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ASSESSMENT AND FURTHER DEVELOPMENT OF THE TREMOVE MODEL

Final Report

TRT Trasporti e Territorio

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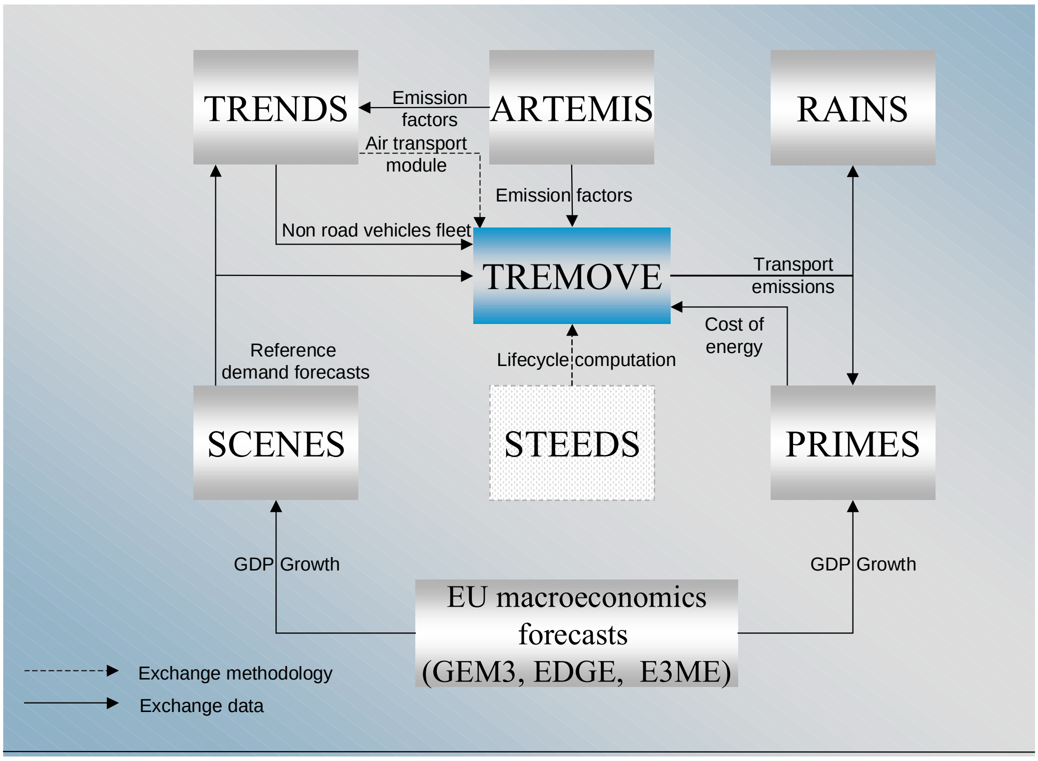
EXECUTIVE SUMMARY AND RECOMMENDATIONS

1. The TREMOVE model is an integrated simulation tool developed for strategic analysis of costs and effects of a wide range of policy instruments applicable to local, regional and European transport markets. The model was developed to support the policy assessment process within the framework of the Auto-Oil II Programme. In evaluating the opportunity of investing in further development of the TREMOVE model, the Commission requested an assessment of the model and its abilities to handle critical options and issues in strategic EU programmes for environment, transport and energy.

2. The assessment performed starts with a technical analysis of the TREMOVE model, focusing on its general structure, its main assumptions, and the content of its components. The weak and strong points of the model are derived and discussed. A set of comparisons is also derived from the main European models dealing with traffic and transport (SCENES, TRENDS, STEEDS and PRIMES). TREMOVE base case transport data result not too far apart from those of the other models. However, a stricter coordination of the quantitative base of the different European transport-related models emerges as an urgent need, in order to generate comparable results. The TREMOVE updating process may well become an occasion to work further on information requirements of European transport modelling.

   The main conclusions from the findings on its "internal" characteristics are favourable: TREMOVE looks both solid and consistent, its components are in general well balanced, and the results meaningful and allowing for important impacts on policy-making. Furthermore, the model seems capable of further extensions and developments without too radical modifications.

3. A second necessary step of the assessment regards the requirements expressed by a large set of parties involved, and especially by potential users. These requirements deal with policies to be tested, user friendliness, and other specific issues and components, but above all with the relations of TREMOVE with other European projects and models. This for two complementary goals: a) to avoid any waste of resources, doubling efforts already performed elsewhere, and b) to guarantee a consistent "general structure" of related models, capable of optimising a set of specific outputs and results. This "general structure", where the role and position of TREMOVE can be located, is illustrated in the picture.



4. From the previous analysis, a set of indications for improvements and developments of the TREMOVE model have been derived. The basic assumption is that any model can be extended to encompass almost everything, but this in general has little meaning, since the effectiveness of a tool is strictly linked with the specific target at which the tool is aimed. Furthermore, very large models tend both to become unfriendly for the users, and specially tend to be less transparent in their assumptions and their theoretical structure.

   The “optimal” degree of complexity of the future TREMOVE will depend also from factual, exogenous factors, like the resources allocated, the development of other, “parallel” models, and its final use by the policy-makers or by other parties involved. But all these suggestions keep both the basic structure and the intended aims of TREMOVE unvaried, i.e. focused on testing alternative policies on transport-related environmental impacts.

   Main advised extensions of the model concern:

   a) Geographical extensions, in order to include all the 15 EU Countries, Norway and Switzerland, the Accession countries, and more detailed regional and urban subdivisions within each country;

b) Scope extensions, to include more types of pollutants, new technologies, air and sea-shipping modes, lifecycle emissions, and more detailed transport demand characteristics;

c) Methodological extensions, to include explicitly the external social costs of the environmental impacts. This extension, nevertheless, is not supposed to change the basic structure of the model, that is a microeconomic and static one: external costs, within the dominant literature on the issue, are mainly based on microeconomic factors analysed in a static contest;

b) Links, both improved and new, with other models, in order to develop a consistent base of traffic data (mainly with SCENES). Eventually, a link with a macroeconomic model (ASTRA approach could be a possible reference) and a possible relation with a regional-land use model are envisaged; this is a challenging task not only for TREMOVE, and it is well worth an intellectual effort, given also the fact that its cost is probably limited. Recognising the theoretical difficulty of the task, probably an "internal" exploration is needed before any.

5. The final recommendations resulting from the TREMOVE assessment can be summarised in the following way.

The model is solid, consistent, and properly set in a context of other simulation and forecast tools. Therefore, it is worthwhile to invest more resources in order to obtain a more complete picture of the problems involved, and a more effective simulation of the policies considered.

An existing strategic transport model at the European level can provide the base case forecasts (i.e. no-policies scenario): a loose linkage between TREMOVE and SCENES is the suggested solution. The link with a transport forecasting model is also useful to provide a sensible classification of non-urban traffic between rural and highway, so that the appropriate emission factors can be applied.

With reference to the model accessibility, although the model should continue to be run by experienced modellers, a web site is recommended to be used to allow requests of simulations and to give access to simulation results.

It is also recommended to assure broad consensus about data and results among experts and stakeholders and to consider the possibility to have a formal approval/review from Member States, along the lines of the AOP II experience.

Further to the above general recommendations, a list of improvements is proposed: some of these improvements are considered indispensable, while

other ones, requiring a larger effort, can be considered more optional, depending both on the available resources and the specific interests of the stakeholders and final users involved. Therefore, the extensions proposed are organised within a hierarchy, going basically from the more simple and straightforward, to the more complex and resource-consuming.

6. Four options combining the suggested improvements are presented. The five general recommendations illustrated above are common to all options. It is important to remark that options are presented in "additive" terms (i.e. each options add some elements to the previous one), but this does not involve that elements included in option 1 are the most important. Options do not identify a hierarchy from the most relevant improvements to the less relevant ones. Instead, the options have been built with the aim of define "packages" of developments which describe different versions of the model, with an increasing level of complexity in terms of modelling requirements and data requirements. A given item can be included in the first options because is relatively easy and not because is considered more important than another. The recommended option for the TREMOVE development is option 3.

Option 1 concerns the extension of the scope of the model within the limits of the Western Europe and of road transport while keeping the current description of transport demand. The inclusion of Norway and Switzerland as well as a fully detailed description of all EU countries would allow a full coverage of Western Europe, where data are more readily available and reliable. The addition of new pollutants would allow a more complete computation of emissions and does not involve relevant modelling problems, provided that emission factors are available. Considering new motor/fuel technologies would allow to take into account the possible developments of vehicles fleet and simulate the effect of policies aiming at favouring cleaner vehicles; again the implementation should not be too complex provided that suitable parameters can be estimated. Computing the external costs of pollution would be straightforward as the amount of emissions is already calculated and would complete the description of external costs. Finally, the inclusion of lifecycle would enlarge the scope of the model to a relevant aspect with a limited methodological effort if the experience of other models is assumed.

Option 2 (which includes option 1) is focused on the enlargement of the scope of the model to non-road modes of transport. The addition of air and sea shipping and the computation of emissions for all modes would allow a better evaluation of policies taking into account the effects to all modes of transport. This task is not straightforward in modelling terms (e.g. the problem of representing international traffic should be solved) and requires a revision of demand categories, in order to identify correct sets of alternative

modes, more homogenous parameters and so on. In brief, this option adds significant modelling power at the price of a significant growth of complexity.

Option 3 consists in enlarging the model, with the enhancements envisaged in option 1 and 2, to Accession Countries. This option would allow to build an instrument to compare the situation of eastern Europe countries to EU with regard to a very important aspect like transport emissions. The difficulty here is data availability which is generally far less complete than for EU countries so that data collection and processing would likely require a considerable effort.

Option 4 concerns with long term further development. The aim of the work in this is option should be considered in terms of theoretical work for suggesting possible way to deal with the suggested further improvements (connection to land-use and macroeconomics models, improving spatial domains) which would be very interesting but involve demanding modelling problems. While items in the previous options can be considered as theoretically solved, the issues included here would need significant research work.

FINAL REPORT

1. INTRODUCTION

1.1 Background

The TREMOVE model is an integrated simulation tool developed for strategic analysis of costs and effects of a wide range of policy instruments applicable to local, regional and European transport markets. The model was developed to support the policy assessment process within the framework of the Auto-Oil II Programme and incorporates components of various models developed at European scale (TRENEN, EUCARS, FOREMOVE), the European Environmental Agency COPERT-II methodology and the EPEFE equations, to account for changes in the average fuel quality over time. TREMOVE is used to compute the effects of various types of policy measures on the key drivers of transport emissions. It belongs to the family of the integrated models, as it is composed of three inter-linked main simulation blocks: transport demand, vehicle stock and transport emissions.

The use of such simulation tools has increasingly become of general use in order to appreciate the impact of transport policies on the quality of the environment. This is reflected by the growing number of models and studies being developed and implemented under the European Commission umbrella and not only at the Directorate for the Environment (see recent studies and programmes managed by the Directorates for Transport and Energy and for Research).

Therefore in evaluating the opportunity of investing in further development of the TREMOVE model, the Commission wants to consider the features of the model itself as well as the results of the several R&D activities and models which have produced simulations of the impacts of transport policies on the environment after the completion of the second European Auto-Oil Programme (AOP II).

The Terms of Reference for the "Assessment and further development of the TREMOVE model" then ask for a well-specified development plan for an updated version of TREMOVE being based on:

- an assessment of the model and its abilities to handle critical options and issues in strategic EU programmes for environment, transport and energy;
- a clear understanding of the position of TREMOVE in the family of relevant models developed/improved in EU programmes;
- an analysis of links with existing network-based transport forecast models.

1.2 The study project

The study has been performed by TRT Trasporti e Territorio on behalf of the Directorate General for Environment of the European Commission.

An *ad hoc Steering Group* composed by representatives of different Commission Directorates has been set up for the purpose of giving directions to the technical assessment and also to support the study with first-hand information about European research activities and programmes in the same field.

Significant contribution to the assessment project has been supplied by the *Tremove Contact Group* which gathered experts around Europe with some connection to the TREMOVE model. The Group included the model developers, the Auto-Oil II Programme participants, representatives from Accession countries, experts from other related European projects, etc. The *Tremove Contact Group* first meeting was held during the first half of the assessment project and gave a open review of the comments and the expectations about the model development. The second meeting took place at the end of the project to discuss the draft final report prepared by the Consultant.

1.3 Structure of the report and its annexes

The report is composed by three main chapters. Chapter two is the analysis of the TREMOVE model, where the modelling framework is discussed in detail and a comparison of TREMOVE base case transport forecasts with other models is also reported. The following chapter three illustrates the discussion about the TREMOVE development and is mainly based on the contributions from the *ad hoc Steering Group* and the *Contact Group* experts.

The proposal for the way ahead with TREMOVE is presented in chapter four, including a ranking of the suggested improvements according to different options. Chapter five and six respectively contain the acknowledgements and the references for the preparation of the report.

There are then four annexes to the report: the first one provides more details about the comparison of TREMOVE base case transport scenario; the second one is a brief review of European strategic transport models that might provide a base case transport scenario to TREMOVE; the third one is the list of data needed to extend TREMOVE to the Accession countries and the last annex is the list of European environmental, transport and energy models and programmes in some way related to TREMOVE.

2. TECHNICAL ANALYSIS OF THE TREMOVE MODEL

In this chapter, the main features of the TREMOVE model are discussed. The analysis starts with a brief recall of what the TREMOVE model is. A detailed description of the model's components is not included; it can be found in Part II of the AOPII Cost-effectiveness study WG 7 report (AOPII, 1999).

After a brief presentation (section 2.1) extracted from the published documentation (AOPII, 1999), the main components of TREMOVE are analysed in terms of model design, assumptions, critical parameters, etc. Then a technical assessment is expressed for each component with reference to the theoretical design and its capability of reacting to different policies (section 2.2). Relevant parameters used in TREMOVE are also compared to literature values with the aim of examining their representativeness. A specific section is devoted to the comparison of TREMOVE transport base case scenario with other European models and studies (section 2.3). Strengths and weaknesses of TREMOVE structure are summarised in the last section 2.4.

2.1 The TREMOVE model

TREMOVE is an integrated simulation model developed for the strategic analysis of costs and effects of a wide range of policy instruments applicable to local, regional and European transport markets. The model has been developed to support the policy assessment process within the framework of the second European Auto-Oil Programme (AOPII). It has been used to simulate the impacts of the transport base case and the policy measures.

TREMOVE has been used to simulate consumer behaviour with regard to the choice of transport modes and vehicle types, to assess how these choices were affected by the introduction of various policy measures, and to assess what effects these choices had on emissions from the vehicle fleet. The authors stress that TREMOVE is a simulation model, not a transport-forecasting model: i.e. the equations in TREMOVE are specifically designed to analyse changes in behaviour as a result of changes in economic conditions, but incorporate few of the "dynamic" change relationships that would be required in a forecasting model (it relies on exogenous trends and demands for transportation). TREMOVE also incorporates equations to analyse changes in the environmental performance of the vehicle fleet as a result of changes in the technical features of the future fleet. Interactions are accounted for to the extent that the technical conditions influence the economic conditions and vice-versa.

The model describes annual transport flows, vehicle stocks and vehicle usage, and emissions across three modelling domains for each country considered, i.e., a sample-city, the other urban areas and the non-urban areas. Nine countries and ten so-called OPII-cities are covered. The time horizon ranges from 1990 through 2020 with

annual intervals: the base case data include historical data over the period 1990-1996 and forecast data for the period 1997-2020.

The transport flows covered by TREMOVE include those for on-road passenger and freight transport, rail (both metro and train) passenger and freight transport, and in-land waterway freight transport. Vehicle stocks and usage are specified for a wide range of passenger and freight vehicles, including motorcycles. The main pollutants covered are CO, NO_x, VOC (broken down into methane and non-methane VOCs), benzene, and PM_{10}. In addition, other emissions can be calculated such as CO_2 and SO_2.

TREMOVE computes the effects of transport policy measures on the key drivers of transport emissions, i.e. the size and composition of the vehicle stock and vehicle usage. The transport policy measures that can be analysed include emission abatement technologies for vehicles, fuel quality and alternative fuels specifications, inspection and maintenance, non-technical and fiscal measures. The cost modelled in TREMOVE is the total cost to society, including the cost to transport users, the costs to transport producers, and the cost to governments.

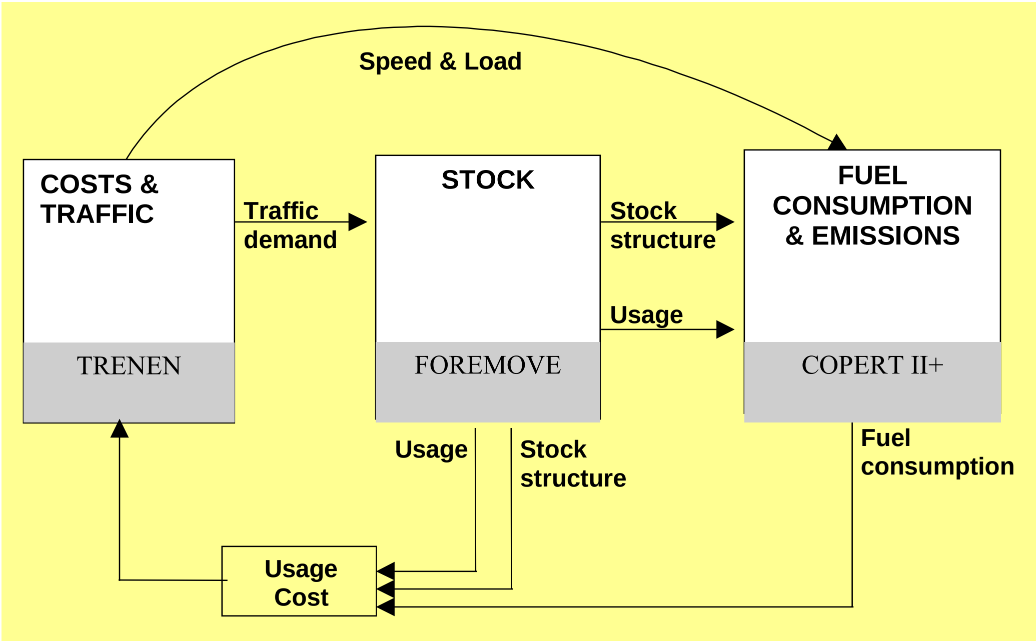
A simplified illustration of the TREMOVE modules is provided in Figure 2.1. The first module "TRE" is adapted from the TRENEN model. It describes the users' decision making process when it comes to making their modal choice. The second module, "MOVE", is adapted from the FOREMOVE and EUCARS models. This vehicle stock and usage module describes how changes in demand for transport across modes or changes in price structure influence the number and types of vehicles in the stock. The third module (also referred to as "MOVE") is also adapted from on the FOREMOVE methodology and includes the COPERT II methodology. This module is used to calculate fuel consumption and emissions, based on the structure of the vehicle stock and the number of kilometres driven by each type of vehicle.

When a policy measure is introduced, such as a fuel tax or a tightening of a speed limit, transport users will adjust their behaviour, some reducing their demand for transport and some switching to a different mode. Based on the total demand for "kilometres" on each mode, the model calculates what the implications will be for the next vehicle stock vintage and the average usage of the vehicles. Because of the need to account for these interactions, the three modules in TREMOVE cannot be run separately, as inputs and outputs from both parts are required at all times. The detailed model structure shown in Figure 2.2 holds for every year and region considered: every year from 1990 until 2020 is linked to the previous year via the stock of transport means and the available infrastructure (but not via the total transport demand which is exogenous every year).

