. Then all traffic needs to enter the network at one of the sub-zone centroids rather than being concentrated solely to and from the main zone centroid. The problem with this approach is that it will not necessarily spread the traffic in a manner that is consistent with observed behaviour. For example, virtually all traffic that goes west from the main zone will be channelled through the most westerly sub-zone, while virtually all east bound traffic will leave by the most easterly sub-zone.

Capacity restriction

Here the approach is that each of the connector links from the main zone centroid to the sub-zone centroid will have a capacity coded that ensures that overall the trips are spread among the sub-zone centroids. Those sub-zone connector links that are carrying too great a proportion of the traffic will have it choked off by the application of the increase in the value of the difficulty term that is created by the capacity restriction process. Unfortunately this approach merely dampens the problems apparent with the pure assignment approach, but does not actually solve them.

Annex B - Air Capacity Issues

B1 SUMMARY

The objective of this Annex is to analyse different aspects of the capacity problems faced by air transport. Congestion is already a serious problem and a limiting factor at some airports (Section B2). This problem added to the fact that many of the major international airports have their capacity limited by space and in many cases also by environmental constraints, implies that the airlines need to use other airports which are not at the present experiencing capacity problems (Section B3).

There are sources of information, which allow us to estimate the current capacity of the airports (Section B5). The introduction of this capacity in the model could be done in two ways:

- the points at which the demand exceeds the future capacity level could be detected.
- capacity restraint functions that could reassign the flows according to the criteria of the function applied could be incorporated.

The following sections analyse all the mentioned topics in depth. Finally a table sums up the information provided by ATAG report concerning the main airports characteristics.

B2 CAPACITY PROBLEMS

Overview

The air traffic increase is already an important issue, which is giving rise to significant capacity problems in certain EU airports (see Table B1). The number of flights delayed will increase, ticket prices will rise (despite the best efforts of European Commission to liberalise the air transport market) and people could desert air travel for the new fast train networks springing up throughout the continent.

The main hubs like London Heathrow (54 million passengers 1995), Amsterdam (25 million passengers 1995), Frankfurt (38 million passengers 1995), and Paris (CDG with 28 million passengers 1995 and Orly with more than 26 million passengers 1995); are becoming stronger. In this sense some solutions have to be adopted. If traffic rises as is shown in the following section, then many of Europe's major airports will reach their uppermost capacity limits early next century. Of course, European airport managers are taking some provisional solutions like adding a terminal extension, redeveloping the ramp area or persuading airlines to fly more off-peak services. These solutions could be adopted, but in some airports like Schiphol (Amsterdam) environmental problems constrain the airport capacity (five runaways but for eight hours a day the airport cannot use them ('Airport Capacity/Demand Profiles' ATAG).

There is the idea however, that the present airport system will be able to face the increasing demand of airport travel by introducing a few changes in airport operating systems relaying on three basic assumptions to be taken into account:

- **The major cause of the delays in Europe have been in route ATC (air traffic control) problems caused mainly by Europe's fragmented ATM (air traffic management) system.** In the opinion of the UK's National Air Traffic Services 19% of delays are due to ATC reasons. The airport authorities must make an effort in order to solve this problem, but it is not the main cause of the delays.

- **Much of the demand for new services will be met by larger aircraft, not more movements.** According to figures compiled by 'Areoports de Paris' the demand for more air travel is being meet by smaller aircraft and more frequent services. While it is true that Boeing and Airbus are noticing a gradual rise in the size of aircraft being ordered and some capacity constrained airports are seeing a rise in seats numbers, it is also true that there is an 'efficiency ceiling' in aircraft size. Beyond a certain size (which varies from airport to airport) wake vortex considerations lead to spaces between very large aircraft on final approach having to be increased beyond traditional levels. In these circumstances, smaller aircraft could increase airport throughput.

- **The main hubs might be congested but there still plenty of room at regional airports –see Table B1-, which will bear much of the traffic load in the future.** However, more than 90% of all inter-continental air services originating or ending in Europe are concentrated in the continent's 33 largest airports. Even though this fact is true and taking into account that it will be difficult to change this tendency, this could be one of the best solutions for the capacity problem. Secondary hubs have emerged at large regional airports such as Munich, Nice and Birmingham and this is confirmed by the fact that big growth rates have been recorded in recent years at these airports.