Within each country domain or regional module, passenger and freight transport is analysed simultaneously. Both use the same road network, and influence each other through congestion. For example, increased road congestion due to heavier truck

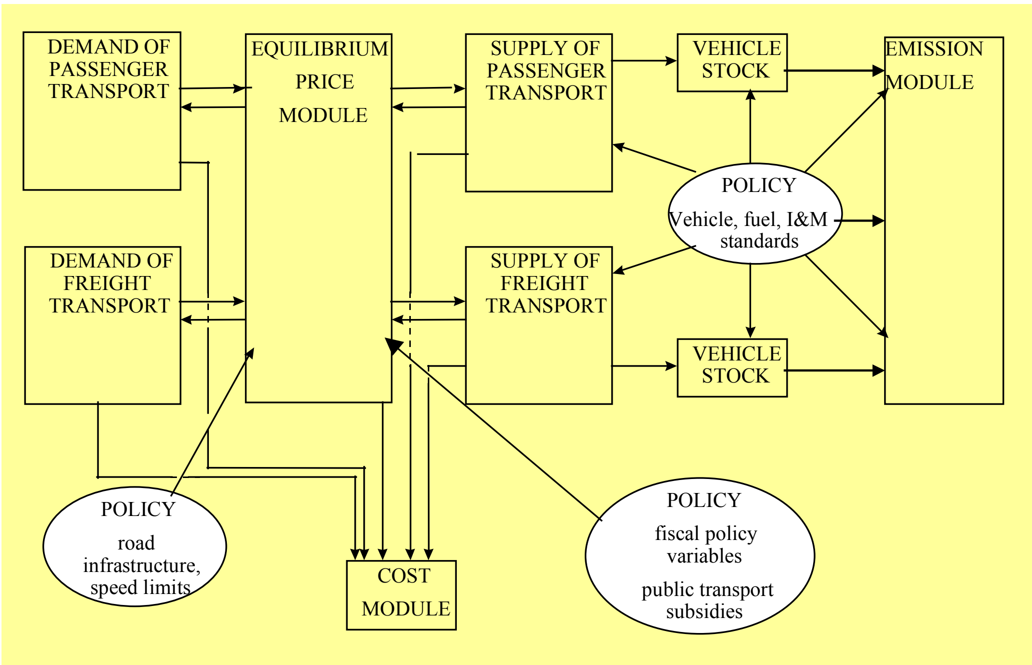
traffic will influence passenger transport flows, causing some road transport users to shift to another mode, such as trams & metros.

Fig. 2.1 The TREMOVE modules



Source: AOPII, 1999

Fig. 2.2 Overview of the TREMOVE model structure



Source: AOPII, 1999

Policies simulated by TREMOVE belong to the three main categories:

- Vehicle technologies and fuels: motorcycles technology, early introduction of advanced technologies, fuel quality, alternative fuels (GNG, LPG, FAME and E85G).
- Non-technical measures: urban road capacity, urban public transport misutilisation, urban public transport fares, city logistic, park pricing and road pricing, scrappage schemes.
- Fiscal measures: fuel excise rates, tax structure, diesel and petrol taxation ratio, promotion of clean vehicles.

Policy measures results are presented in terms of percentage changes of relevant variables in comparison to the base case scenario.

2.1.1 The model software and implementation

The TREMOVE model software is programmed in GAMS language. The current user interface to the TREMOVE models can be characterised as follows:

- The data for the countries are maintained as Excel files.
- These Excel files have to be exported to a GAMS readable format by the modelling
- The simulation runs have to be started through either a set of batch files or through the GAMS IDE. The duration of a simulation run for one country depends on the available computer but is in the range of 5 to 10 minutes.
- The output of a simulation is being saved as a csv-file (comma separated values), which has to be imported back to Excel.

A link between these spreadsheets and the input files required for the models has not been implemented and thus, every time the spreadsheets are modified, they have to be exported to the GAMS input files manually. The process of setting up scenarios for simulations requires human interaction and is error prone. This approach was appropriate during the development phase, but certainly needs to be automated and made more robust. In the GAMS short term expertise (Gams, 1999) some suggestions about the improvement of the software code were put forward (see box 2.1 for a summary of a selection of the proposed items).

Box 2.1 Review of the TREMOVE model software

Proposed computer technical improvements to the model code and suggestions for further modelling work

- *Development of a model structure with less country specific model files*. Currently the TREMOVE models are a collection of different files for each country. Some of them are shared between all countries, other files are country specific. This is natural for country specific data sets, but within some TREMOVE models, it is also the case for other files. It should be possible to reorganise the TREMOVE models in order to have only one file which contains country specific data.

- *Implementation of more sophisticated solution strategies*. During a simulation run a large number of small non-linear programs have to be solved. This includes providing initial values for the optimisation but also an improved scaling of the variables. Depending on data, scenario definitions and used solver, some of these solutions may fail and the entire simulation run is void. Enhancements to the optimisation model could improve this aspect.

- *Tuning of parts of the GAMS code*. Substantial time is required to carry out simulations. It takes currently about one hour to run a TREMOVE simulation for all countries on a PC. This time could be improved by re-writing some part of the code (some arrays, loops, etc.). Currently the optimisation part of the TREMOVE models is formulated as a non-linear problem and solved with a general-purpose code for non-linear problems (MINOS). A reformulation of the model as mixed complementary problem (MCP) may provide more robust solutions and may also lead to faster solution times for larger problems. Tuning of the parts of the GAMS code in connection with some specific enhancements to the GAMS system could dramatically improve performance (improvements by a factor of 5 to 10 could be expected).

- *Improved link to spreadsheets (Excel)*. The process for generating scenarios and reports is currently cumbersome. Some of the steps can be automated, there are free tools available Excel macros to export and import data from and to GAMS could be written.

- *Development of the TREMOVE models should be done in a platform independent form*. A tight integration into a currently available technique may have some advantages on the short run but leads to higher maintenance costs. A web based front end to the TREMOVE system is one of the options for the future. The GAMS system is available on all major platforms.

- (…..)

Source: GAMS (1999)

2.2 Analysis of TREMOVE components

2.2.1 Spatial representation

The TREMOVE model simulates demand in three different spatial contexts for nine EU countries[1]:

- ten sample cities[2];
- other urban areas;
- non-urban areas.

For the remaining six EU countries, results are extrapolated according to a simplified methodology, that is computing emissions for each vehicle category on the basis of the average emission factors of a "similar" country (the similar country being chosen in the list of nine countries analysed in detail[3]). As the AOPII report says, this method implies many assumptions and less reliable results are unavoidable.

The demand generated in each country includes both the domestic one and the part of international demand on the national territory[4]. As a consequence, policy measures cannot induce a displacement of transport demand from one country to another.

The choice of distinguishing urban and non-urban areas is important with respect to the calculation of emissions because of the very different driving conditions in the two contexts.

Within each country, the three spatial domains are independent to each other, that is demand cannot shift from one domains to each other. Some possible reactions of demand to policy changes are not addressed by such a structure: i.e. faced with a change in the cost of urban transport, the user will adjust his or her behaviour within the city (reducing his mileage or shifting to another transport mode) but will not exit the city to move into a rural area or another city. Natural migration patterns between

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1 Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Spain, United Kingdom.

2 Athens, Berlin, Cologne, Dublin, Helsinki, Utrecht, London, Lyon, Madrid and Milan. The ten sample cities had been selected by the Urban Impact Assessment project of AOP II for a detailed examination of air quality using an integrated methodology developed by JRC.

3 Similarity is defined as a country in which climatic conditions are similar, and which have reached a similar level of economic development. See AOPII Cost-effectiveness study report – Part III for more details.

4 Although there are then no explicit links between countries, the nine models take into account international trade and transport in the base case

cities or between cities and rural areas are taken into account in the base case, but they are not influenced by the policy measures to be tested.

In addition, while urban traffic can increase or decrease without effects on non-urban one, the reverse case hardly applies (because most of the trips start and/or end in an urban area). Thus, in principle it should be the case that changes of non-urban traffic are reflected in urban traffic.

2.2.2 Transport demand

The model simulates both passenger and freight demand in terms of passengers*km and tonnes*km. On the passenger side, two different demand categories are considered with reference to urban areas: inhabitants and commuters. The distinction is useful as elements like average distances, available modes, etc. are significantly different in the two cases. However, commuters and inhabitants model parameters are not distinguished according to the trip purpose, although in the scientific literature elasticities of demand are usually considered dependent on this element (Trace, 1998) and also monetary perceived costs can be different by trip purpose.

The model initially calculates the demand for passenger transport per individual for a certain mode in peak or off-peak Each individual of a group (inhabitants or commuters) is supposed to have the same average demand. Consequently the total demand of a group is equal to: (demand per individual for the relevant year)*(number of group-members for the relevant year). The demand per individual, for inhabitants or commuters, is a function of: generalised prices for the different modes per pkm, preferences (i.e. elasticities of substitution) and total income. The demand per individual inhabitant is not necessarily equal to the demand per individual commuter and the ratio of inhabitants-demand to commuters-demand changes over time

The proportions of inhabitants and commuters in the total regional population change over time. As a consequence, the proportion of transport demand of inhabitants/commuters in the total transport demand changes over time. However, the trend is exogenous, that is if a given policy had the effect of pushing people out of urban areas (for instance, increasing parking costs) this would not be simulated by the model in terms of an increment of commuting.

Freight transport is split into urban and non-urban without any further classification. As for passengers, the scientific literature often considers elasticities as dependent on demand segments (i.e. the type of commodity), see for instance, Fowkes, A. Tweddle G., (1992), Widlert, S., Bradley, M., (1992),

2.2.3 Demand development over time

The overall demand development in each year and for each spatial context of each country is determined according to population and production trends, which are pre-determined as exogenous variables. In each year and in each domain policies can vary the amount of traffic of the base case, as there is a response to changes of generalised costs.

Considering that TREMOVE is not a transport forecasting model, the transport demand trends in the future were derived form existing national forecasts (and for those countries where forecasts were missing simple forecasting rules were used): given the forecasts for transport demand for the different modes in, say 2010, TREMOVE is (only) able to compute how a certain policy would influence transport demand in that year. If no policy is applied, transport demand calculated by TREMOVE will be exactly the same as the transport demand stated in the base case data. If a policy is applied (for instance, if a fuel tax policy is applied from 2005 onwards), generalised costs of car and truck transport will rise: using the calibrated demand model, the demand for all modes will be calculated and will not be equal to the base case.

However such changes are not cumulative over time, in the sense that in one year the effect of policies is computed with respect to the base case level: the level of demand in one year does not affect the level of subsequent years.

In this respect it could be noticed what has been applied in the STEEDS model where the annual feedback loop between the demand and stock models allows the changes in vehicle stock/costs in year x (as a result of policies in year x) to influence the demand calculation for year x+1 (STEEDS, 2000). In TREMOVE there is a connection between one year and the following one in the fleet module, because the number of new vehicles required is computed according to the difference between the fleet needed for current demand and the fleet existing in previous years. However, this connection assumes demand and does not modify it.

In brief, the way the demand is represented makes the model able to simulate the effects of policies only in a "static" way on a yearly basis; thus dynamic phenomena over time are not captured.

2.2.4 Transport modes

Transport modes available to passenger demand are: car (further divided into driving alone or pooling[5] and into small and big cars), bus, metro, train, motorcycles and

[5] The alternative "Pooling " includes Taxi.

non-motorised (only in urban areas). The range of the alternatives is complete for shorter and medium-distance trips, while air transport is not present.

Transport modes available to freight demand are: trucks (further divided into small trucks and big trucks), rail and inland navigation. Sea shipping is not included in the alternatives.

2.2.5 Simulation of choices

The choice process in TREMOVE is represented according to a utility tree that has several branches and levels, each representing one option that is an aggregate of (at least) two options at the next lower level of the utility tree. A change in the price of one transport mode does not only affect the demand for that transport mode, but, through the utility tree, the demand for all other transport modes as well (because they are in one way or another substitutes of that transport mode). At each level of the utility tree, a CES (Constant Elasticity of Substitution) demand function is specified for each option available at that level. CES (Constant Elasticity of Substitution) demand function type are not commonly used in models simulating transport choices, where Logit algorithms, based on Random Utility Theory (Ben Akiva, Lerman, 1984) are usually preferred.

The utility tree allows to use a unique structure to simulate first the choice between travelling and consuming other goods (moving goods and increasing other inputs for freight), then the time of departure, then the transport mode and so on. The utility tree links directly the departure time choice to the modal choice, allowing a shift from peak to off-peak hours, for instance, if peak tolls are applied.

The use of a utility tree with constant elasticity of substitution implies that the choice between two alternatives at a given level of the tree is not dependent on the choices between the alternatives at lower levels. For instance, the elasticity of substitution between public transport and private transport is the same whatever the choice between alternative public modes (e.g. bus or train) is.

The independent terms of the demand functions used in the TREMOVE model are the generalised costs of each alternative. The generalised cost is made up of the monetary cost for the users and the monetary equivalent of time (see following section 2.2.6). This variable can well be considered the main explanatory element of choice, but it is not the only element. The choice between public and private transport is often due also to qualitative elements (like comfort, reliability, etc.) as well as habits, prejudices and so on. Such elements are normally summarised by means of suitable modal constants in a discrete choice framework. In the TREMOVE model some “level” parameters are calibrated in order to reproduce the observed base case data. In this way the model can deal with preferences which are not explained by relative generalised prices, but by qualitative changes of the alternatives. The role of “level” parameters is therefore equivalent to “modal constants” used in Random

Utility Models. It could be said that thanks to such parameters the model knows that even if generalised cost of car and bus, say, is the same, car will have a higher modal share.

Being the structure of the model pivoted on elasticities of substitution, its capability of simulating correctly the effects of policies affecting the relative prices of alternatives is strictly linked to the values of such elasticities.

From the elasticity of substitution, which are the parameters directly used in TREMOVE, and given the structure of the model, implicit elasticities of demand with respect to cost can be derived. A sample of values regarding private modes is reported in Annex A of Part II of the AOP II Cost-effectiveness study. In the same annex some literature figures are shown. The figures drawn from the model are of the same size of the literature ones. Most of the short-run elasticities with respect to fuel price lie in the interval 0.05 - 0.2 (with negative values) and the same applies for the TREMOVE values. Other literature figures can be drawn from the European project TRACE (1998). From this source elasticities are sometimes slightly higher, but still the values compare well to the TREMOVE figures. In AOP II report own elasticities of bus and train are not shown.

It should be considered that transport demand in TREMOVE is highly aggregated and this prevents the use of specific parameters for different segments of demand. The identification of segments which are more homogenous in their response to market changes (and thus in their elasticity) might be a useful improvement.

2.2.6 Monetary and generalised costs

The choice between alternatives in the model is driven by the generalised cost, which is defined as a monetary cost plus taxes or subsidies plus the correspondent in monetary terms of travel time. In the following, the computation of costs is discussed for each mode, the values of time used are presented afterwards.

Cars

The cost of using car is the sum of different elements: purchase, maintenance, insurance and fuel (resource costs) and taxes (both on vehicle and on fuel). Fuel costs and taxes are calculated based on the consumption factors (COPERT II), fuel prices and fuel excise rates. The fuel costs and taxes for a mode (big or small cars) are a weighted average of the fuel costs and fuel taxes for all vehicle-types in this mode (vehicle-types are classified with respect to type of fuel, technology, vintage, size). The resource taxes and resource costs are also a weighted average over all relevant vehicle types.

Car costs are computed according to the elements above for all demand segments (i.e. both inhabitants and commuters for passenger trips). If a different segmentation

was considered (e.g. working trips and non-working trips as suggested below) attention should be paid to the elements used to compute car costs for each segment. In fact, for non-work trips usually only fuel cost is accounted (SCENES, 2000) because it is assumed that for non-work trips, the choice of using car or not is only weakly linked to the choice of purchasing the vehicle, whereas this link is much stronger for work trips. Since the TREMOVE model does not distinguish between working and not-working trips, the choice of considering all costs can be accepted, but an overestimation of car perceived costs is a likely consequence.

Public transport

For public transport, a function of fixed and variable costs, plus subsidies, is used. The inclusion of subsidies is here relevant to take into account the difference between producer and user costs, which is usually very important. A more refined way of modelling costs to take into account special fares (e.g. monthly tickets, discounted tariffs for students) would require the definition of more demand segments (e.g. working trips, non-working trips).

Road freight vehicles

The cost calculation of using road freight vehicles is the same as for cars - i.e. the sum of purchase, maintenance, insurance and fuel plus taxes - but an additional term, that is drivers' wage, is accounted.

Non-road freight modes

The cost of using non-road freight modes (i.e. train and inland waterways) is computed as operating costs plus taxes and subsidies.

Value of time

The generalised cost is computed adding the value of travel time to the monetary cost. The inclusion of transport time, put into monetary value by means of values of time, is the standard way of considering the variable "time" in choices relating to transport. The Values of Time (VOTs) used in TREMOVE are reported in the base case data source files. As for elasticities, values can be compared to literature figures.

The TRACE report quoted above collects several values from a number of studies in different countries. Such values are very variable depending on a number of factors like the country where the study has been carried out, the context (e.g. mode choice or not), the population surveyed (e.g. drivers, public transport users, etc.) and so on. Thus values range from less than 5 EURO/hour to more than 20 EURO/hour[6].

[6] All values are expressed in 1998 EURO.

Most of the VOTs concerning car users for commuting or other reasons are between 5 and 8 EURO/hour. VOTs for Employer's business are higher, around 15-20 EURO/hour. The values used in TREMOVE for year 1998 were 7.38 EURO/hour (off-peak) and 8.20 EURO/hour (peak). Since commuting and non working purposes constitute the vast majority of trips, such VOTs look very consistent with the TRACE ones.

Regarding public transport, TREMOVE uses values of 4.44 and 4.87 (off-peak and peak respectively) for bus and metro, while for train VOTs are 5.36 and 6.12. Most of the VOTs reported by TRACE for bus and metro lie in the interval 1.5 – 5 EURO/hour with higher values around to 15 EURO/hour for business trips. TREMOVE values are therefore in line with such estimates. TRACE VOTs regarding train are very variable with some very small value (around 1.5 EURO/hour) but the range 5 – 8 EURO/hour is the most representative. As for bus, 15 EURO/h can be considered as an average estimate of business VOT. In general, VOTs of rail users looks a bit higher than those of bus users and this is reflected in the TREMOVE values as well.

From the analysis above it is apparent that different values of time are used according to the transport mode. In principle the same value of time should apply to all modes when the modal choice is the object of the analysis because value of time belongs to who makes the choice not to the objects of the choice. Although also literature values reported are different by mode, this is an *ex-post* consequence of the choice (i.e., rail users are likely to have a lower value of time than car users); *ex-ante* the use of a single VOT for each class of demand would be preferable. In addition it would be worth to consider the possibility to distinguish between peak and off-peak.

2.2.7 Transport time and congestion

Transport time of road modes is an endogenous variable computed by the model according to the total volume of traffic. An exponential speed-flow function is used. The volume of traffic is computed in car units; buses and freight vehicles correspond to two car units. The transport time is computed independently for different types of roads (urban, motorways, etc.) with different coefficients.

The calculation of transport time according to speed-flow functions for different types of roads would require an explicit network and is not included. The treatment of capacity is therefore not very sophisticated in TREMOVE, however at this scale of application, capacity representation is necessarily rough. An aggregate speed-flow curve seems to be an appropriate tool for the TREMOVE level of detail, provided that they are correctly calibrated. A more detailed simulation of congestion would require a deep change of the philosophy of the model, that is a tight connection with a transport model where an explicit network is simulated.

It is however important to note that the relation used does not take into account the differences between the EU countries and, more important, the growth of network capacity. As such, a growth of traffic leads always to higher times: as the total capacity of infrastructure could be growing through the years, travel time might be overestimated in the model simulations.

2.2.8 Fleet module

The fleet module of TREMOVE is very detailed. It is divided into a number of groups, according to cubic capacity and type of fuel. On the one side, each vehicle type is further divided into fifteen subgroups representing the age of the vehicle. On the other side, some vehicle types are grouped into "macro-types" used in modelling the transport activities[7].

The total number of vehicles required depends on the volume of traffic for each "macro-type" according to the average annual mileage (different by macro-type of vehicle and changing over time). The number of new vehicles depends on the difference between the desired fleet and the current fleet minus the scrapped vehicles.

The scrapped vehicles are function of a breakdown probability (increasing with age) and repairing cost. Once the number of new vehicles of a macro-type is defined, a second module rules the subsequent choice among the different type of vehicles within the macro-type itself.

Eventually, vehicles per type are also distributed according to their technology (e.g. EURO categories) by using suitable assumptions on the share of each technology group for the vehicles sold in a given year.

Among vehicle types, one category for future introduction of different categories (e.g. new fuels) is included. If two or more new categories were of interests, new types should be included.

2.2.9 Fuel consumption and emissions

In TREMOVE, the calculation of emissions applies basically the COPERT II methodology. The use of such a methodology is a positive feature of the TREMOVE model, which can benefit of a consolidated approach. Currently such a methodology has been enhanced and a COPERT III has been released with a number of improvements (Ntziachristos, Samaras, 2000). Part of such improvements - mainly

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[7] The choice of the size of car is part of the tree of choices which starts from the "travelling-not travelling" alternative in the TRE module of TREMOVE: such a choice is between a small car and a large car. In the fleet module, large cars are further detailed according cubic capacity and type of fuel. Thus "large car" represents a macro-type.

those relating to future EURO categories and catalysts - are already considered in TREMOVE.

On the other side, the methodology is based on assumptions which can be discussed on the light of the results of other studies (ARTEMIS and PREMTECH II[8]). First, the emission factors depend essentially on average speed assuming that any information about driving cycle is summarised by the road class (urban, extra-urban, highway). Second, the emission factors for a given speed in given conditions are actually not fixed values, but show a significant variability, so the amount of emissions estimated is an average with a non negligible interval of confidence around it. Third, the emission factors of future vehicles (e.g. future EURO classes) are decreased exactly as much as the emission limits do (i.e. if emission limit for a given pollutant is reduced by one half, the average emission factor is reduced by one half as well), which is a simplified assumption.

While TREMOVE anticipate COPERT III for some improvements, it does not cover all the pollutants included in COPERT III: Ammonia (NH_3), Polyciclyc Aromatic Hydrocarbons (PAHs), Persistent Organic Pollutants (POPs), Dioxins and Furans as well as heavy metals included in the fuels are not present in TREMOVE. Also lifecycle emissions are not computed in TREMOVE.

When the TREMOVE model is further developed, the differences between the fuel consumption in the base case and the fuel consumption according to the energy balances (e.g. from Eurostat) need to looked at very carefully. An appropriate calibration process needs to be established to verify that, taking into account e.g. fuel consumed by non transport vehicles, "non residents" and other use of fuel, the model would not lead into an under or overestimation of fuel consumption in transport sector. This requirement is even more important if the model is used to analyse issues which go beyond a cost-effectiveness analysis of emissions reductions.

2.2.10 Social costs

The computation of social costs applies a classical welfare-economics framework. The utility function, which is specified to compute the equilibrium quantity of demand, is used to derive the consumer surplus given the demand function where generalised prices are the independent variables.

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8 The TREMOVE model will be adapted to the scope of the PREMTECH II network (2001-2004), whose interest is addressed to the evaluation of each technology contribution in reducing CO_2 and pollutants. The model development activity will be carried out by the Catholic University of Leuven and will be co-ordinated with the technology platforms D-ULEV, GET-CO_2 and SUVA. Such platforms of the Premtech network will develop fuel–efficient / low CO_2-emitting vehicle-technologies. D-ULEVwill be focused on low CO_2 diesel passenger cars, SUVA will deal with hybrid cars diesel – electricity and GET-CO_2 will consider advanced gasoline powertrains for reduced fuel consumption and CO_2-emissions. A modified version of Tremove will be used to analyse the effects of the new types of cars on the car market.

In this way, as the utility function includes all the alternatives, the variation of consumer surplus can be computed for all markets at once, without the need of repeating the calculation for each market (e.g. car, public transport), which would be a complex tasks given the interactions among alternatives.

A measure of marginal cost of public funds is further added in order to take into account the orthodox notion of efficiency loss due to taxes. Indeed, in the model the tax leverage is used in a neutral way (e.g. additional taxes levied on transport demand are counterbalanced by lower income taxes). This involves that demand reacts in different way when the resource cost is increased or when taxes are increased of the same amount. For instance, if fuel price increases of a given amount, consumers will lower their car and motorcycle transport demand in favour of public transport and other goods; if fuel taxes increases of the same amount, then the model considers a reduction of income taxes and so average income grows partially counterbalancing the demand decrement (see box 2.2). Here the microeconomic content of the model shows some limit: in fact the impact of reduced taxation is assumed only as felt by households, while in a dynamic context also firms will benefit from increased demand and reduced labour costs, generating in turn more traffic etc.

TREMOVE adopts a value of 1.2 for the marginal cost of public funds. This value is used to "weight" the discouraging effect of tax pressure on the economy. In some literature other estimates of such an element can be found, but not so frequently yet. For example, a recent macroeconomic model for Italy derives a value of approximately 1.13[9], quite consistent with the one of TREMOVE. The rationale of this parameter can be found within the Maastricht constraints: if a goal of reducing the overall fiscal pressure is set and politically accepted, a shadow price for the related constraint has to be derived, as it has to be done for every economic constraint. This shadow price is the marginal opportunity cost of public funds, a concept certainly not acceptable within a strict Keynesian context.

9 TRT elaboration on the basis of Fiorito (2000)

Box 2.2 Impacts of two different policies increasing fuel price

Two different policies to assess the impact of the increase of fuel price were tested with the TREMOVE model by the Environment, Transport and Energy Policies unit of the Economic Evaluation Service of DG ECFIN:

1. an increase in 85.9% of the fuel price before tax (corresponding with a crude oil price around 30$/barrel);
2. an increase of excise duties leading to the same price increase (for gasoline and diesel) than policy one;

In both policies it was supposed no variation in the exchange rate, taxation and profit margins of the fuel production and distribution firms, in order to compare more easily the effects in the transport sector. The results of the simulations were compared with the Auto-Oil II Programme base case at the year 2010.

On the side of passenger demand, the decrease for policy two is lower than policy one and complemented with a strong increase in bus transport. At the opposite, the increase in excise duties leads to a stronger impact on freight transport (-3.2% instead of –1.2% of policy one). The examination of the cost to society and its decomposition provides essential information for understanding this difference between the two simulations. Indeed the major difference is in the government component: the increase in excise duties (policy 2) leads to a substantial increase of fiscal revenues. TREMOVE model assumes that this 'benefit to the State' is partially returned to households, relying on a strong hypothesis that the revenue is recycled in a reduction of labour taxes filtered by the 'marginal cost of public funding'.

Due to the increase in household income, the demand for passenger transport is boosted, and the final decrease in the demand is lower than for policy one (-0.7% instead of -0.9% pkm). This leads to a reduced improvement in pollutant emissions levels in policy two, except for PM, due to the stronger decrease in road freight demand. The cost for consumers and freight transport is also higher than for policy one, due to higher travel times.

In brief, the difference between the two policies is due to the existence of an 'income effect', based on the fiscal revenues from the increase in excise duties (policy two) partially recycled in the transport demand, boosting road transport demand and leading to a smaller decrease in the pollutant emissions. Such an income effect does not appear in freight transport (and this needs further elaboration, since it is an outcome not fully explicable).

Furthermore, in policy one there is no consideration that profits from higher fuel prices might be partially recycled into the domestic economy, leading to a smaller income effect in this case as well.

Source: Environment, Transport and Energy Policies unit - Economic Evaluation Service - DG ECFIN, internal note, October 2001.

In addition of internal transport costs, some external costs are considered, namely noise and accident. They are accounted by means of marginal costs applied to the volume of traffic. Although the size of pollution is calculated (see section 2.2.9 above) its external cost is not computed among social costs.

In general, the whole microeconomic structure is well established in the mainstream theory and it looks as one of the most robust part of the TREMOVE model.

2.3 Comparison of base case transport forecasts

The base case scenario for passenger and freight transport is exogenously defined in TREMOVE. The model uses external data collected from a variety of sources at national level, including public organisations, transport authorities, transport ministries, private consultants. It is important then to compare the base case values used in the model with estimations provided by other models.

It should be recalled that great care was devoted in the Auto-Oil II Programme in the involvement of the stakeholders and member States in the modelling analysis. TREMOVE base case data then reached a broad consensus among the participants of the Programme, as this was the pre-requisite for the acceptance of the policy simulation results produced by the TREMOVE model. This means that even though the base case scenario is not built as a coherent picture, it reflects the approved specific forecasts of the nine member States modelled[10].

TREMOVE base case transport data results not too far apart from those of the other models, however, a more strict coordination of the quantitative base of the different European transport - related models emerges as an urgent need, in order to generate comparable results. In fact, it is well acceptable that different methodologies, different policy goals and different assumptions produce different outcomes from the models employed. What is unnecessary is that factual inputs, as traffic quantities, are also different only for lack of co-ordination. The TREMOVE updating process may well become an occasion to work further on this basic aspect of European transport modelling.

2.3.1 Comparison with SCENES and TRENDS

In the context of this technical assessment, TREMOVE base case scenario was compared with the corresponding data from the SCENES model (SCENES, 2001) and from the TRENDS used in the INFRAS-IWW study on external costs of transport (INFRAS-IWW, 2000).

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10 Traffic forecasts supplied by Member States in some cases show very high growth (of about 2% per annum).

Summing up, the traffic data used by TREMOVE is generally consistent with the other two models'. There are some specific figures where differences are high. The causes of such differences are hard to be explained and can probably be attached to the sources used by each model. The three databases were built independently to each other and even if they have some basic sources in common (e.g. EUROSTAT figures of transport), the information collected was elaborated case by case in order to match the specific requirements of each application. For instance, SCENES is a strategic transport model, its forecasts are the outcome of a complex modelling process where the trend of each mode is appraised endogenously starting from assumptions about the development of trades, production, supply conditions and so on. In TREMOVE as well as in TRENDS, the evolution of demand is not the result of a model but it is estimated exogenously under a different set of assumptions. Aggregated tables and country level demand data are reported in annex 1 (section A1.1).

From such a comparison it can be argued that a common scenario used by all European projects would mean saving time and allowing to identify the specific results of each model with reference to a unique consistent basis.

2.3.2 Comparison with STEEDS

In the STEEDS project a direct comparison between STEEDS and TREMOVE base case scenarios was performed (STEEDS, 1999). Two major European countries were chosen for such a test: Germany and the UK. The comparison is quite detailed and includes indicators of transport demand, vehicle stock and emissions of various pollutants, primarily for road transport. Its outcome is positive, which means that the two models are on the same alignment. More details on comparison are reported in annex 1 (section A1.2).

2.3.3 Comparison with PRIMES

The future transport demand estimated by the PRIMES model (National Technical University of Athens) was compared with TREMOVE results by AEA Technology in the context of a study considering options to reduce greenhouse gas emissions from transport, and using a 'bottom up' approach to assess the cost-effectiveness of options and the reductions it might achieve (AEA Technology, 2001).

According to the report, a comparison of pkm, tkm and vkm, between PRIMES and TREMOVE for the nine Member States modelled in TREMOVE showed that:

- Total passenger traffic demand (pkm) in TREMOVE is generally slightly higher and increases more between 1990 and 2010, leading to a greater difference in 2010.

- Passenger car pkm, vkm and vehicle load factors compare reasonably well, although, unlike PRIMES, TREMOVE load factors change over time.

- Bus and coach load factors are higher in PRIMES leading to lower vehicle kilometres despite transport demand being fairly similar.

- Freight demand (in tkm) is significantly higher in TREMOVE (by 30% in 1990 and 50% in 2010) and vehicle load factors significantly lower giving much higher vkms[11], even though this difference is only partially accounted for by the differences between the vehicle load values used in the different models.

- Truck tkm, vkm and vehicle load factors generally do not compare well across all the 9 EU Member States modelled.

The report conclusion is that the alignment between PRIMES and TREMOVE predictions is satisfactory on the EU scale with the exception of the truck category where TREMOVE transport demand estimates are 30-50% larger. However, on the Member State level, predictions can vary considerably for buses and coaches as well as motorcycle categories. Predictions of car transport activities tend to remain fairly similar with only a few exceptions. New work on modelling energy demand in transport with PRIMES is underway.

2.4 Summary of the analysis: strengths and weaknesses of TREMOVE

Summing up the analysis in the sections above, the main strengths of the TREMOVE model are:

- the modular structure by country, which allows for separate analysis of policies aimed at regional emission reduction;

- the use of different spatial domains (urban and non-urban) for a more correct computation of emissions;

- the explicit simulation of the choice between travelling or not;

- the endogenous computation of travel time, according to a speed-flow curve, which interacts with choice of modes;

- the detailed description of vehicle fleet;

- the use of a consolidated methodology for the computation of fuel consumption and emissions;

[11] PRIMES vehicle load factors are all larger than the corresponding TREMOVE ones: in some cases up to 2-3 times larger.

- the used of a robust theoretical approach to compute social costs of transport.

At the same time, the main weaknesses of TREMOVE seem to be:

- the use of a simplified methodology for six EU countries out of 15;
- the absence of a suitable classification of demand by category (e.g. trip purpose) and distance classes and the use of generic parameters;
- the absence of non-road emissions;
- the absence of some relevant pollutants emissions as well as lifecycle in the calculation of emissions;
- the simplified treatment of road network capacity;
- the assumption of the recycling of taxation revenue is fixed (assuming optimality).

3. THE DISCUSSION ABOUT THE DEVELOPMENT OF TREMOVE

There is a large consensus on the judgement that TREMOVE has demonstrated its capability to address transport-related air pollution issues with an appropriate combination of economic theory and technical detail. At the same time, is also widely recognised that in order to provide all necessary support for analyses of the transport sector to be carried out within both Clean Air for Europe (CAFE) and the European Climate Change Programme (ECCP) some improvements of TREMOVE are required.

This chapter collects the result of the fruitful discussion among modellers, Commission's representatives, stakeholders and experts about the feature of the model, the expectations regarding its enhancements, the methodological and modelling issues. The following paragraphs then build on the contributions collected during the *ad hoc Steering Group* and *Contact Group* meetings as well as on comments submitted by some *Contact Group* high level experts.

The elements reported here constitute the basis for the definition of the most promising directions of development of TREMOVE, which are illustrated in the following chapter. The discussion is summarised around the following main issues:

1. Which impact from which policies should be simulated.
2. Which elements should be improved and how: coverage of pollutants, emission functions, lifecycle analysis, transport modes, geographical coverage, trip purposes, etc.
3. The position of TREMOVE with respect to other projects and the definition of a common baseline.
4. The need of linking TREMOVE with a transport forecasting model.
5. The model interface and user friendliness.

The chapter is organised according to the above list of contents. Please note that all the research projects and programmes mentioned here are listed in the annex four.

3.1 Policies and impacts to be simulated

Starting from the current features of the TREMOVE model, improvements can in principle be developed along many directions. One the most relevant criteria to identify priorities is to define which use of the model is envisaged by the Commission services and/or is recommended by the experts.

In the following, the expectations of the Commission services about policies and impacts to be studied by the enhanced TREMOVE are summarised. The lists include a broad range of items, definitely wider than in the original TREMOVE model. The amount of work required to make the model able to deal with every policy and impact may well be certainly huge.

The list of policies to be simulated by an enhanced version of TREMOVE include, of course, those policies already simulated in AOP-II: vehicle technologies; non-technical measures, fiscal measures (see section 2.1). On this side, an improved version of TREMOVE could add some details to the analysis. On the other side, new policies should be added to the list.

The following policies were listed at the *ad hoc Steering Group* meeting:

- introducing new fuels types (e.g. fuels cells);
- extending pricing to all modes of transport;
- changing the tax structure for all modes of transport;
- favouring the market for innovative vehicles (considering life cycle effects);
- introducing measures affecting short distance mobility (including slow modes of transport);
- favouring freight intermodality;
- investing in transport infrastructures (TENs);
- introducing land use policies.

It was also stated that the enhanced version of TREMOVE would have to consider the impacts:

- on transport behaviour;
- on environment (noise, pollutant emissions, life cycle assessment);
- on the macroeconomic level;
- on network congestion and on modal share;
- on different geographical areas or income groups, etc. (distributive effects).

3.2 Improving TREMOVE components

The expectations about the policies and the impacts to be simulated by TREMOVE do require a wide number of improvements of the modelling framework or, in some cases, radical changes of its design. The following paragraphs present a detailed analysis of some of these improvements, selected on the basis of the attention devoted during the technical debate.

3.2.1 Extending the coverage of pollutants

With reference to the coverage of air pollutants, the extension to the whole set of elements dealt with by COPERT III can be considered a minimum desired target. The further work, which is currently being undertaken in ARTEMIS, should also be integrated in the TREMOVE structure.

As addressed also by the AOP II (CEC, 2000), in the future of air quality policies there is a special interest to go in more detail in the analysis of particulate matter taking into account also the non exhaust emissions of tyre wear and road abrasion. In relation to the pollutants already treated by TREMOVE, this means adding $PM_{2.5}$ and $PM_{ultrafine}$ to PM_{10}. The work of the PARTICULATE research project could offer valuable input on this side.

Mobile air conditioners emissions have been also mentioned in the discussion. On this side, the Climate Change 2001 Report, edited by Intergovernmental Panel on Climate Change, makes reference to the estimate reported in Baker (1999). The Commission is currently assessing what the leakage of HFC 134a is from mobile air conditioners and what the extra fuel consumption and corresponding CO_2 emissions are due to the operation of mobile air conditioners. It needs to be defined how the results of this work will be added to the TREMOVE structure.

Finally, a further proposed enhancement concerns the modelling of vehicle noise for all modes. TREMOVE currently does not compute the level of noise, but does compute the external cost of noise according to a marginal cost per vehicle*km. There is probably room to improve this computation, e.g. extending to non-road modes.

3.2.2 Improvement of the emission functions

At the time of TREMOVE development, COPERT II emissions functions were used and, in some cases, improved. There has been a lot of progress in the last years in this field and now COPERT III is already available and, in less than a couple of years, also COPERT IV might be ready as well (on the basis of the on going ARTEMIS project and the following approval of the European Environmental Agency).

Therefore, it has been suggested that the TREMOVE structure can be well designed to easily incorporate such developments.

From a different perspective, it has been considered that the needs of research studies like PREMTECH II suggest that the COPERT methodology can be not always satisfying. In particular, the use of driving cycles (urban, rural, motorway) as the only proxy for different patterns of emissions seems to be a too simplistic approach that can lead to biased estimations. It is important to remark that any refinement of the TREMOVE methodology should be considered also in terms of implementation requirements. Indeed, a more detailed classification of driving contexts would require a more detailed input from the traffic model, distinguishing the amount of vehicle-km which take place in congested roads from those in roads or streets without traffic. Within the refinement of the COPERT III methodology, the ARTEMIS project is also dealing with uncertainty analysis of emission estimations, with the aim to make quantitative statements about the error ranges of emissions estimates. Some results seem to show that other than the uncertainty regarding emission factors, there are also other sources which affect the variability of estimates. The case for producing interval instead of point estimates might be then worth to explore. This would involve further research in the direction of analysing the distribution of emission of pollutants in different circumstances. The aim of the research should be the identification of suitable measures of the size of variability of the variables "average emission", in order to produce intervals of confidence around the average emission factors currently produced.