All these problems show a delicate situation on some EU airports. But, which is the economic cost of this problem?

The Economic Cost of Capacity

Through all the paper we are using the term capacity, but what can be understood by the term capacity? The term 'capacity' can be used to refer to a number of factors, any of which could be the limiting factor that might place a constraint on the amount of air traffic that can be handled. These factors could be categorised as follows:

- Air Space Capacity: the number of aircraft that can be fitted into ATC sectors, keeping in mind aircraft separation and safety standards, area navigation direct routings, etc.
- Controller capacity: the maximum workload of controllers.
- Equipment capacity: The number of flights can be handled by ATC systems.

- Airport capacity: which is increasingly limited by ‘available concrete’ for landing and manoeuvring aircraft.

The above definitions necessarily simplify the term capacity to enable an assessment to be carried out: in reality capacity is a complex issue that is affected by all of these as well as another factors (e.g., access to terminals).

As said at the beginning of this Annex, air traffic forecasts indicate steadily increasing levels of demand for air travel in the near future. The relationship between capacity and demand may lead to ‘bottlenecks’ or constrained demand. This situation is actually present in some European airports and it will become a problem in others. Three types of constrained demand can be identified:

- **Demand generally less than capacity, but exceeding it during peak periods:** If demand exceeds capacity only during certain peak-periods of a day, the excess demand may be accommodated by allowing delays to build up during the peak period and then recovering during the subsequent quiet period. The delayed traffic does, however, incur significant cost to the user, including:

    - increased operating costs to airlines such as additional fuel burn, crew, cost...
    - cost of passengers in terms of time

- **Demand approaching/exceeding capacity:** if capacity is, on a regular basis, insufficient to meet demand at certain times of the day, airlines may be forced to operate services at less busy times (demand spreading) or to fly non-optimum routings. In such cases, the constraints of capacity are already known and therefore the incurring by airlines of additional costs would be planned in advance.

  Both demand spreading and re-routing can result in a considerable cost to operators and passengers. Airlines may lose revenue by operating services at off-peak times, or incur additional fuel penalties by re-routing to non-optimum trajectories. Passengers would also be disadvantaged in terms of significant additional travelling time, flying at less convenient times of the day and possibly, having to travel to lees accessible airports.

- **Non-accommodated demand:** Non-accommodated demand results from a shortfall between demand and airspace capacity. Demand may exceed capacity to extent that there are simply no available slots for further service provision by the airlines in certain markets, and therefore demand spreading and re-routing are not possible. Thus demand serves as an indicator of capacity related benefits and costs, respectively.

  In the most straightforward approach the problem can be seen as airlines being unable to satisfy any additional demand from passengers for further services. The cost to the airlines would be the revenue lost as a consequence of not being able to provide services to meet passenger’s demand.

However, the complexity of the nature of system capacity constrains on demand for, and the provision of, air transport will often require the use of the economics metrics. The demand spreading and re-routing are not the only possible consequences. The competition will have effects on the ticket price. The ticket price is directly related to demand. This higher price level could be constrained the demand. The increase in capacity is in this sense related to the reduction on air tickets price. In this sense the monetary benefits for the aircraft operators presents a trade-off between higher yields/less passengers and lower yields/more passengers.

To sum up, reducing delays result in the following benefits:

- Reduced operating cost to airlines, through reduced fuel burn, more predictable crew scheduling, etc.
- Reduced cost to passengers in terms of time.

Looking at numbers, ATAG estimates that the airport congestion will cost about $6 billion per year in the year 2000 up from $1.4 billion in 1992 (1992 US$). Traffic lost to congestion is estimated to be 27 million passengers per annum by the year 2000.

Available data

Even though we have mentioned some data on capacity in the headlines above, this section tries to sum up certain results obtained from the ATAG report 'Airport Capacity/Demand Profiles'. As was said earlier, capacity is a complex issue that is affected by many factors not only for one but we need to simplify the term in order to be able to compare one airport to another. The ATAG report shows the capacity of the airports relating to the following factors:

- Runway: the runway is referring to the space where the aircraft land and take off.
- Apron: the apron is the area where the aircraft park (alongside the terminal).
- Terminal the terminal is the building where all the activities are taking place.