3.2.3 Simulating lifecycle analysis

It has been argued that the computation of emissions should include also those generated during the production of vehicles and fuels. In other words, the focus of the model should be enlarged from the vehicle use only to the analysis of the whole lifecycle of transport vehicles. In principle it seems to be feasible without major modifications of the TREMOVE modelling framework. As an example, the STEEDS model considers the integration of life-cycle emissions analysis (for the vehicle manufacture/disposal cycle, the fuel cycle and new infrastructure build) into the modelling chain – also allowing primary energy (nuclear, coal, oil etc.) to be estimated. The computation is carried out by a specific module fed by the vehicle stock and fuel consumption data produced endogenously in the model (AEAT, 2000).

A similar approach was adopted in the ASTRA System Dynamics model of Europe, where production factors were used to calculate the environmental burdens caused by the production of fuel (FPE) and by the production of vehicles (VPE) for road transport (ASTRA, 2000)[12].

[12] According to the methodology developed by the MEET project, the ASTRA module took into account four different gaseous emissions during fuel production: extraction of crude oil from the ground, transportation of crude oil to the refinery, refining process and transport of fuel (e.g.

3.2.4 Extending the coverage of transport modes

The inclusion of air and sea shipping in the scope of the TREMOVE model is one of the most significant points among the expectations regarding its enhanced version. Indeed, the relevance of such two modes is well recognised. Air is the passenger mode of transport which has been growing faster in last years and its per capita emissions are definitely not negligible. On the other hand, sea shipping moves a large amount of goods, its modal share on international traffic is substantial.

It has been stressed that originally TREMOVE was conceived to focus mainly on policies affecting road transport at urban level and thus it considered long distance movements only in a rough way (and this was the case for cross-border traffic, where air and sea become relevant). This aspect should be bear in mind as it appears that the inclusion of these new modes of transport would require a clear change to the structure of the demand/supply module of TREMOVE, bringing into consideration also long-distance transport.

A second element which has been mentioned is that TREMOVE computes currently only emissions of road modes while other modes already included in the model (i.e. rail and inland navigation) are not considered on this side. It has been argued that the inclusion of air and sea would be relevant if all modes of transport were considered with a comparable structure of analysis in terms of vehicle fleet and emission factors; however the modelling of non-road emissions raises some additional problems. The critical points concerning the modelling of train emissions mentioned in the discussion are:

- availability of sufficient information related to vehicle stock and usage (diesel/electricity trains);
- availability of related emission factors;
- allocation of emissions resulting from electrical trains[13].

The emission allocation consideration holds also about air transport. An additional difficult for this mode is that EU energy use and transport volume statistics are not consistent.

gasoline, diesel) to the end-user. The gaseous emissions due to the production of the energy needed to produce vehicles were computed using aggregated data from the German federal statistical agency.

[13] Data about electricity consumption per domain, localisation of electricity production and technology implemented for each modelled country.

About sea shipping it has been highlighted that a simplified approach to model emissions is difficult because there is a lot of information needed to define what kind of ship is used, the commodity type only is not sufficient. And, as one ship can be in itself a relevant source of emissions, if the features of such a ship change the results can also be very different.

For all non-road modes the problems associated with the need of including international trips in the structure of the model have been raised. This has to be solved in the definition of the envisaged connection with a transport forecasting model of Europe.

On the emission side, it has been said that there are other projects and models which deal with non-road emissions. ARTEMIS is developing emission specific functions for all modes and these are being used by TRENDS, which considers all modes of transport, including air, sea shipping and inland navigation. Emissions factors for the TREMOVE model might be drawn from such sources.

Even though air is mainly interesting for passenger traffic and shipping is relevant especially for freight, it was suggested to consider also air freight and passenger navigation (ferries). Finally, also the opportunity to consider off-road modes of transport (agriculture tractors, mobile cranes etc.) was mentioned.

3.2.5 Further classification of vehicle stock and usage

The TREMOVE model deals with traditional fuel technologies: gasoline, diesel, LPG. Even if the fleet module includes a category for “other technologies”, the treatment of innovative vehicles is poor. As the introduction of innovative vehicles is a significant element of possible future scenarios, the capability of TREMOVE of dealing with other fuel technologies has been mentioned as a relevant aspect.

On this side, the main issues seem to be: (a) choosing the technologies to be implemented and (b) including a suitable set of emission factors. Concerning with point (a), in principle, fuel cells, bio-gases, electric vehicles and hybrid vehicles are considered the main candidates.

The opinion collected is that point (b) is more demanding. The COPERT methodology was developed on the basis of traditional fuels and engines and there is no comparable knowledge about driving cycles and emissions for new technologies. Furthermore, completely different problems (e.g. wasting of exhausted batteries) have to be considered when dealing with new technologies. For electric cars it is also important to consider that the location of pollution would be no more linked to the location of vehicles: the location of power plants would be important insteadlike for electric trains.

It has also been suggested that currently the model assumes a perfect competition among car manufacturers and in reality this is not the case (it is rather an oligopoly). This is relevant when considering the vehicle costs in the choice functions of individual consumers.

Some experiences have been mentioned as potentially interesting contributors to fleet modelling. One is the COWI model (COWI, 2001), which estimates the effect of fiscal measures on CO_2 emissions from new passenger cars in each of the 15 EU Member States. A detailed car choice framework is the core of the model with elasticities of demand with respect to several attributes[14]. The COWI model could be considered as a valuable contribution for the modelling of fiscal measures on the composition of vehicle fleet. A second remarking experience is that of the STEEDS model, where a sophisticated fleet model has been built which might provide interesting input for the development of the treatment of vehicles fleet in TREMOVE.

With regard to heavy duty vehicles, it has been suggested that the TREMOVE current classification of heavy trucks could be more detailed since significant differences exist in terms of emissions among the various types of trucks.

3.2.6 Extending the geographical scope

As far as the TREMOVE model is to be used within European programmes, all the EU15 countries should be covered at the same level of detail. Therefore it is expected that the six EU countries for which a simplified methodology is currently used in TREMOVE are upgraded to the full methodology.

Considering the feasibility of such an extension, the issue of enlarging the geographical scope is extended to non-EU countries. It has been suggested that Switzerland and Norway, at least for their geographical position, could be included in TREMOVE. With their addition a complete picture of Western Europe could be achieved. At the same time, it has been argued that the Central and Eastern Europe countries which are candidate to join EU would be equally relevant objects of an extension of TREMOVE in order to compare their situation to the EU's[15].

However, it has been stressed that while for Norway and Switzerland the availability of data should not represent a problem, the situation is rather different with regard to accession countries. The data and transport modelling situation differs from one accession country to another (as it does between EU Member States). The reliability of officially published data is judged questionable for different reasons:

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[14] The elasticities were calibrated on a full-scale database of new cars registration on Denmark.

[15] Such countries are: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia, Turkey

- the problem of grey market (whose share was assessed to be in decline),
- the availability of behavioural parameters (values of time, elasticities were assessed to be critical also because these are strictly linked to the GDP),
- the availability of values of life estimates,
- the predictability of cost parameters (vehicle taxation, insurance, etc.),
- the compatibility of national statistics with Eurostat standards.

In order to favour the extension of TREMOVE to more countries it was also proposed a “multipolar” approach splitting the model development if two phases:

a) a general model with universal components (e.g., emissions by vehicle category and travelling conditions, policy strategies, ...) and

b) specific models for different cases (city, region, country) using local data.

Output of the first task (model, including computer program) could be used for specific pilot cases (countries, cities etc.) to calibrate the model and to assess its quality and, in addition, anywhere where there are interested clients.
According to such an approach, the development of the model and first applications (testing) belong to tasks which qualify for funding at the international level (European Commission), whereas further applications should be financed by national and local governments.

3.2.7 Distinguishing trip purposes and freight categories

The TREMOVE model distinguishes three main categories of passenger demand: urban inhabitants, urban commuters and non-urban. For freight, urban and non-urban movements are considered.

As far as the reactions of different segments of demand to changes of supply conditions are different, the use of a limited number of categories could be misleading when modelling the transport demand reaction to different policies. A more detailed classification would allow to simulate that in different segments the elasticities of substitution are different both with reference to substituting trips with the consumption other goods and with reference to substituting one alternative mode with another.

The opinion collected about this proposal has been that this requires some modelling work and it might be a demanding task (perhaps not realistic within a short time frame), because it involves an intensive work of calibration of a more complex choice structure with a larger number of parameters.

Possible problems with the detail of input required have been also mentioned. On the one side it can be said that the availability of demand data does not look as a serious problem as the results of a transport forecasting model can be used (see section 3.4).

3.2.8 Improving the definition of spatial contexts

The possibility of introducing a more detailed classification of regions, getting rid of the strict division between "urban areas" and "rest of country" has been mentioned. With reference to this issue, the approach adopted in the ASTRA and SCENES models can be considered. In such models, zones are classified on the basis of the nature of the urban settlements within the zones: six classifications representing the full scope of zone types, from metropolitan centres to highly dispersed, rural areas.

However, it has been argued that splitting into more geographical contexts than 'urban' and 'non-urban' would require extensive data collection work. It has been suggested that this aspect should be considered with reference to the use of the model results. For instance, some more detail might be necessary for the purpose of the CAFE (or any other) programme. In that case a strategy for improving the definition of spatial contexts, which includes also more detailed emission functions, could be considered. At present it seems important, as a first step, to dedicate care to the assignment phase of inter-urban traffic, that is the way how the single 'non-urban' driving class is disaggregated by TREMOVE into rural and highway trips.

3.2.9 Improvement of elasticities and values of time

TREMOVE uses average parameters for all countries, but, as stated by the same authors in the AOPII report, a differentiation would be preferable[16]. Also other improvements mentioned in this section involve the use of different parameters, e.g. the distinction of working and non-working trips (see section 3.2.7).

Still according to the AOPII report, literature is the primary source of more detailed parameters, essentially elasticities of substitution and values of time. Projects like TRACE (HCG at al., 1998) and UNITE (ITS et al., 2000) are two examples.

3.2.10 The treatment of costs

TREMOVE was conceived as a tool to analyse the cost-effectiveness of emission reduction policies and therefore it was set to calculate, based on the consumer surplus, the social cost of policies. Within these boundaries it has been suggested that an improvement of the treatment of public funds values should be considered.

16 Specific country parameters (values of time, costs, etc.) have been successfully used in the SCENES transport model.

TREMOVE also considers external costs from noise and accidents. It has been mentioned that the addition of monetary values to be attached to transport externalities due to pollution would enlarge the scope of the model, making it a tool for a full cost-benefit analysis of policies.

Finally a further step would be from the "micro" to the "macro" level, assessing indirect macroeconomic and land use impacts of transport. From the discussion it can be drawn that this task may pose more difficulties than those listed above, and it has been suggested that it is considered as long as it does not delay the required immediate improvements of TREMOVE.

3.2.11 The horizon year of the model

In view of the slow turnover of vehicle stock outside the road sector, an extension of the simulation period to 2030 was proposed. Nevertheless TREMOVE is a partial equilibrium model which does not consider long terms elasticities and the demand structure in 30 years might be totally different. Furthermore, emission data beyond 2020 is currently unknown as the future legislation which would dictate these data is yet to be developed: the ARTEMIS project, which should provide emission factors is only intending to develop transport emission data up to 2020.

For such reasons, it was suggested keeping year 2020 as final date of simulation (production of quantified results) and assuming year 2030 to appreciate looser tendencies with the caveat listed above.

3.3 The positioning of TREMOVE among other projects

There are many relevant projects which might be linked (either to provide input or to analyse output) with the enhanced TREMOVE model and there is also a general agreement about the need of exploiting as much as possible synergies among models, avoiding to replicate modelling work. Therefore, it is very important to get a clear understanding of the assumptions and the linkages on which the enhanced TREMOVE model has to be build.

DG ENV emphasised that their preliminary orientation is to see TREMOVE as one of the reference models for the CAFE programme together with RAINS (climate), PRIMES (energy), SCENES (transport) and a model for agriculture. Thus, TREMOVE would be part of a set of models which shares a common baseline and offer different specialisation.

This point is also in relation with the actions undertaken in ETIS (European Transport Information System) area of research managed by DG TREN with the aim

to offer decision-makers with a modelling service in support of transport policy making[17].

Some links are already operational. For instance, the RAINS model currently uses the results produced by TREMOVE – in particular the cost of policies produced by TREMOVE - even though the link is not automated and requires a lot of manual work to be implemented.

However, in most cases the models work independently. For instance, it has been stressed that there is an evident necessity for coherence between the PRIMES energy system model and TREMOVE, firstly because both models are widely used by the Commission for complementary studies and secondly because the transport module of PRIMES applies the same basic principles (though in a more aggregate manner) with TREMOVE[18].

From the discussion emerged that different levels of synergy among models can be considered, from "light" linkages (e.g. the use of a common set of data and assumptions and independent runs) to a complete integration of part of one model (or even one entire model) into another. For instance, in order to realise a link between TREMOVE and PRIMES two options can be envisaged:

- Keeping the two models 'apart' and connecting them with a suitable user interface that will 'translate' the aggregate output of PRIMES into detailed input to TREMOVE (and vice versa);

- Incorporation of the whole (improved) TREMOVE into PRIMES.

The need of linking different models raises the problem of the definition of a common interface language which could help in making the process automated. This problem has been addressed in the SPOTLIGHTS Thematic Network (ETIS DG TREN) starting from the specific case of transport models but leading to a more general approach (see box 3.1).

3.3.1 Definition of common data

It has been highlighted that a specific aspect in linking the different environmental projects is the definition of a common database, that is a common set of inputs for all the strategic transport/energy/environment models used at the European level.

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17 The active projects are DATALINE (a pan-European long distance passenger mobility survey) and SPOTLIGHTS (a thematic network for European transport modellers to explore ways for advanced transport models fully transparent to end-users, open and more into policy-making processes). A third project about the definition of the ETIS interface is going to be launched.

18 A new version of PRIMES transport module is being developed by the TREMOVE modellers.

For instance, in order to provide consistent forecasts, it is absolutely necessary that both TREMOVE and PRIMES are calibrated to the same data and deliver the same results for the base year but also for the baseline scenario.

It has been recommended that the common database shared by TREMOVE and other models is built with the co-operation of all the relevant subjects and stakeholders. The possibility to have a formal review of model data and results from Member States has been suggested, making reference to “broadly supported” data and parameters.

Transparency during the construction of the database and sensitivity analysis is how it could be achieved and how the consensus could be extended to a broader public. However, consensus building through sensitivity analysis and transparency (i.e. documenting and “publishing”) is time consuming. Therefore this should be duly accounted for early in the project planning. A suggested quicker alternative to the harmonisation of transport baselines is to make baseline data of each model interchangeable by means of an agreed format of data.

As far as data is involved, EUROSTAT is one of the main subjects as it provides a significant part of the transport data used. On this side it should be considered that although there is quite good coverage of transport within the statistical system of EUROSTAT, these data cannot simply be plugged in, and ample provision of resources are usually needed to "pre-process" the data according to the needs of the specific model. Therefore, the definition of a common database could require also to verify the requirements of each model in terms of basic data.

Box 3.1 The Generalised Transportation-data Format (GTF)

GTF, currently, is a specification of a conceptual model structuring the terms, language and concepts found in the problem domain of transportation modelling, esp. strategic, by formal definition. As a result these terms, language and concepts can be understood and processed automatically by computers.

GTF is a long term action to solve the problem of "communication" between different transportation models and between transportation models and other software or computer systems. Currently, "communication" takes place only on the basis of exchanging "data" But this is not enough, what is needed, is an exchange of "information", which is defined as "data" plus "meaning". Data structured according to the GTF specification adds the necessary "meaning" to the raw "data". Only data with meaning, i.e. information, has the necessary semantics required for meaningful further usage of the data.

The "GTF vision" is to reach a level of interoperability of transportation models through harmonisation of their input/output structures and protocols, i.e. by providing input/output software "translators" that convert from proprietary data structures to and from GTF (mediator) structures.

This concept has the advantage that databases and transportation models' software will not need to be completely restructured to comply with GTF. The only requirement will be that the computer system hosting the database and transportation models must provide GTF translators.

Source: Request of a common understanding towards GTF, Spotlights, 2001.

3.4 Development of a link with a traffic forecasting model of the EU

This point was one of the main issues highlighted in the terms of reference of the assessment project. Given the nature of TREMOVE, the availability of a coherent reference case for transport development in the next years is a critical pre-requisite. The opportunity to link the model with a strategic transport model of EU was emphasised as well as the importance of collecting forecast information for the accession countries.

Among the existing models, SCENES is considered the ideal candidate at least for EU15 countries. For Eastern Europe countries the "Forecasts for the 10 Helsinki pan-European transport corridors" (EU Commission, PHARE, DG I, 1999) project was mentioned. Such a project uses the NEAC model. A review of the main existing transport models at the European scale is reported in annex two.

Once the opportunity of linking TREMOVE to a transport forecasting model is established, the relevant issue is understanding how this linkage can take place. Three possible ways to connect TREMOVE and SCENES have been envisaged:

- to adopt the SCENES transport forecast as base case scenario for TREMOVE;

- to use SCENES as benchmark model for refining TREMOVE calibration parameters;

- to radically change the modelling TREMOVE framework directly connecting the stock vehicle module and the emission module to SCENES.

The first option represents a loose connection. The TREMOVE model should be calibrated to reproduce the SCENES results of the base scenario, but the TREMOVE model would maintain its structure and form of parameters.

The second option would involve a slightly tighter connection in that also the scale of parameters would be drawn from the SCENES model. In this way the structure and the algorithms of TREMOVE should be able to work with a set of parameters consistent to those used in the transport model. As the framework of TREMOVE is significantly different from the classical Logit algorithms used for the modal split and the assignment phase in SCENES, such a task might be not simple.

The third option would involve a radical change in the philosophy of the TREMOVE model. The whole demand/supply equilibrium module should be replaced and all the connections with the other components of the model should be completely revised. The risks of this option in terms of model complexity and especially long running times were underlined by the modellers. It should be considered that the modelling work would not be limited to TREMOVE, but it would involve also the transport model. Improving and adjusting forecasts of such transport models to the needs of a model like TREMOVE (which requires much more detailed traffic data for emission calculation) may be a large task. There are many (and not trivial) differences between, for instance, the pilot STREAMS/MEET/COMMUTE study and the work that is necessary for a TREMOVE linkage with transport models. For instance, a forecasting model like SCENES is run only for a base year and a horizon year (2020) whereas TREMOVE II should continue to provide annual data out to the horizon year. This is because the evolution of the vehicle stock has a critical influence on emissions.

3.5 Interface and user friendliness

This aim of facilitating the access to TREMOVE model has deserved a lot of attention in the discussion and was tackled by different points of views. With reference to the facilitation of the model use, due to the continue rotation of the internal staff of the Commission services, the Commission intention is not to develop expertise to directly run the TREMOVE model. Additionally, when TREMOVE

model was developed there were doubts of the usefulness of making the model as wholly available to any users (e.g. putting it on the web) as changing the parameters in a meaningful way requires some experience of transport issues.