Some of the main EU airports are actually experiencing capacity problems. The following table shows the available capacity in summer 1996 for the EU airports reported in the ATAG handbook.

Table B1: Available capacity in EU airports - Summer 1996

Airports	Runway	Apron	Terminal
Amsterdam	B	B	
Arrecife	B	B	A
Berlin (Flughafen)	C	C	C
Berlin (Tegel)	B	B	A
Denmark (Billund)	B	B	B
Brussels	B	B	B
Copenhagen	B	B	B

Dresden	B	C	B
Dublin	C	B	B
Faro	B	B	B
Frankfurt	A	A	B
Goteborg	B	B	B
Hamburg	C	B	B
Hannover	C	B	B
Lisbon	B	B	B
London – Heathrow	A	B	B
London – Stansted	C	C	C
Marsella	C	C	C
Milan – Linate	A	A	A
Milan – Malpersa	C	C	C
Munich	B	A	B
Naples	C	B	B
Nice	B	B	C
Nurenberg	C	B	B
Oslo	A	A	A
Paris – CDG	A	B	B
Paris – Orly	A	B	B
Rome – Leonardo da Vinci	C	B	B
Stockholm	A	B	A
Stuttgart	C	B	A
Turin	C	B	C
Viena	B	C	B

Where:

Near Saturated Most of Day	A
Near Saturated at Peak Hours	B
Capacity Available all Day	C

The situation described above is as bad as expected. The worse situation corresponds to the biggest international airports as London-Heathrow, Milan-Linate, Oslo, Frankurt, etc. Looking through the data, it can be said that the average delay in London-Heathrow is 10 minutes, in Amsterdam it rises to 15 minutes just like Berlin-Tegel, decreasing for Milan-Linate down to 13 minutes. There are other airports, like Brussels, Copenhagen, Faro, etc. in which the capacity is quite saturated at peak hours. On the other hand we have airports i.e.: London-Stansted, Marsella, Turin, Naples, Nice etc. which do not present any capacity problems.

The majority of airports are actually looking for a solution. ATAG summarise in the following table the current and planned development in order to increase the capacity of the airports.

Table B2: Current and Planned Development

Airports	Runway	Apron	Terminal
Amsterdam	PD	PD	
Arrecife	PD	PD	CD

Berlin (Flughafen)	NR	NR	NR
Berlin (Tegel)	PD	PD	CD
Denmark (Billund)	PD	PD	PD
Brussels	PD	PD	PD
Copenhagen	PD	PD	PD
Dresden	PD	NR	PD
Dublin	NR	PD	PD
Faro	PD	PD	PD
Frankfurt	CD	CD	PD
Goteborg	PD	PD	PD
Hamburg	NR	PD	PD
Hannover	NR	PD	PD
Lisbon	PD	PD	PD
London - Heathrow	CD	PD	PD
London - Stansted	NR	PD	PD
Marsella	NR	NR	CD
Milan – Linate	CD	CD	CD
Munich	PD	CD	PD
Naples	NR	PD	PD
Nice	PD	PD	NR
Nurenberg	NR	PD	PD
Oslo	CD	CD	CD
Paris – CDG	CD	PD	PD
Paris – Orly	CD	PD	PD
Rome – Leonardo da Vinci	NR	PD	PD
Stockholm	CD	PD	CD
Stuttgart	NR	PD	CD
Turin	NR	PD	NR
Viena	PD	NR	PD

Where:

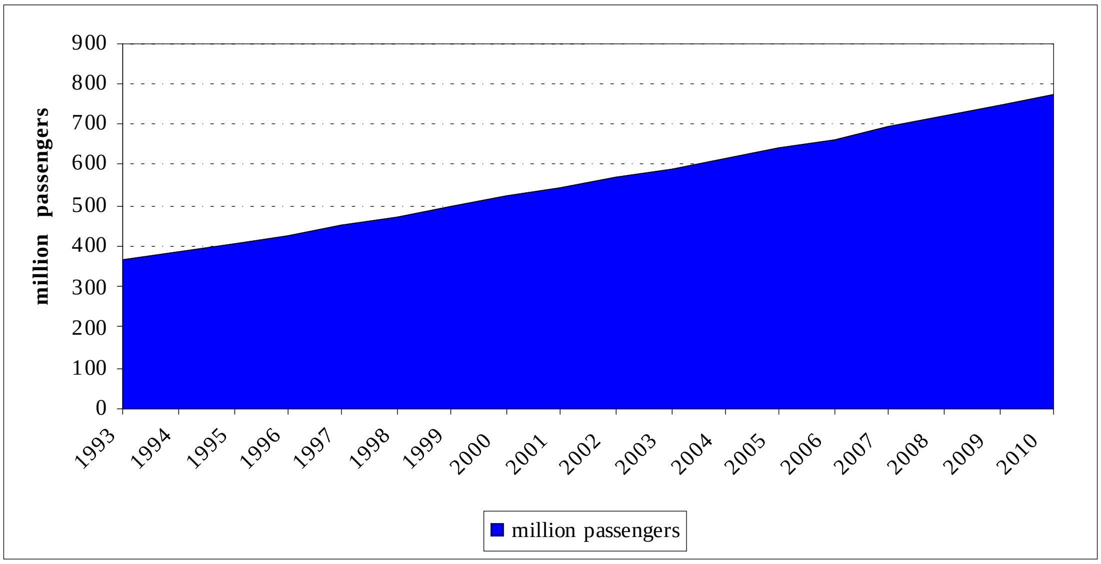
Current Development	CD
Planed Devepolment	PD
Nil Reported	NR

As the above table reflects not only the airports with capacity problems but also the secondary airports are searching for solutions to face this congestion problems. The ATAG report provides us a brief description of the projects planned for each airport. This fact confirms the hypothesis that many countries are trying to promote their regional airports in order to reduce the congestion in the international ones.

B3 TRENDS AND FORECASTS IN AIR TRANSPORT

The previous section describes a worrying situation for some of the EU airports. Even more, this situation could be worse in the future. Analysing the forecast provided by ATAG it reflects that the total demand for air transport in Europe was nearly 367 million passengers in 1993. This includes domestic, international scheduled and international charter passengers to, from, and within the region. This overall demand will more than double by 2010 to 774 million passengers. This is a 2.1 fold increase over the 17 year forecast period. The projected average annual rate growth is 5.2% between 1993 and 2000, 4.2% between 2000 and 2005 and 3.8% between 2005 and 2010. These growth rates are shown in Figure B1, below.

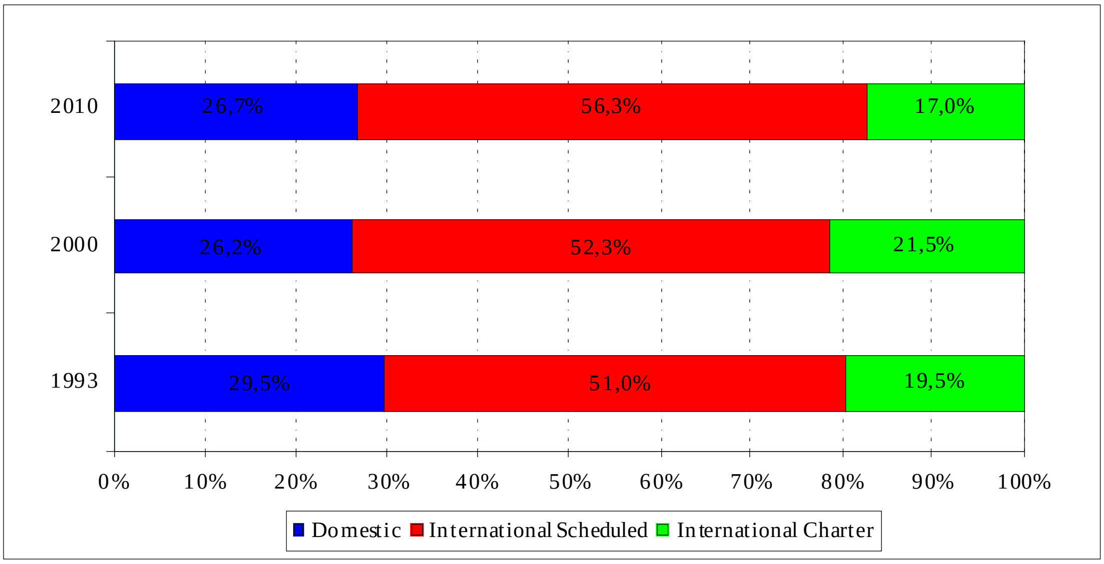
Figure B1: Total demand for air transport in Europe



Source: European Traffic Forecast 1980-2010. ATAG.