A first issue is therefore the simplification of the access to scenarios prepared by the modellers. The STEEDS experience, where suitable tools designed for analysing, comparing and visualising pre-defined scenarios was extensively used, was suggested as a valuable approach. For modelling expertise which would have knowledge enough to run the model meaningfully, it would be useful to have the model in the public domain or available at a low price. On this side, however, it was highlighted that TREMOVE requires a program environment like GAMS: the cost of acquiring such a commercial software license can be then seen as a prohibiting factor for wider model applications. A possible solution to this issue, was suggested by GAMS itself on the basis of their recent experience, where the model code and GAMS resides on another machine and all the communication is done via e-mail. An alternative possibility suggested is to circulate executable versions (e.g. with temporary licences) of the model, with the scope of facilitating the dissemination of the model results as well as the understanding of the model structure, but it was generally agreed that making the software code public would not be a good idea. This for two main reasons; first because not experienced users of the model could make serious mistake when using the model and, second, because there would be a danger of having different versions of TREMOVE, giving different results without any control on the reasons of such differences.

An interesting document reporting different proposal for improving TREMOVE interface was prepared by GAMS in the context of their expertise for DG ENV (GAMS, 1999). The document highlights the difficulty of imaging an interface which can meet the requirements of different subjects (academic partners, model managers, model users, decisions makers, etc.) and makes a distinction between the so called "casual users"[19] and "domain specific experts"[20].

[19] "Casual users wants to run the model [with a] limited interest in the model itself".

[20] "Domain specific experts wants to run the model with different scenarios… may want to make minor modifications to the code and the data or have suggestions for improvements".

4. THE PROPOSAL FOR THE DEVELOPMENT OF TREMOVE

After the review of the feature of the model, the discussion of the expectations regarding its enhancements, the methodological and modelling issues, the analysis of the position of the model among the existing environmental/energy/transport programmes, a proposal about the development of TREMOVE can be formulated.

4.1 The outcome of the assessment

The technical assessment and further development of the TREMOVE model can be summarised in three parts: general recommendations, recommendations for model improvements and research directions for further development of the model. These are listed below and are discussed in detail in the rest of the chapter.

4.1.1 General recommendations

These are the main conclusions of the assessment study:

I. the TREMOVE model framework is valid and should be retained;

II. it is recommended to include TREMOVE in a network of energy/environment/transport models sharing a common baseline;

III. a loose connection with a strategic transport model is recommended in order to build on a sound and coherent transport base scenario, while a tight connection is not advisable;

IV. with reference to the model accessibility, although the model should continue to be run by experienced modellers, a web site is recommended to be used to allow requests of simulations and to give access to simulation results;

V. it is also recommended to assure broad consensus about data and results among experts and stakeholders and to consider the possibility to have a formal approval/review from Member States, along the lines of the AOP II experience.

4.1.2 Recommendations for model improvements

A list of improvements is envisaged to enhance and enlarge the scope of the model; the presentation order is based on the level of complexity with reference to both modelling and data collection and not on their priority:

a) extending the model to all the 15 EU countries plus Norway and Switzerland;

b) adding new pollutants;

c) adding new motor/fuel technologies;

d) adding full computation of external costs;

e) adding computation of lifecycle emissions for all modes of transport;

f) revising the demand categories, including purposes/freight types and distance instead of commuters/inhabitants;

g) adding air and sea shipping among transport alternatives and computing emissions for all modes of transport;

h) extending the model to the Accession countries which guarantee the availability of data.

4.1.3 Research directions for further development of the model

Some other improvements would be useful, but their inclusion in the TREMOVE structure would be a very complex task and therefore they should be regarded as further possible enhancements on the longer term or "external" connections on the shorter term:

i) connecting TREMOVE to a macroeconomic model;

j) improving the definition of spatial domains with a more articulated classification;

k) including a simplified regional/land-use module.

The analytical discussion of the list of general recommendations, suggested improvements and research directions is presented in sections 4.2, 4.3 and 4.4. In the following pages table 4.1 and 4.2 illustrates the relevance of the proposed improvements with reference to the policies and impacts discussed at the *ad hoc Steering Group*.

In both figures cells filled with a darkest colour indicates a strong link between the modelling improvement in row and the policy (or impact) in column. A lighter colour stand for indirect effects. For instance, in figure 4.1, the inclusion of new fuel/engine technologies has a direct link with the policies "introducing new fuel types" and "favouring innovative vehicles", whereas the addition of the computation of external cost is not directly linked to any policy, but would allow a better representation of all. In figure 4.2 the extension of the model to the Accession Countries is directly linked to the analysis of the effects of policies on different geographical areas, but also indirectly to the analysis of the effects of policies on different income groups.

Tab. 4.1 Relevance of TREMOVE improvements with reference to the policies to be simulated

	Introducing new fuel types	**Extending pricing to all modes of transport**	**Changing tax structure for all modes**	**Favouring innovative vehicles**	**Favouring slow modes**	**Favouring freight inter-modality**	**Investing in transport infra-structure**	**Introducing land use policies**	**Scrapping schemes**
a. extending the geographical scope									
b. adding new pollutants									
c. adding new fuel technologies									
d. adding full computation of external costs									
e. adding computation of lifecycle emissions									
f. revising demand categories									
g. including new modes									
h. extending the model to the Accession countries									
i. connecting to a macroeconomic model									
j. refining spatial domains definition									
k. adding a land use module									

Tab. 4.2 Relevance of TREMOVE improvements with reference to the impacts to be simulated

	Effects on transport behaviour	Effects on the environment	Effects at the macroeconomic level	Effects on network congestion	Effects on modal shares	Effects on different geographical areas	Effects on different income groups
a. extending the geographical scope							
b. adding new pollutants							
c. adding new fuel technologies							
d. adding full computation of external costs							
e. adding computation of lifecycle emissions							
f. revising demand categories							
g. including new modes							
h. extending the model to the Accession countries							
i. connecting to a macroeconomic model							
j. refining spatial domains definition							
k. adding a land use module							

4.1.4 Four options to further develop TREMOVE

Four options combining the suggested improvements (a to k) are presented. The five general recommendations illustrated above are common to all options. It is important to remark that options are presented in "additive" terms (i.e. each options add some elements to the previous one), but this does not involve that elements included in option 1 are the most important. Options do not identify a hierarchy from the most relevant improvements to the less relevant ones. Instead, the options have been built with the aim of define "packages" of developments which describe different versions of the model, with an increasing level of complexity in terms of modelling requirements and data requirements. A given item can be included in the first options because is relatively easy and not because is considered more important than another.

For each option an estimate of the time and the monetary budget is provided. Such estimates are strictly referred to the technical/scientific tasks and do not include consultation and communication expenses.

The recommended option for the TREMOVE development is option 3. In such a option the scope of the model would be substantially enlarged within the limits of its methodological framework.

Options 1, 2 and 3 are also presented in a synthetic form in table 4.3.

Option 1: Improvements to the current model scope

The model scope is still the same and the focus is kept on the land modes and mainly on urban areas:

- *extending the model to the 15 EU countries plus Norway and Switzerland (a)*
- *adding new pollutants (b)*
- *adding new motor/fuel technologies among road vehicle types (c)*
- *adding full computation of external costs (d)*
- *adding computation of lifecycle emissions for all modes of transport (e)*

Option 1 concerns the extension of the scope of the model within the limits of the Western Europe and of road transport while keeping the current description of transport demand. The inclusion of Norway and Switzerland as well as a fully detailed description of all EU countries would allow a full coverage of Western Europe, where data are more readily available and reliable. The addition of new pollutants would allow a more complete computation of emissions and does not involve relevant modelling problems, provided that emission factors are available. Considering new motor/fuel technologies would allow to take into account the possible developments of vehicles fleet and simulate the effect of policies aiming at favouring cleaner vehicles; again the implementation should not be too complex provided that suitable parameters can be estimated. Computing the external costs of pollution would be fairly straightforward (provided that an agreed set of monetary values can be used) as the amount of emissions is already calculated and would complete the description of external costs. Finally, the inclusion of lifecycle would enlarge the scope of the model to a relevant aspect with a limited methodological effort if the experience of other models is assumed.

Time schedule: *1.0 years*

Budget: *250.000 Euro*

Option 2: Extending the scope to other modes of transport

The model focus includes all modes of transport:

- *Option 1 +*
- *revising the demand categories, including purposes/freight types and distance instead of commuters/inhabitants (f)*
- *adding air and sea shipping among transport alternatives and computing emissions for all modes of transport (g)*

Option 2 is focused on the enlargement of the scope of the model to non-road modes of transport. The addition of air and sea shipping and the computation of emissions for all modes would allow a better evaluation of policies taking into account the effects to all modes of transport. This task is not straightforward in modelling terms (e.g. the problem of representing international traffic should be solved) and requires a revision of demand categories, in order to identify correct sets of alternative modes, more homogenous parameters and so on. In brief, this option adds significant modelling power at the price of a significant growth of complexity.

Time schedule: *1.5 years*

Budget: *400.000 Euro*

Option 3: Extending the model to accession countries

The model focus includes all modes of transport and, where possible, other countries outside EU

- *Option 1 + 2 +*
- *extension to the Accession countries which guarantee data availability (h)*

Option 3 consists in enlarging the model, with the enhancements envisaged in option 1 and 2, to Accession Countries. This option would allow to build an instrument to compare the situation of eastern Europe countries to EU with regard to a very important aspect like transport emissions. The difficulty here is data availability which is generally far less complete than for EU countries so that data collection and processing would likely require a considerable effort.

Time schedule: *2 years*

Budget: *500.000 Euro*

Option 4: Research directions for further model development

The model focus if further enlarged in order to assess macroeconomic and spatial/regional impacts

- *Option 1 + 2 + 3 +*
- *connecting TREMOVE to a macroeconomic model (i)*
- *improving the definition of spatial domains (j)*
- *including/connecting with a simplified regional/land-use module (k).*

Option 4 concerns with long term further development. The aim of the work in this is option should be considered in terms of theoretical work for suggesting possible way to deal with the suggested further improvements (connection to land-use and macroeconomics models, improving spatial domains) which would be very interesting but involve demanding modelling problems. While items in the previous options can be considered as theoretically solved, the issues included here would need significant research work.

Time schedule: *2.5 years*

Budget: *700.000 Euro*

Tab. 4.3 Options for the improved TREMOVE

Model feature	AOP-II TREMOVE	Improved TREMOVE Option 1	Improved TREMOVE Option 2	Improved TREMOVE Option 3
Geographical coverage	9 EU countries remaining 6 EU countries with a simple method	All EU15 countries + Switzerland and Norway	All EU15 countries + Switzerland and Norway	All EU15 countries + Switzerland and Norway + Accessions countries
Pollutant emissions	CO – CO_2 – SO_2 – NO_x – VOC – N_2O – PM_{10} – C_6H_6	CO – CO_2 – NO_x – VOC – N_2O – PM_{10} – C_6H_6 - CH_4 – NH_3 – SOx – PM_5 – $PM_{2.5}$ – PAHs – POPs – Dioxins – Furans – HFCs – PFCs	CO – CO_2 – NO_x – VOC – N_2O – PM_{10} – C_6H_6 - CH_4 – NH_3 – SOx – PM_5 – $PM_{2.5}$ – PAHs – POPs – Dioxins – Furans – HFCs – PFCs	CO – CO_2 – NO_x – VOC – N_2O – PM_{10} – C_6H_6 - CH_4 – NH_3 – SOx – PM_5 – $PM_{2.5}$ – PAHs – POPs – Dioxins – Furans – HFCs – PFCs
Demand categories	Passengers (commuters and inhabitants) and freight	Passengers (commuters and inhabitants) and freight	Passengers: Working trips (short and long distance) – Non-working trips (short and long distance) Freight: Low value goods (short and long distance) – High value goods (short and long distance)	Passengers: Working trips (short and long distance) – Non-working trips (short and long distance) Freight: Low value goods (short and long distance) – High value goods (short and long distance)
Modes of transport	Motorcycles – Cars – Bus/Coaches – Metro – Train – Trucks – Inland navigation	Motorcycles – Cars – Bus/Coaches – Metro – Train – Trucks – Inland navigation	Motorcycles – Cars – Bus/Coaches – Metro – Train – Trucks – Inland navigation – Sea shipping - Air	Motorcycles – Cars – Bus/Coaches – Metro – Train – Trucks – Inland navigation – Sea shipping - Air
Fuel technologies	Gasoline – Diesel – LPG	Gasoline – Diesel – LPG - Fuel cells – Electric vehicles – Hybrid vehicles	Gasoline – Diesel – LPG - Fuel cells – Electric vehicles – Hybrid vehicles	Gasoline – Diesel – LPG - Fuel cells – Electric vehicles – Hybrid vehicles
Emissions computation	Emissions from use of road vehicles	Emissions from use of road vehicles and from vehicles and fuels production (lifeycicle)	Emissions from use of road and non-road vehicles and from vehicles and fuels production (lifeycicle)	Emissions from use of road and non-road vehicles and from vehicles and fuels production (lifeycicle)
External costs	Accidents and Noise	Pollution, Accidents and Noise	Pollution, Accidents and Noise	Pollution, Accidents and Noise

4.2 General recommendations

I) Retaining the basic TREMOVE structure

The TREMOVE model is built on a robust and consistent structure. It was developed to estimate the effects of various policies in terms of emissions and costs (at the microeconomic level) and it performs well. In particular, its micro-economic solid foundations allow for the extensions both of its scope (to cost-benefit approaches) and of its reach (i.e. a possible “dialogue” with macroeconomic models).

At the same time, the opportunity to improve the model with regard to the weaknesses highlighted in chapter 2 should be considered. Although most of those issues are dealt with in the proposed improvements described below (section 4.3), the remaining aspects should be addressed as well. For instance it is recommended that the asymmetric treatment of the income effect underlying the modelling of fiscal policies could be solved allowing a suitable representation of the income effect also for firms other than for households. At the same time a simplified representation of the links to the macroeconomic side (e.g. via some parameters like the already used marginal cost of public funds) would be a useful improvement. The use of different values of time by demand category and by country should be introduced and the revision of demand categories helps on this side.

It is fair to say that the problem of computing air pollution concentrations – a major concern within the Clean Air for Europe (CAFE) programme – should be managed at a local level outside of TREMOVE, whose structure is valid to compute emissions but not concentrations.

The recommendation to retain the TREMOVE modelling framework implies that the proposed improvements have to be developed in the GAMS programming language. On this side there is room for enhancements of the procedures and the code optimisation already addressed by the GAMS expertise (see section 2.1.1).

II) Connections between TREMOVE and other projects

In its enhanced version, TREMOVE could work in conjunction with other models in order to

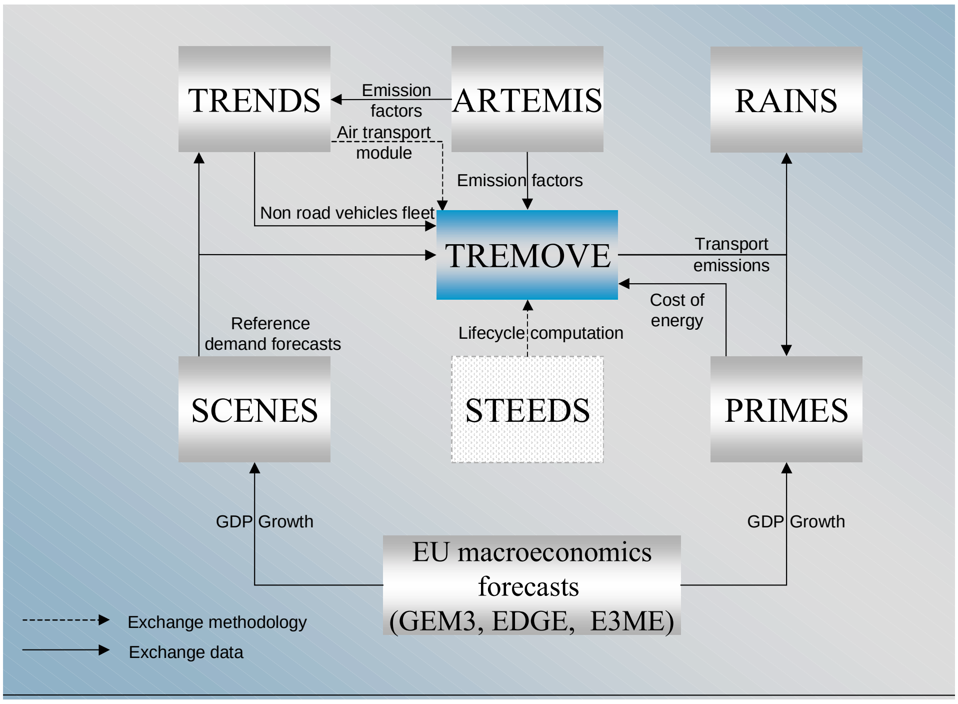
- assure that if a given data is used by more models, it is the same data, by the same source;
- each model works directly on its core scope and uses results of other models as input.

Main potential connections with the currently available models are depicted in figure 4.2. ARTEMIS, SCENES, TRENDS, STEEDS and PRIMES would be feeder of TREMOVE, whereas PRIMES and RAINS would be fed by TREMOVE.

The nature of linkages is not always the same. For some models is a matter of data/parameters provision: ARTEMIS would provide emission factors (for a larger set of pollutants) for road and non-road modes, TRENDS would provide detailed data[21] about non road vehicles fleet, SCENES would be the source for the base forecasts of transport demand[22]. On the other side, TREMOVE will feed RAINS and PRIMES with the estimation of emissions. In addition, PRIMES would provide feedbacks in terms of fuels price (eg. petrol, diesel, electricity).

A second type of linkage is in terms of methodological elements. STEEDS could provide the methodology for computing lifecycle costs starting from vehicle stock and fuel consumption, while from TRENDS could be drawn the air transport module.

Fig. 4.1 Main connections between TREMOVE and other models



21 Transport and Environment Database System (TRENDS) is a project administered by Eurostat using extensively EUROSTAT data. The data sources identified under TRENDS are likely to be be very helpful when the updating of data for TREMOVE is looked into.

22 Please note that it is suggested that SCENES provide the base forecasts of transport demand for all the models which require this type of information (i.e. TRENDS), in order to guarantee that results are consistent.

It should be considered that not all the projects mentioned are at the same level of development and, in any case, most of the links depicted are potential connections and not actual ones. TREMOVE is already linked to RAINS as a input data feeder, while PRIMES already has (and is currently further developing) an internal transport module and therefore it actually doesn't use TREMOVE outputs. SCENES and STEEDS are complete, while ARTEMIS and TRENDS are still under development and the link between these projects and TREMOVE is only a proposal at this stage.

The connections among models should guarantee that a common database – for transport demand as well as for other data - both for the base year and for a base forecast scenario, is used. Such a database should consist of information which are broadly supported by stakeholders.

It is important to stress that the connections are described on the basis of the currently available models. Such models appear as the current best candidates to be member of a European network of models which work in synergy, but if and when new models are available they can enter in the network and substitute one of the model quoted above.

A non-secondary aspect of the connection among models is the format of input/output data. Different options are adopted in the models which are based on separate modules: spreadsheet files, ascii files according to a predetermined data format, etc. This aspect is particularly relevant in the light of the need of guaranteeing that new models can be added to the network or can substitute existing ones. It is then highly recommended that the data exchange format (as well as any other element required for linking the models) is not thought specifically for the existing models but in a general form opened to new entries.

The development of a exchange format based on universal rules is exactly the topic under analysis in the SPOTLIGHTS Thematic Network (ETIS- DG TREN) where a conceptual model for a Generalised Transport data Format (GTF) was proposed. GTF is a long term option which gives an idea on how the problem of exchanging data might be addressed in the context of TREMOVE and its linkages.

A relevant issue which should not be disregarded is that connecting various models to each other require some work from the developers of each model. When it is envisaged that one model supplies data to another, it should be taken into account the work required to produce the data and the total budget for the development of TREMOVE should include the required resources.

In more general terms, as the enhancement of TREMOVE requires the establishment of links with several models, it is advisable that representatives of the various modelling teams are involved in the project. This would favour the development of a consistent framework and the adoption of solution agreed by all subjects involved and the connections among models would be strengthen.

III) Loose connection with a transport model

Good forecasts of future demand are a necessary (though not sufficient) condition for good forecasts of future emissions and this part of TREMOVE should be improved. An existing strategic transport model at the European level can provide the base case forecasts (i.e. no-policies scenario), but a tight linkage between TREMOVE and a transport model seems hardly feasible and it is not advisable.

Among the existing models, SCENES appears as the candidate for being the reference model at least for EU15 countries. SCENES provides a detailed description of both freight and passenger data by mode, region, flow type, etc. For the level of detail and for the wide coverage of modes and types of traffic it can be considered at the leading edge of strategic transport model at the European scale. A feature which is particularly relevant in the light of the data required by TREMOVE is that also short distance traffic is modelled. This would help to identify urban and non-urban traffic and also to include distance bands in the structure of the TREMOVE model as proposed as part of the TREMOVE improvements. In addition it will provide a sensible classification of non-urban traffic between rural and highway, so that the appropriate emission factors can be applied.

Not all the transport data required to define the baseline scenario can be provided by SCENES. First, the SCENES transport forecasting model simulates transport demand with a time step of ten years (base year 2000, 2010 and 2020): it will be then necessary to interpolate results in order to feed TREMOVE with annual data. Second, SCENES is calibrated around EUROSTAT statistics which generally do not include freight traffic performed by vehicles under <3.5 tonnes of payload. Third, SCENES models daily traffic without any indication of peak and off-peak hours. Fourth, vehicle fleets are not modelled in SCENES and eventually, Accession Countries, Norway and Switzerland are treated in less detail than EU countries[23].

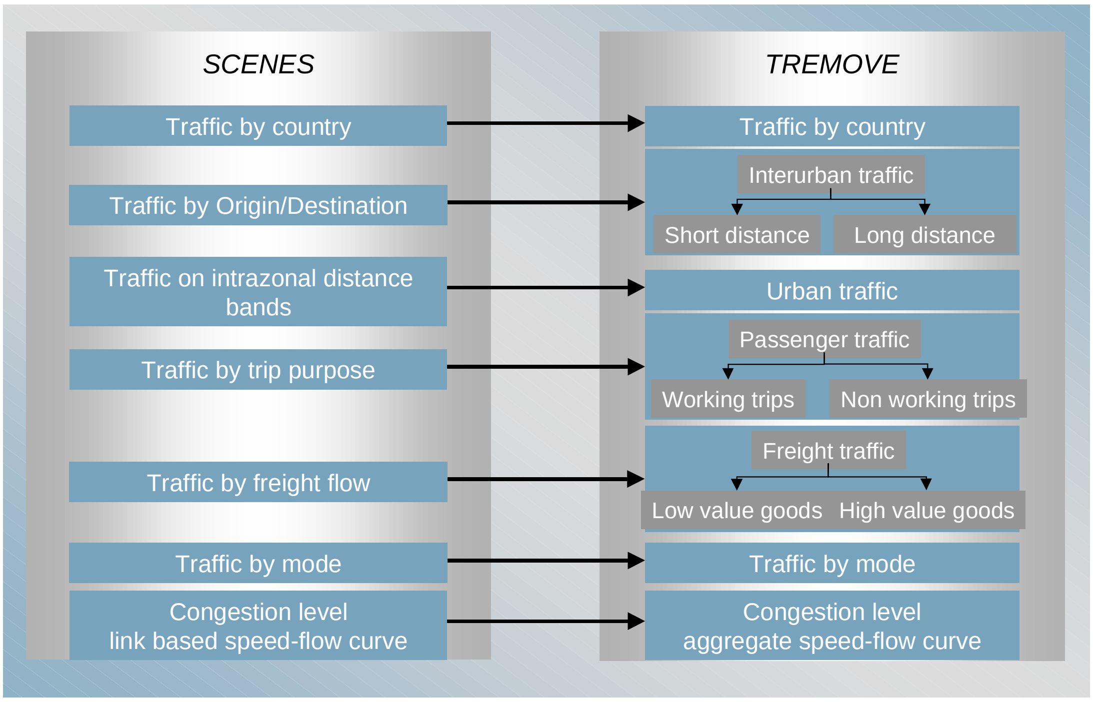
Figure 4.2 shows which data produced by the transport model would be passed to TREMOVE and to produce which input. For instance, Origin/Destination traffic would be translated into short-distance and long-distance traffic; traffic by flow would be used to quantify demand by trip purpose or freight type; congestion on single links would be used to calibrate the aggregate speed-flow curve.

It should be also stressed that data provided by SCENES should not be taken "as they are", but it should be validated against other sources. The SCENES model is the result of a research project which has demonstrated the feasibility to have a does not produce official forecasts and therefore its results should be verified and discussed

[23] For central-eastern Europe as well as for Norway and Switzerland, the NEAC model for freight transport can be a useful source even if the level of detail is lower than SCENES especially for short distance traffic. The use in conjunction of the two models might be considered.

with country representatives, EUROSTAT and all relevant subjects in order to define the accepted reference baseline.

Fig. 4.2 TREMOVE linkage with a strategic transport model - base case transport scenario



An additional item on which the linkage between SCENES and TREMOVE will need a specification is the growth of transport infrastructure, road network, rail network, ports, etc. in order to update capacity over time in a coherent way between the two models. Once the base case forecasts are drawn from SCENES, the description of the dynamics of demand in TREMOVE should be improved. The effect of policies should not affect demand starting each year from the base level. Instead, the effect should be cumulative, e.g. the change of demand registered in a given year should be accounted in subsequent years. A possible way to tackle this issue might be a change of the format of the base case input data to TREMOVE: instead of coding the absolute value of demand, it could be coded the relative increment with respect to previous year. In this way if demand in previous year changes this would be reflected in the future trend. This method or any other method to improve the dynamics of the model is recommended.

When very large changes of conditions are involved in policies, i.e. big shocks are simulated it could be safe to envisage a check by the transport model. This should not represent a direct connection between TREMOVE and SCENES, but rather a check of the effects of a non-marginal change by means of a more sophisticated transport

forecasting tool. In other words, as TREMOVE is not a forecasting model, it can be considered that its outcome is reliable as far as the conditions in the transport market are similar to the base case and only "marginal" changes are involved. If huge variations to supply or demand conditions are considered (e.g. massive addition of rail services, large increments of prices) the validity of the model parameters can be questionable. In such cases, the transport model can be asked to run the same variations in order to verify whether a tool specifically build to deal with transport forecasts provides results consistent to those produced by the TREMOVE model.

IV) Access to the TREMOVE model

Accessing the TREMOVE model means especially:

i. making this tool readily available to different subjects (Commission's staff, stakeholders, developers of linked models, researchers, etc.) for simulating specific policies and

ii. allowing the results of simulations to be readily consulted and compared by the same subjects.

Regarding point (i), a full accessibility in terms of whole availability of the model (e.g. downloading from a web-site) for own use seems not advisable. This is due not only to the GAMS licensing problem but also because it requires some insights into transport issues to be able to change the parameters in a meaningful way. Thus, the help of experienced modellers would be required even if an immediate user-friendly interface were developed.

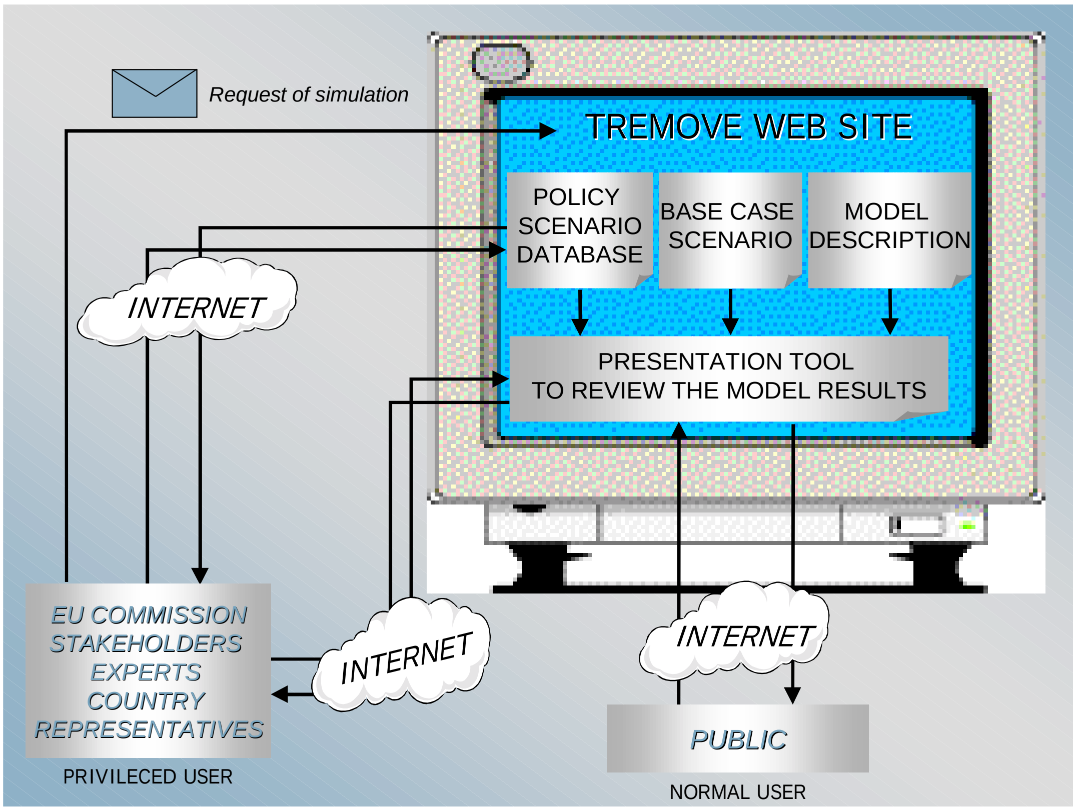
In principle, two different groups of potential users can be identified, as depicted in figure 4.3: *privileged* users and *normal* users. The first group, *privileged* users, includes stakeholders, Commission staff, staff from Member State governments, etc. and should be allowed to access the model to read and compare the results as well as to use the tool to run customised simulations. For the second group, *normal* users (e.g. students, public, etc.), a different access should be envisaged with just the opportunity of reading predefined results: this interface could be much very simple as it has a minor relevance with respect to the access of interested users.

The proposed way to make the TREMOVE model accessible for the *privileged* users is based on the general orientation of the software platform development and has been also experienced by GAMS itself for other applications. The model resides on a machine where a few users actually run the model. The user which would like to use the TREMOVE model for a test should translate such a test in a set of changes in the model variables. These changes should be collected in a spreadsheet of pre-specified format and the user would send a spreadsheet to a special account as an e-mail attachment. On the mail server the attachments would get automatically extracted, that is the data included in the spreadsheet would be translated into the appropriate

input for the model run. Results would be mailed back again as spreadsheets to the user and at the same time made available in the Policy Scenario Database. This is a dedicated area in the TREMOVE web site which collects results of the requested runs and is made available to all *privileged* users also to avoid that different users require the simulation of the same (or very similar) policy.

Thus the user does not need either a GAMS system on his machine or a specific knowledge about transport models, but only a spreadsheet program and access to the Internet. The TREMOVE web-site will also made available the base case scenario and a detailed description of the model functioning, assumptions and parameters as well as a set of examples of different applications in order to facilitate the correct interpretation of the model results.

Fig. 4.3 Access to the TREMOVE model



Regarding point (ii) other projects offers insights into potential improvements of TREMOVE, which might be useful for the development of the Policy Scenario Database for the *privileged* users or the Presentation Tool for the *normal* user. This is the case for STEEDS, ASTRA, and PROPOLIS. With reference to STEEDS we can consider:

- the stand-alone user-friendly software tool that allows the policy analyst to study pre-calculated results "ex-post" (i.e. exploring a set of policy options he/she defined in advance to an expert modeller who then ran the models);

- the "results visualisation" tool allows to pre-define a range of presentational formats, and then create user-friendly data manipulation and graphics capabilities. One can't forecast every type of graph that a policy analyst may require but with the option that data are transferred from a "results data table" into a spreadsheet bespoke manipulation are possible.

STEEDS works in ACCESS environment therefore there is the need of software expertise for exploring the transferability of such kind of tools in the TREMOVE framework.

A similar approach for a easy access to model results was also adopted in the ASTRA project, a research managed by DG TREN where a pilot software tool for the strategic assessment of transport policies and investments at EU scale was developed. The ASTRA–TIP (Tool for Implementation of Policies) was developed in the Vensim System Dynamics software and was designed to provide the user an easy-to-use platform to display and to compare the ASTRA model results for the pre-calculated five ASTRA policy packages.

In the PROPOLIS project (DG RESEARCH, EESD Programme, City of Tomorrow key action) an analytical framework for the assessment of urban sustainable transport policies has been developed. An internet-based analysis package, which will allow presentation and comparison of model data, in standard format, in a central data repository is being developed in the course of the project. The study includes seven case cities with seven different integrated land-use and transport models where policies are simulated; the internet-based analysis package will facilitate detailed comparisons of indicator values between policy options and between cities in an interactive GIS environment.

V) Build consensus on the TREMOVE model

TREMOVE is candidate to be one of the key tools of the Clean Air for Europe (CAFE) thematic strategy for air quality launched by the European Commission. The model will be used as well in the context of the European Climate Change Programme (ECCP). It is then strictly necessary to assure a large consensus about the model technical characteristics and results.

The lessons from Auto-Oil II, where great care was devoted to involve the stakeholders and Member States in the modelling analysis. In this way the TREMOVE data and methodology reached a broad consensus and this was the pre-requisite for the acceptance of the policy simulation results produced by the TREMOVE model. Furthermore, as far as the TREMOVE model is part of a broader

family of models (see point II above) the acceptance of its methodology involves that the consensus spreads out implicitly to the whole modelling system.

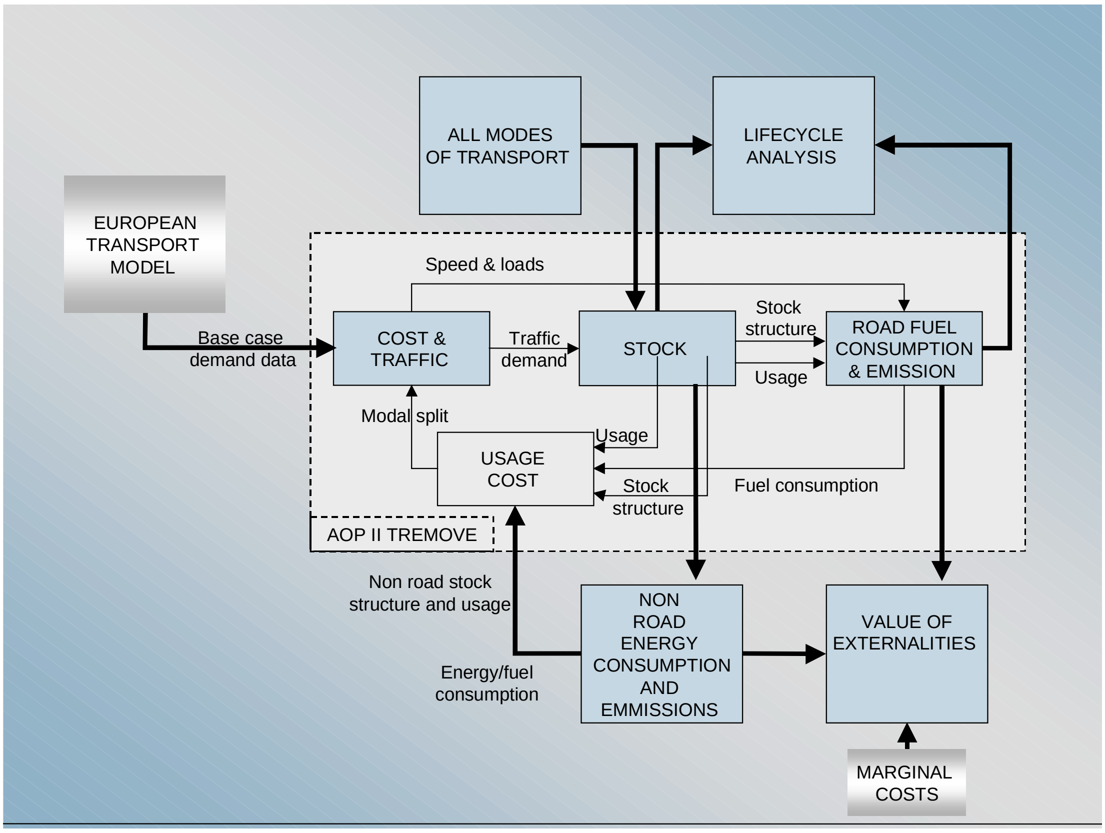
Sensitive issues require particular care: for instance, the inclusion of computation of external costs of pollution within the TREMOVE framework and the consequent change of "identity" of the analysis – from cost-effectiveness to cost-benefit – is highly relevant in policy terms and should agreed – to the extent possible – among stakeholders.

Consensus can be achieved with transparency during the construction of the database and sensitivity analysis (i.e. documenting and "publishing"). This is time consuming and therefore should be considered at the very beginning of the project planning.

4.3 Recommendations for model improvements

In terms of enrichment of the current structure of TREMOVE, the proposed improvements can be depicted as in figure 4.4. The improvements are analysed in turn in the following.

Fig. 4.4 Proposed development of the TREMOVE structure (option 3)



a) Extending the geographical coverage to all 15 EU countries plus Norway and Switzerland

The six EU15 countries for which the model currently uses a simplified approach have to be considered with the same level of detail of other nine countries. If some specific data is not available estimates can be used, but the whole structure of the model should be replicated. Norway and Switzerland can be added to the model. Such two countries have a developed statistical system and therefore they should be able to provide the data required for the model.

b) Adding new pollutants

COPERT III covers a larger range of pollutants than TREMOVE. It is advisable that the latter is extended to cover all the elements included in the former. Furthermore, also other relevant pollutants could be added. The complete list of pollutant which should be dealt with by TREMOVE include:

i. greenhouse gases: Carbon dioxide (CO_2), Methane (CH_4), Nitrous protoxide (N_2O);

ii. other exhaust emissions: Carbon oxide (CO), Nitrous oxides (NO_X), Volatile organic component (VOC), Ammonia (NH_3), Sulphur oxides (SOx);

iii. Diesel exhaust particulates (PM). PM includes different categories according to the dimension of particles (PM_{10}, PM_5, ecc.), what PM has actually to mean in TREMOVE is subordinated to the results of projects like ARTEMIS and PARTICULATES and therefore to the availability of emissions factors.

iv. Other pollutants: Polyciclyc Aromatic Hydrocarbons (PAHs), Persistent Organic Pollutants (POPs), Dioxins and Furans.

v. Specific gases emitted by mobile air conditioning fluid leakage: Hydrofluorocarbons (HFCs), Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC) and Perfluorocarbons (PFCs)[24];

vi. Sulfur hexafluoride (SF_6) emissions from tyres.

If the list above includes all the elements which in principle should be considered, it is worth to note that the knowledge about the emission factors is not at the same level for all pollutants. Items from i) to iv) are all covered by COPERT III with regard to road emissions, however only for CO, CO_2, NO_X, VOC and PM_{10} the emission factors can be considered as reliable at this stage. For other pollutants, much more uncertainty exists especially for non road vehicles. Additionally, items v) and vi)

[24] Theoretical work on mobile air conditioning pollution is available in Baker, 1999.

have not been part of projects like COPERT and therefore more work is required to derive usable parameters.

Thus, while it is suggested to expand the structure of TREMOVE in order to cover all the pollutants listed above, a starting list of parameters which should actually be implemented in the model might be decided in the light of the existing knowledge. Once the structure of the model is ready, remaining elements might be added as reliable parameters are available.