If we analyse this forecast considering the type of flights (shown in Figure B2) it can be said that in 1993 the international scheduled traffic to, from and within Europe represented 51% of total European passengers traffic. This percentage is expected to increase to 56.3% by 2010. Domestic passenger traffic represented 29.5% of the total in 1993. This share is forecasted to drop to 26.7% by 2010. Finally the international charter traffic accounted for 19.5% in 1993, present a share of the market which will decline to 17% by 2010. The different shares' evolution could be explained by the fact that many charter airlines are expanding increasingly their scheduled services.

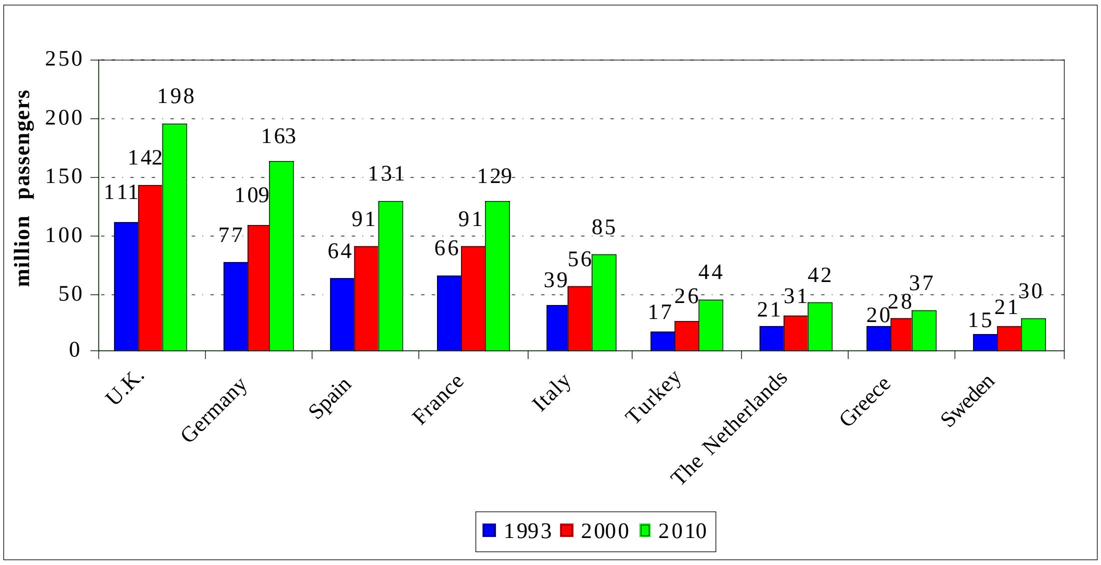
Figure B2: Breakdown of traffic between domestic, international scheduled and international charter in Europe



Source: European Traffic Forecast 1980-2010. ATAG.

Looking through the data by country (Figure B3), the UK has been and will remain the region's dominant traffic market. By 2010, 198 million passengers will travel to and from that country. The region's other major markets in 2010 will be Germany, Spain, France and Italy.

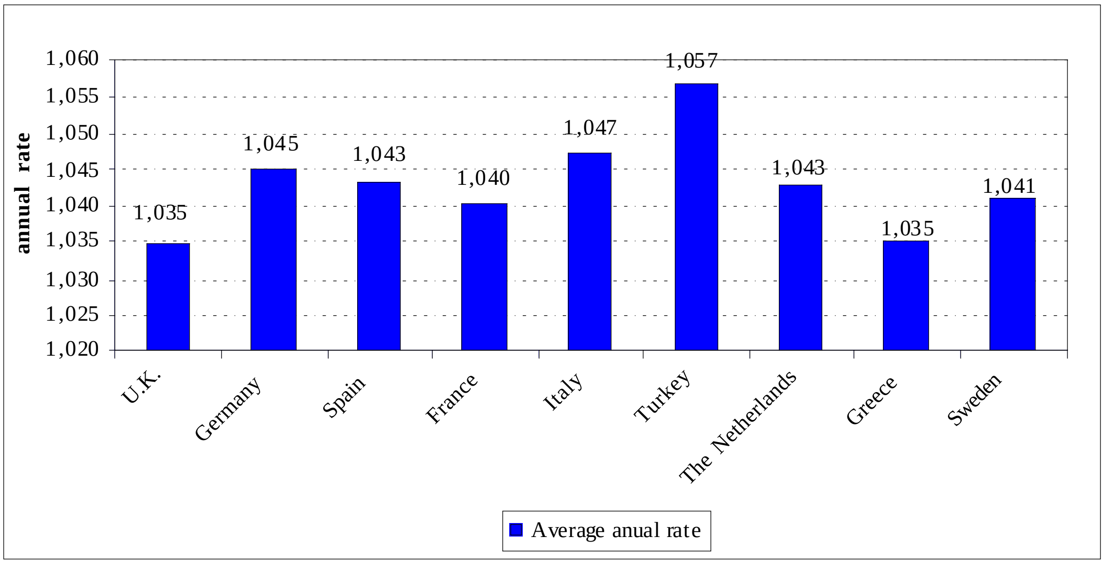
Figure B3: Forecast for air traffic in Europe by country



Source: European Traffic Forecast 1980-2010. ATAG.

The strongest growth in traffic between 1993 and 2010 will be achieved by Turkey (Figure B4). Turkey's total passenger traffic will increase at an average annual rate of 5.6%, from 17.6 million passengers in 1993 to nearly 44 million in 2010.

Figure B4: Average annual rate by country (period 1993-2010)



Source: European Traffic Forecast 1980-2010. ATAG.

B4 LOOKING FOR A SOLUTION

One solution proposed by EUROCONTROL to solve the airport congestion problems referred to in the above mentioned sections which is to homogenize the way that airports are organised, airspace above them is structured, passengers processed through the terminal and baggage sorted and distributed. It is not surprising therefore that there are vast differences between levels of declared runway capacity per hour (see Table B3), e.g., London Gatwick, a simple runaway airport, had a declared hourly capacity of 40/47 movements whereas Goteborg, also with one runaway, declared a maximum of 20.

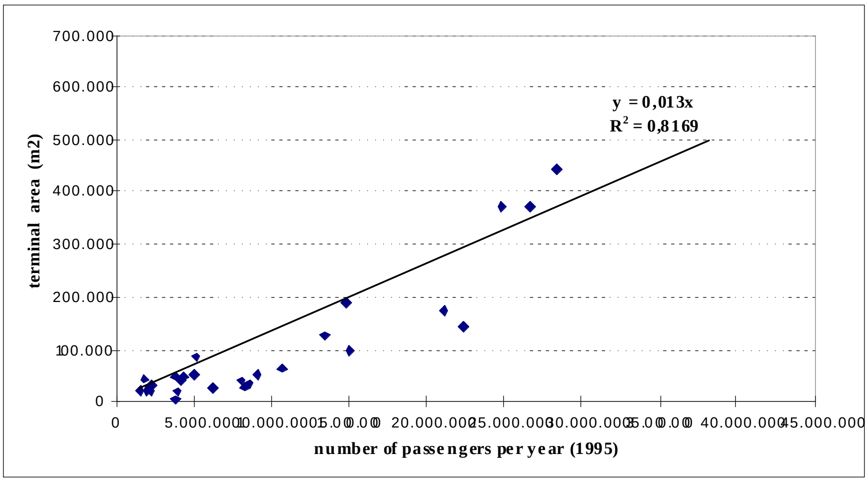
Other solutions could be as suggested above to develop regional airports. It is a solution which has already been adopted by some countries. ATAG shows that in most countries with many airports, airline operations grew more rapidly at regional (or secondary) airports than at the main airport. The types of operation which contributed to this trend were international short and medium-haul operations. However, the long–haul flights continued to be concentrated at the main airports. The airports authorities must take steps in order to use up more air traffic. This solution could be easily incorporated into the model as a possible solution of air congestion.