The definition of a "open" structure would be also relevant in terms of the kind of parameters which might be available in the future. The uncertainty analysis carried out in ARTEMIS shows that there are many elements which affect emission factors other than those currently considered. It might be expected that more detailed factors are available in the next future. For instance, the weight of vehicles is a significant element which is currently considered only in average terms. More generally, for a given vehicle class/driving conditions, a distribution of unitary emission levels rather than a single average value could be supplied. This kind of improvements should be taken into account.

It is then recommended that the incorporation of more recent emissions functions is not conceived as a "one-shot" task, because possible revisions to be brought about later by on going research projects will have to be incorporated easily. These aspects should be included among those who deserve a large debate to achieve a large consensus about a workable solution.

c) Adding new motor/fuel technologies

In the future years, new technologies might be available and they might be competitive with consolidated ones, especially if specific policies were set to sustain them. The fleet module of TREMOVE can easily adapted to consider additional fuel/motor types. Automotive industries and oil industry representatives might provide indications about the foresee development of specific technologies to be considered.

d) Computing external costs of pollution

The TREMOVE model includes the computation of <u>social</u> costs which is well founded in welfare microeconomics. The addition of <u>external</u> costs of pollution is both consistent (external costs are social ones) and compatible with the modelling approach, and is recommended in order to achieve a full analysis of policies at the microeconomic level. In fact, the present approach only can derive a cost-effectiveness analysis, leaving implicit (i.e. entirely to the policy maker) the estimate of the social costs of the external impacts of transport.

This would represent a very valuable feature of the TREMOVE model, even if left as an "option", given the high political sensitivity of the matter. The objection that external cost estimates are uncertain can be curbed by the wide literature on the subject, and the large amount of research funded by the Commission on this issue.

A set of marginal costs of pollution is required as exogenous input. Among other things the UNITE project (2000) is producing a set of marginal costs. The results of the ExternE project and the INFRAS-IWW study can be used as a reference.

e) Adding computation of lifecycle emissions

The extension of the computation of emissions to the contribution of lifecycle of fuel and vehicles can enlarge the scope of the model. In broad terms the basic principle of lifecycle assessment is to take into account all transport relevant up - and down - stream processes within a defined system boundary. The Engineering Society For Advancing Mobility – Land Sea Air and Space[25] has been producing a wide range of studies about the lifecycle assessment in the transport sector.

In operating terms, the approach used in STEEDS can be considered as a feasible solution. In STEEDS, lifecycle analysis includes the manufacture, maintenance, and the scrappage of all kind of vehicles (i.e. road and non road) as well as the provision of fuels. A specific module is used to compute lifecycle emissions which uses inputs from other components of the model, namely the vehicle fleet module and the fuel consumption module. As such inputs are already produced by TREMOVE, the addition of a specific similar module to compute lifecycle emissions along the lines of the STEEDS methodology should be straightforward.

Other projects are also concerned with some aspects of lifecycle analysis. TRENDS project considers lifecycle for road transport, with the exception of vehicle production. PRIMES deals with the emission due to fuel production on the basis of the refinery technologies. Within the lifecycle analysis, the problem of mobile air conditioners disposal should be addressed.

f) Revising transport demand categories

The TREMOVE model distinguishes three main categories of passenger demand: urban inhabitants, urban commuters and non-urban. For freight just urban and non-urban is considered.

[25] http://www.sae.org/

A more detailed description of demand is proposed in order to allow the use of more specific parameters and therefore to better simulate the effect of the policies on the transport demand (trip generation, modal split, etc.)[26].

For passengers, a first classification should be working and non-working trips. The distinction urban vs. non-urban trips can be retained for each of the two categories above[27]. Non-urban trips should be further distinguished between shorter (e.g. less than 50 km) and longer trips. Considering working and non-working trips separately would allow to simulate that the substitution of the former is much less of the latter. The distinction of shorter and longer trips would allow the definition of a proper set of alternatives (e.g. air is not available on shorter trips whereas motorcycles might be considered only for such trips).

For freight, the same structure would apply with commodity values instead of trip purpose (e.g. higher value goods and lower value goods) and with a wider threshold to identify longer trips (e.g. 250 km).

The indication of including two groups both for passenger and for freight should be considered as a proposal, a larger number of groups, if compatible with a workable size of the model, would be even better. For instance, for goods density of the goods is important as much as value for modal split. Also in terms of distance, more than two bands would be helpful.

This requires some modelling work. The number of submodels for each country increases as well as the complexity of the tree of alternatives. Also the calibration of a more detailed set of elasticities is required.

g) Adding new modes of transport

Air and sea shipping cannot be disregarded in assessing the effect of transport policies on the emission levels. The inclusion of such modes within the scope of TREMOVE is recommended[28].

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[26] The differentiation by trip purpose and commodity type does not have a direct impact on the emission functions to be used in TREMOVE: i.e. it is not expected to apply different emission factors for trucks or trains carrying diverse type of goods.

[27] The distinction between sample cities and other urban areas should disappear instead. Within the revised categorisation of demand, urban trips should be entirely represented by data provided by the transport model.

[28] With reference to agriculture tractors and mobile cranes, the way these modes can be included in the framework of TREMOVE is difficult to see. In addition data about the number of such modes, their performance, the composition of fleets, etc., is not generally available. Therefore the inclusion of such modes is not recommended.

The addition of such modes would add much value to the model, but it is not an easy task, also because the modelling experience is less developed in comparison to what has been developed for land modes of transport. The set of alternatives has to be re-designed within non-urban traffic; new elasticities of substitution regarding such modes have to be estimated (probably shorter and longer distance demand have to be separated, even if in a coarse way, because the substitution does not concern the whole traffic, see below).

Perhaps the main difficulty is that air and ship are relevant essentially with reference to international traffic which is not modelled in TREMOVE. The problems associated with the need of including international trips in the structure of the model can only be addressed by modellers. One possible solution is to add international trips as a module in itself at the same level of those of each country. The allocation of the volume of traffic and of the resulting emissions to each country is a major issue. The allocation could be achieved according to observed Origin-Destination data and assumptions about paths or by other methods. This is a very important element as international traffic has been growing faster than domestic one and, especially for some countries (e.g. Austria, Belgium) its contribution on environmental effects is significant.

Another issue is the estimation of operating cost of non road modes. Data available regarding trains, ships or aircrafts are much less detailed than road vehicles one and a not negligible appraisal effort might be required.

TREMOVE currently computes only emissions of road modes while other modes already included in the model (i.e. rail and inland navigation) are not considered on this side. The inclusion of air and sea would be relevant if all modes were considered with a comparable structure of analysis; the addition of new modes with only road emissions still computed would be of limited sense. Non-road emissions are currently considered by TRENDS and ARTEMIS (and were included in STEEDS), which can be useful sources to feed TREMOVE.

h) Extending the geographical coverage to the Accession countries

The extension of TREMOVE to Central and Eastern Europe countries is much more problematic. The availability of data, especially temporal series, is often limited. The suggestion is to include only those countries which can provide the main bulk data and to exclude all other countries until sufficient data is available. The structure of TREMOVE is not a closed one and additional countries can be added quite straightforwardly.

If the group of Eastern Europe countries which can be considered is large enough, for the other Accession Countries the approach base on proximity currently used by TREMOVE for six EU countries could be adopted.

The extension of the model means also the use of specific parameters by country as already envisaged among future improvements in the AOPII report.

4.4 Research directions for further development of the model

The improvements mentioned above do not exhaust the list of topics considered in the discussion reported in chapter 4 of the report. Other elements of the model can be enhanced, in principle, however this would involve a very complex modelling work or data that are not readily available.

These elements are discussed below. It is worthwhile to explore the development of TREMOVE in these directions but it is not the case for including these aspects in an enhanced version of TREMOVE to be produced in a reasonable time. Therefore the items outlined are to be considered as long term views. They are presented in order of relevance: the connection with a macroeconomic model is considered the most promising (and also the less resource-consuming) task, the improvement of the definition of spatial domains follows, while the inclusion of a land-use model is the most complex issue.

i) Connecting TREMOVE to a macroeconomic model

The treatment of costs in TREMOVE is very robust although limited to the microeconomic level. In the general recommendation above, it has been suggested to implement some simplified parameter (like marginal cost of public funds) to simulate general effects of policies on the macroeconomic side.

A further step, which would require a dedicated analysis both from the theoretical and the modelling point of view, can be directed toward the connection to a macroeconomic model in order to simulate the macroeconomic effects of policies. The model would enlarge its scope from a micro/static perspective to a macro/dynamic one becoming a powerful tool for the analysis of transport policies.

This operation is challenging in intellectual terms, but further dedicated research may prove that this task will not be very expensive nor long, and therefore may present a high benefit-cost ratio. The rationale of this extension lies in the possible dynamic links between social surplus, measured in microeconomic approaches, and overall economic development impacts, where GDP, employment and income distribution can be taken into account over an extended period of time (ASTRA, 2000). In this context, also the dynamic environmental impacts may well play a role, even if a specific analysis is required on this further dimension of the macro - content of the proposed extension. Besides, this theoretical effort can generate important benefits beyond and above the TREMOVE context, since the relation between micro and macro approaches is a major issue, regarding a wide set of models also outside the transport sector.

Thus, the connection to a macroeconomic model should be included within the tasks which require a significant research effort even though the economic resources required would be somewhat limited also in the light of the general value of the result.

j) Improving the definition of spatial domains

Currently, the model produces results for urban areas, motorways and rural areas. This is perfectly consistent to the kind of parameters available from COPERT. When external costs are considered or when land use is to be simulated, a more detailed classification would be desirable.

For instance, the external cost is considered higher in metropolitan areas, densely populated, than in small town, so the domain "urban" should be specified. This refinement would need a much more complex model and suitable parameters which are hardly available in the short terms.

k) Including a simplified regional/land-use module

The capability of simulating the land-use effects of policies or, on the other side, testing the effects of land-use policies is a desirable one. However, given the very coarse modelling of spatial contexts in the model, a considerable change of the philosophy of the model would be required.

A location module at regional/urban level should be realised. The spatial contexts should be defined with a greater detail. The maximisation of utility under the income constraint should include explicitly the cost of the land used (e.g. data about the floorspace prices should be then collected for all countries).

With such a module, migration between different areas could be modelled both with regards to the natural trend and concerning the effect of policies.

5. ACKNOWLEDGEMENTS

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Significant contributions to the project development were provided by the high level experts of the TREMOVE *Contact Group*.

It is important to remark that in any case only the authors have the responsibility for what is included in this report.

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ANNEXES

ANNEX 1 COMPARISON OF BASE CASE TRANSPORT FORECASTS

A1.1 Comparison with SCENES and TRENDS

In the context of this technical assessment, TREMOVE base case scenario was compared with the corresponding data from the SCENES model (SCENES, 2001) and from the TRENDS used in the Infras-IWW study on external costs of transport (Infras, IWW, 2000). Please note that for the SCENES model, vkm are not available as for non-road modes traffic is simulated in terms of passengers or tons and not in terms of vehicles. For road modes there are a number of occupancy factors according to trip purpose and freight type, so that vkm figures cannot be derived from pkm and tkm figures.

Tab. A1.1 Passenger traffic – TREMOVE/SCENES/TRENDS – year 1995

		TREMOVE 1995			TRENDS for Infras-IWW 1995			SCENES 1995
Country	Mode	Mpkm	Mvkm		Mpkm	Mvkm		Mpkm
9 EU countries	bus/coach	322 364	21 094		297 278	18 681		347 300
	Car	3 451 572	1 954 684		2 931 587	1 720 083		3 313 300
	Rail	320 136	2 713		241 659	n.a.		242 600
	Motorcycles	91 985	91 985		36 589	33 714		
	non-motorised	53 549	53 549		n.a.	n.a.		187 300
	Total	**4 426 906**	**2 124 025**		**3 507 113**	**1 772 478**		**4 090 500**

Tab. A1.2 Freight traffic - TREMOVE/SCENES/TRENDS – year 1995

		TREMOVE 1995			TRENDS for Infras-IWW 1995			SCENES 1995
Country	Mode	Mtkm	Mvkm		Mtkm	Mvkm		Mtkm
9 EU countries	LGV	73 051	230 799		75 798	252 662		1 024 200
	HGV	1 248 941	181 713		1 312 397	238 345		
	Rail	176 085	992		176 700			175 900
	Total	**1 498 077**	**413 504**		**1 564 895**	**491 007**		**1 200 100**

The comparison for the year 1995 (base year for the SCENES model) shows that TREMOVE simulates a larger amount of passenger traffic than the other two models. The difference is wider in comparison with TRENDS where for all modes the

amount of both pkm and vkm is lower. With respect to SCENES, the negative difference is due to car and rail, whereas for the other modes TREMOVE data is slightly lower.

Concerning freight traffic, TREMOVE figures lie between SCENES and TRENDS. The three models are very close to each other regarding rail transport while road traffic explain all the differences. It should be especially considered that the SCENES model was calibrated to reproduce domestic and international freight traffic according to the EUROSTAT statistics. Such statistics do not take into account road traffic performed by vehicles with a payload lower than 3.5 tonnes whereas this part of traffic is included in TREMOVE and TRENDS. So the lower tkm figure for SCENES is due to this discrepancy.

When looking at the country level (see tables A1.7 and A1.8 below) some significant differences can be annotated, especially regarding freight data. Such differences are all attached to road traffic, while rail figures compare well.

Transport forecasts at year 2010 can be compared between TREMOVE and TRENDS. With regard to passengers, TREMOVE figures are significantly higher than TRENDS data. However, almost the whole difference can be accounted to the different starting point. In fact, TREMOVE adds about one million of Mpkm whereas TRENDS adds about 800 thousands Mpkm, this means that both models forecast a growth rate of 1.4% per year. The only relevant different is about bus and coaches where growth is significantly higher in TREMOVE than in TRENDS. For most of the countries, the two models forecast a similar growth rates, the main exceptions are France, Ireland and Spain where the growth rate of TREMOVE is significantly higher.

Forecasts regarding freight are very similar in absolute value. However, as TRENDS starts from a higher level of demand it implicitly describes a slower growth trend. The explanation is mainly due to the stability of rail traffic assumed in this model.

Tab. A1.3 Passenger traffic forecasts - TREMOVE and TRENDS – year 2010

		TREMOVE 2010			**TRENDS for Infras-IWW 2010**	
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**	**Mvkm**
9 EU countries	bus/coach	399 242	26 317		322 059	19 862
	Car	4 471 281	2 556 499		3 658 611	2 143 554
	Rail	425 476	3 832		298 175	
	Motorcycles	120 479	120 479		46 108	42 486
	non-motorised	62 422	62 422			
	Total	**5 478 900**	**2 769 549**		**4 324 953**	**2 205 902**

For the year 2020, the term of comparison is the SCENES model. Both for passenger and for freight, the final volume of demand is very similar for both models. In TREMOVE, rail passenger grows less than in SCENES, the reverse applies for rail freight. Looking at the countries, the only significant differences regard The Netherlands and Spain for passengers and Germany for freight.

Tab. A1.4 Freight traffic forecasts - TREMOVE and TRENDS – year 2010

		TREMOVE 2010			TRENDS for Infras-IWW 2010	
Country	**Mode**	**Mtkm**	**Mvkm**		**Mtkm**	**Mvkm**
9 EU countries	LGV	107 134	315 032		99 320	331 075
	HGV	1 698 463	232 887		1 700 390	307 604
	Rail	234 673	1 318		176 700	
	Total	**2 040 270**	**549 237**		**1 976 410**	**638 679**

Tab. A1.5 Passenger traffic forecasts - TREMOVE and SCENES – year 2020

		TREMOVE 2020			SCENES 2020
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**
9 EU countries	bus/coach	450 416	30 175		434 500
	car	5 042 615	2 886 785		5 105 700
	rail	499 548	4 508		559 400
	motorcycles	138 493	138 493		167 700
	non-motorised	66 291	66 291		
	Total	**6 197 363**	**3 126 252**		**6 267 300**

Tab. A1.6 Freight traffic forecasts - TREMOVE and SCENES – year 2020

		TREMOVE 2020			SCENES 2020
Country	**Mode**	**Mtkm**	**Mvkm**		**Mtkm**
9 EU countries	LGV	126 979	368 693		2 174 478
	HGV	2 044 276	270 860		0
	Rail	283 272	1 589		181 373
	Total	**2 454 527**	**641 142**		**2 355 851**

In brief, the comparisons show that TREMOVE is broadly in line with other models. However, the mere fact that different demand data are considered in different projects can be considered as a negative element. As far as European based models developed within EU research projects are concerned, working with a unique database on which a large consensus is obtained would be a significant progress. Common data would mean avoiding the need of re-estimating the same variables in each project and would allow more meaningful comparisons among the outcome of the models.