B5 CAPACITY QUANTIFICATION

The air capacity is not explicitly represented in the model but looking through the problems shown above we need to collect information on future year airport capacity data in order to include this feature in the model. These data are pointed out in Table B2. Even so, this information does not quantify the future capacity although it gives an indication on the planned development on each airport.

The ATAG report provides us information on some variables like: number of passengers per year, number of terminals and size (m^2), number of runways and length (m), declared runways capacity per hour (number of movements), average delay assumed (minutes) and declared terminal capacity per hour (number of passengers). In order to establish the relationship between the number of passengers and the area of the terminals, we have made the regression and the results are shown in the following figure:

Figure B5: Relationship between the number of passengers and the terminal area

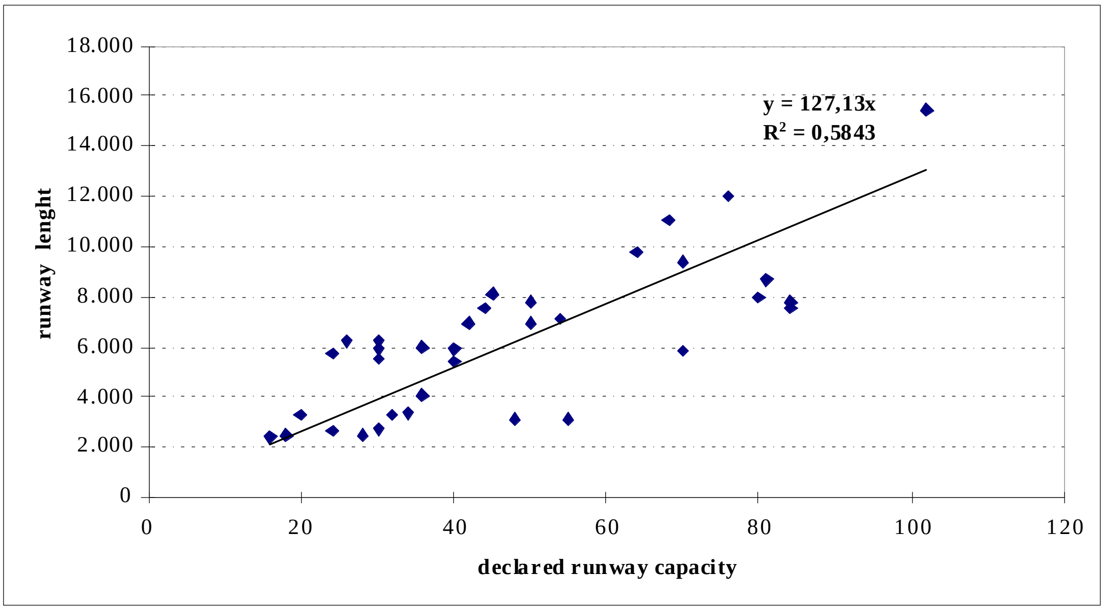


Source: Airport Capacity / Demand Profiles. 1998. ATAG.

This regression reflects that terminal size is positively correlated with the number of passengers. This means that if the number of passengers grow by 1,000,000 the size of the terminal must be increased in 13,000 m^2 in order to maintain the present level of congestion.

If we do the same, but comparing the length of the runways and the declared runway capacity per hour, we observe that this relationship is (as we supposed) positive. The following figure shows the results obtained in this case:

Figure B6: Relationship between the runway length and the declared runway capacity per hour



Source: Airport Capacity / Demand Profiles. 1998. ATAG.

The figure above reflects that the declared runway capacity is positively correlated (as we expected) with the length of the runway. However the R^2 is not very good, whereas it must be near to one. The reason could be that some airports with the same type of runways declare different runway capacity. This fact could be checked in Table B3.

Finally the following Table (B4) makes a summary of the information provided by the report 'Airport Capacity / Demand Profiles' published by ATAG. This table collects only a small number of the variables analysed in the publication.