Tab. A1.7 Passenger traffic - TREMOVE/SCENES/TRENDS – year 1995

		TREMOVE 1995			TRENDS for Infras-IWW 1995			SCENES 1995
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**	**Mvkm**		**Mpkm**
Finland	bus/coach	8 000	620		8 224	637		8 100
	car	50 153	35 760		29 506	21 061		49 400
	rail	3 572	28		3 184	n.a.		3 200
	motorcycles	900	900		900	900		
	non-motorised	1 179	1 179		n.a.	n.a.		2 200
		63 804	**38 487**		**41 814**	**22 598**		**62 900**
France	bus/coach	41 020	2 701		58 213	3 143		47 500
	car	671 249	380 800		543 996	292 390		642 800
	rail	64 500	730		59 100	n.a.		58 700
	motorcycles	19 650	19 650		6 883	6 328		
	non-motorised	14 314	14 314		n.a.	n.a.		34 300
		810 733	**418 195**		**668 192**	**301 861**		**783 300**
Germany	bus/coach	60 343	3 880		83 491	4 503		80 900
	car	946 405	536 896		733 036	508 529		900 800
	rail	107 263	1 223		68 310	n.a.		64 300
	motorcycles	12 184	12 184		12 800	12 800		
	non-motorised	17 975	17 975		n.a.	n.a.		46 700
		1 144 170	**572 158**		**897 637**	**525 832**		**1 092 700**
Greece	bus/coach	9 400	519		2 754	257		9 700
	car	48 428	31 044		66 355	33 508		52 600
	rail	8 261	17		1 568	n.a.		1 400
	motorcycles	4 324	4 324		910	867		
	non-motorised	461	461		n.a.	n.a.		3 500
		70 874	**36 365**		**71 587**	**34 632**		**67 200**
Ireland	bus/coach	5 834	244		1 868	221		5 300
	car	28 829	16 380		31 580	18 491		27 500
	rail	1 291	13		1 291	n.a.		1 200
	motorcycles	277	277		286	260		
	non-motorised	665	665		n.a.	n.a.		2 000
		36 896	**17 579**		**35 025**	**18 972**		**36 000**
Italy	bus/coach	85 898	3 529		57 350	3 386		91 500
	car	581 355	340 830		602 350	319 891		591 000
	rail	58 275	121		49 700	n.a.		52 400
	motorcycles	35 633	35 633		7 650	5 905		
	non-motorised	4 017	4 017		n.a.	n.a.		37 900
		765 178	**384 130**		**717 050**	**329 182**		**772 800**
The Netherlands	bus/coach	11 580	647		9 950	448		16 300
	car	150 128	89 978		111 873	68 556		142 600
	rail	13 344	141		13 977	n.a.		13 800
	motorcycles	2 618	2 618		1 200	1 200		
	non-motorised	13 200	13 200		n.a.	n.a.		14 300
		190 870	**106 584**		**137 000**	**70 204**		**187 000**
Spain	bus/coach	60 671	4 249		33 122	1 316		42 000
	car	341 710	169 836		308 161	152 820		300 300
	rail	26 232	63		15 313	n.a.		16 300
	motorcycles	12 199	12 199		1 960	1 454		
	non-motorised	1 556	1 556		n.a.	n.a.		11 800
		442 368	**187 903**		**358 556**	**155 590**		**370 400**

		TREMOVE 1995			TRENDS for Infras-IWW 1995			SCENES 1995
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**	**Mvkm**		**Mpkm**
UK	bus/coach	39 618	4 705		42 306	4 770		46 000
	car	633 315	353 160		504 730	304 837		606 300
	Rail	37 398	377		29 216	n.a.		31 300
	Motorcycles	4 200	4 200		4 000	4 000		
	Non-motorised	182	182		n.a.	n.a.		34 600
		714 713	**362 624**		**580 252**	**313 607**		**718 200**

Note: all figures are in millions per year

Tab. A1.8 Freight traffic - TREMOVE/SCENES/TRENDS – year 1995

		TREMOVE 1995			**TRENDS for Infras-IWW 1995**			**SCENES 1995**
Country	**Mode**	**Mtkm**	**Mvkm**		**Mtkm**	**Mvkm**		**Mtkm**
Finland	LGV	900	3 150		922	3 075		23 200
	HGV	22 300	2 640		21 350	3 432		
	Rail	9 293	16		9 600	n.a.		9 600
		32 493	**5 806**		**31 872**	**6 507**		**32 800**
France	LGV	20 220	77 800		23 070	76 899		232 800
	HGV	245 236	29 500		183 945	39 743		
	Rail	46 072	269		49 100	n.a.		48 100
		311 528	**107 569**		**256 115**	**116 642**		**280 900**
Germany	LGV	7 539	39 102		7 756	25 853		279 700
	HGV	299 180	49 088		303 983	66 565		
	Rail	68 800	402		69 800	n.a.		68 800
		375 519	**88 592**		**381 539**	**92 418**		**348 500**
Greece	LGV	5 910	8 442		3 468	11 559		14 800
	HGV	38 232	6 585		52 509	7 122		
	Rail	319	2		300	n.a.		300
		44 461	**15 029**		**56 277**	**18 681**		**15 100**
Ireland	LGV	1 701	2 578		373	1 245		5 400
	HGV	6 958	1 240		19 198	2 617		
	Rail	602	4		600	n.a.		600
		9 261	**3 822**		**20 171**	**3 862**		**6 000**
Italy	LGV	23 212	33 161		10 121	33 738		184 800
	HGV	149 956	24 038		245 399	44 571		
	Rail	24 670	144		21 700	n.a.		21 700
		197 838	**57 343**		**277 220**	**78 309**		**206 500**
The Netherlands	LGV	1 997	10 975		53	176		42 200
	HGV	40 255	6 915		116 541	15 576		
	Rail	3 016	18		3 100	n.a.		3 100
		45 268	**17 908**		**119 694**	**15 752**		**45 300**
Spain	LGV	5 014	16 495		19 616	65 386		94 600
	HGV	291 692	31 938		155 100	27 634		
	Rail	10 013	59		10 000	n.a.		10 400
		306 719	**48 492**		**184 716**	**93 020**		**105 000**
UK	LGV	6 558	39 096		10 419	34 731		146 700
	HGV	155 132	29 769		214 372	31 085		
	Rail	13 300	78		12 500	n.a.		13 300
		174 990	**68 943**		**237 291**	**65 816**		**160 000**

Tab. A1.9 Passenger traffic forecasts - TREMOVE and TRENDS – year 2010

		TREMOVE 2010		**TRENDS for Infras-IWW 2010**	
Country	**Mode**	**Mpkm**	**Mvkm**	**Mpkm**	**Mvkm**
Finland	bus/coach	7 851	608	8 327	645
	car	64 316	45 855	38 710	27 631
	rail	5 182	40	4 177	n.a.
	motorcycles	1 147	1 147	1 134	1 134
	non-motorised	1 511	1 511	n.a.	n.a.
		80 007	**49 161**	**52 348**	**29 410**
France	bus/coach	59 284	3 957	63 677	3 438
	car	916 683	520 100	612 526	329 224
	rail	98 124	1 256	66 542	n.a.
	motorcycles	26 930	26 930	8 677	7 977
	non-motorised	17 573	17 573	n.a.	n.a.
		1 118 594	**569 816**	**751 422**	**340 639**
Germany	bus/coach	73 160	4 758	97 916	5 281
	car	1 180 974	670 095	896 444	621 890
	rail	130 612	1 575	83 538	n.a.
	motorcycles	16 876	16 876	16 134	16 134
	non-motorised	20 509	20 509	n.a.	n.a.
		1 422 131	**713 813**	**1 094 032**	**643 305**
Greece	bus/coach	15 293	844	1 361	127
	car	68 970	44 211	92 392	46 656
	rail	10 593	22	2 183	n.a.
	motorcycles	6 015	6 015	1 146	1 092
	non-motorised	592	592	n.a.	n.a.
		101 463	**51 684**	**97 082**	**47 875**
Ireland	bus/coach	8 343	351	2 544	301
	car	42 200	23 755	40 068	23 461
	rail	1 703	18	1 638	n.a.
	motorcycles	379	379	361	328
	non-motorised	859	859	n.a.	n.a.
		53 484	**25 362**	**44 611**	**24 090**
Italy	bus/coach	91 063	3 549	61 398	3 625
	car	739 835	433 907	799 054	424 355
	rail	82 327	173	65 930	n.a.
	motorcycles	47 648	47 648	9 630	7 433
	non-motorised	5 150	5 150	n.a.	n.a.
		966 023	**490 427**	**936 012**	**435 413**
The Netherlands	bus/coach	13 682	776	11 549	520
	car	181 110	108 873	128 431	78 703
	rail	18 223	207	16 043	n.a.
	motorcycles	2 618	2 618	1 513	1 513
	non-motorised	13 992	13 992	n.a.	n.a.
		229 625	**126 466**	**157 536**	**80 736**
Spain	bus/coach	86 824	6 089	35 110	1 395
	car	517 156	257 331	399 069	197 902
	rail	36 681	87	19 830	n.a.
	motorcycles	13 625	13 625	2 471	1 833
	non-motorised	2 018	2 018	n.a.	n.a.
		656 304	**279 150**	**456 480**	**201 130**

		TREMOVE 2010			TRENDS for Infras-IWW 2010	
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**	**Mvkm**
UK	bus/coach	43 742	5 385		40 177	4 530
	car	760 037	452 372		651 917	393 732
	rail	42 031	454		38 294	n.a.
	motorcycles	5 241	5 241		5 042	5 042
	non-motorised	218	218		n.a.	n.a.
		851 269	**463 670**		**735 430**	**403 304**

Note: all figures are in millions per year

Tab. A1.10 Freight traffic forecasts - TREMOVE and TRENDS – year 2010

		TREMOVE 2010			TRENDS for Infras-IWW 2010	
Country	**Mode**	**Mtkm**	**Mvkm**		**Mtkm**	**Mvkm**
Finland	LGV	1 489	5 243		1 306	4 357
	HGV	34 529	4 063		30 196	4 854
	Rail	13 357	24		9 600	n.a.
		49 375	**9 330**		**41 102**	**9 211**
France	LGV	28 537	106 200		28 749	95 829
	HGV	325 213	38 920		229 229	49 527
	Rail	70 175	410		49 100	n.a.
		423 925	**145 530**		**307 078**	**145 356**
Germany	LGV	13 126	48 259		9 417	31 391
	HGV	338 440	54 119		369 091	80 822
	Rail	74 025	433		69 800	n.a.
		425 591	**102 811**		**448 308**	**112 213**
Greece	LGV	9 209	13 156		4 342	14 473
	HGV	64 005	11 024		65 743	8 917
	Rail	575	3		300	n.a.
		73 789	**24 183**		**70 385**	**23 390**
Ireland	LGV	2 221	3 365		535	1 785
	HGV	9 951	1 716		27 524	3 752
	Rail	808	5		600	n.a.
		12 980	**5 086**		**28 659**	**5 537**
Italy	LGV	28 547	40 782		13 691	45 639
	HGV	185 754	29 562		331 967	60 294
	Rail	40 706	238		21 700	n.a.
		255 007	**70 582**		**367 358**	**105 933**
The Netherlands	LGV	4 812	18 328		73	244
	HGV	67 751	8 298		161 269	21 554
	Rail	6 364	37		3 100	n.a.
		78 927	**26 663**		**164 442**	**21 798**
Spain	LGV	6 991	22 997		28 612	95 374
	HGV	433 150	47 484		226 235	40 308
	Rail	15 363	90		10 000	n.a.
		455 504	**70 571**		**264 847**	**135 682**
UK	LGV	12 202	56 702		12 595	41 983
	HGV	239 670	37 701		259 136	37 576
	Rail	13 300	78		12 500	n.a.
		265 172	**94 481**		**284 231**	**79 559**

Tab. A1.11 Passenger traffic forecasts - TREMOVE and SCENES – year 2020

		TREMOVE 2020			SCENES 2020
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**
Finland	bus/coach	7 744	600		9 600
	car	68 169	48 595		60 400
	rail	6 134	47		6 700
	motorcycles	1 214	1 214		2 200
	non-motorised	1 632	1 632		
		84 893	**52 088**		**78 900**
France	bus/coach	77 657	5 235		58 800
	car	1 068 788	606 400		1 084 000
	rail	125 794	1 703		154 900
	motorcycles	31 290	31 290		35 300
	non-motorised	19 740	19 740		
		1 323 269	**664 368**		**1 333 000**
Germany	bus/coach	76 901	5 001		98 000
	car	1 241 361	704 364		1 366 700
	rail	137 286	1 675		141 200
	motorcycles	17 678	17 678		41 200
	non-motorised	21 555	21 555		
		1 494 781	**750 273**		**1 647 100**
Greece	bus/coach	22 075	1 219		16 100
	car	86 376	55 369		77 600
	rail	12 636	27		2 000
	motorcycles	7 175	7 175		2 700
	non-motorised	683	683		
		128 945	**64 473**		**98 400**
Ireland	bus/coach	9 126	384		8 000
	car	46 389	26 064		47 200
	rail	1 865	21		3 100
	motorcycles	413	413		2 100
	non-motorised	938	938		
		58 731	**27 820**		**60 400**
Italy	bus/coach	94 153	3 891		119 600
	car	870 313	510 562		854 900
	rail	111 794	239		113 700
	motorcycles	57 049	57 049		35 300
	non-motorised	6 087	6 087		
		1 139 396	**577 828**		**1 123 500**
The Netherlands	bus/coach	12 940	738		24 000
	car	200 341	120 571		286 900
	rail	17 497	204		34 300
	motorcycles	2 618	2 618		12 400
	non-motorised	13 200	13 200		
		246 596	**137 331**		**357 600**
Spain	bus/coach	103 744	7 275		49 400
	car	609 743	303 418		465 300
	rail	42 048	100		32 900
	motorcycles	15 130	15 130		11 000
	non-motorised	2 219	2 219		
		772 884	**328 142**		**558 600**

		TREMOVE 2020			SCENES 2020
Country	**Mode**	**Mpkm**	**Mvkm**		**Mpkm**
UK	bus/coach	46 076	5 832		51 000
	car	851 135	511 442		862 700
	rail	44 494	492		70 600
	motorcycles	5 926	5 926		25 500
	non-motorised	237	237		
		947 868	**523 929**		**1 009 800**

Note: all figures are in millions per year

Tab. A1.12 Freight traffic forecasts - TREMOVE and SCENES – year 2020

		TREMOVE 2020			SCENES 2020
Country	**Mode**	**Mtkm**	**Mvkm**		**Mtkm**
Finland	LGV	1 723	6 069		57 970
	HGV	40 476	4 763		
	Rail	16 959	30		15 073
		59 158	**10 862**		**73 043**
France	LGV	31 495	123 800		528 919
	HGV	394 513	46 890		
	Rail	86 201	504		48 100
		512 209	**171 194**		**577 019**
Germany	LGV	15 360	50 727		606 682
	HGV	355 748	56 886		
	Rail	77 811	455		68 800
		448 919	**108 068**		**675 482**
Greece	LGV	12 410	17 729		47 475
	HGV	89 442	15 405		
	Rail	836	5		300
		102 688	**33 139**		**47 775**
Ireland	LGV	2 347	3 556		12 080
	HGV	10 529	1 813		
	Rail	949	6		600
		13 825	**5 375**		**12 680**
Italy	LGV	32 009	45 727		348 160
	HGV	209 821	33 147		
	Rail	59 616	349		21 700
		301 446	**79 223**		**369 860**
The Netherlands	LGV	7 146	23 267		94 030
	HGV	96 333	9 483		
	Rail	8 324	49		3 100
		111 803	**32 799**		**97 130**
Spain	LGV	8 220	27 039		221 620
	HGV	531 123	58 224		
	Rail	19 276	113		10 400
		558 619	**85 376**		**232 020**
UK	LGV	16 269	70 779		257 542
	HGV	316 291	44 249		
	Rail	13 300	78		13 300
		345 860	**115 106**		**270 842**

A1.2 Comparison with STEEDS

In the STEEDS project a direct comparison between STEEDS and TREMOVE base case scenarios was performed (STEEDS, 1999)[29]. Two major European countries were chosen for such a test: Germany and the UK.

With reference to UK, the two different approaches have resulted in moderately different passenger/freight-kilometres, but vehicle-kilometres are broadly similar.

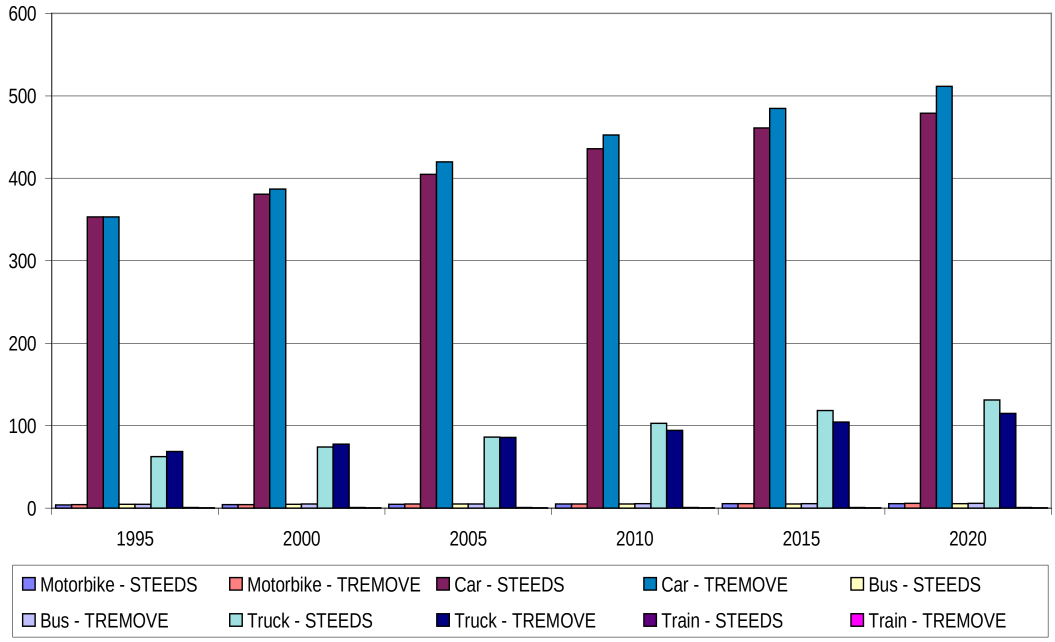
The STEEDS simulation predicts a slower increase in vehicle-km for cars than TREMOVE, but a higher rate of increase for trucks. According to STEEDS modellers, this may be due to the different vehicle size categories in the two models; e.g. in STEEDS, light trucks are a mix of “Ford Escort” type vans and light duty vehicles up to 3.5 tonne gross vehicle weight. The ‘missing’ car-km in STEEDS may therefore be offset by the additional van-km.

STEEDS road passenger-km account for 95.4% of total passenger-km (excluding air) in the UK in 1995, whereas TREMOVE comes up with 88%. According to STEEDS modellers, this is likely to be due to different assumptions for average load factors. STEEDS load factors have been taken from published literature such as *1998 Transport Statistics Great Britain*, whereas for instance the computed load factors for cars in TREMOVE seem rather high, at 1.79 in 1995 (as opposed to 1.58 in the literature).

In general, traffic is growing in both simulations: the TREMOVE growth trend is a straight line, whereas the STEEDS prediction shows a lower rate of increase before 2003. This is due to the fuel duty escalator for gasoline and diesel (assumed to be in force until 2002) which affects the total cost of transport as well as the relative cost between modes.

[29] This section is mainly drawn from the STEEDS final report made available by AEA Technology.

Fig. A1.1 Road and rail transport demand (in billion vehicle-km)
STEEDS/TREMOVE base case comparison for the UK



Source: STEEDS, 1999

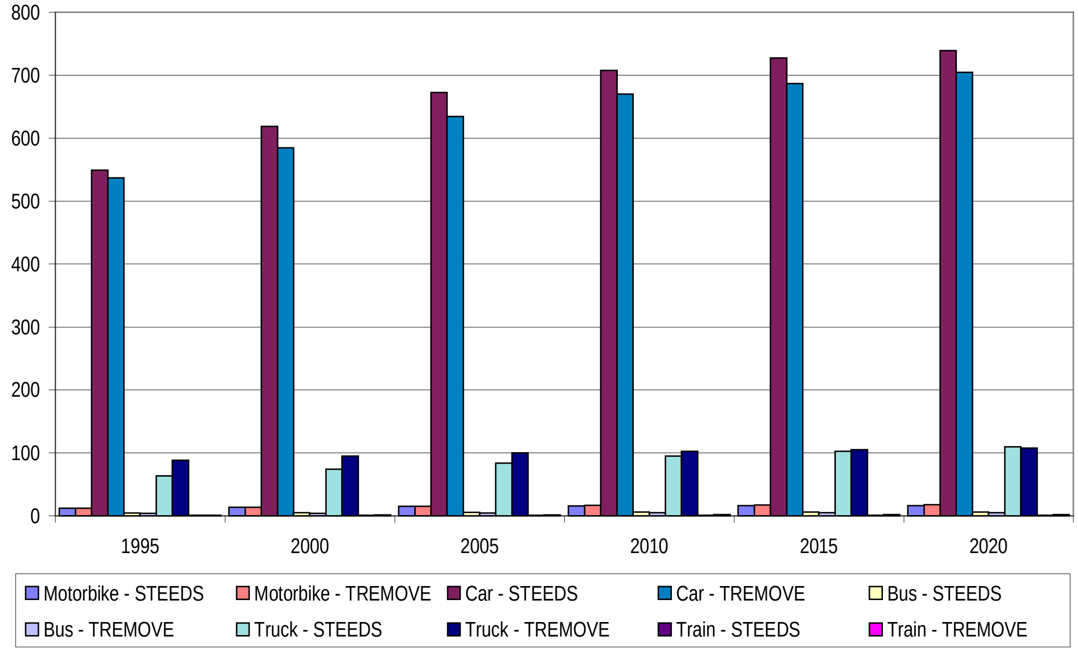
With reference to Germany[30] transport demand forecast, STEEDS and TREMOVE approaches have resulted in moderately different developments of total passenger/freight-kilometres, but vehicle-kilometres (which determine the emissions results) are broadly similar (figure 3.2). The STEEDS simulation predicts a slightly higher rate of increase in vehicle-km for cars than TREMOVE as well as a higher rate of increase for trucks (but starting from a lower level in 1995).

In terms of modal shares, STEEDS road passenger-km account for 93.1% (excluding air) in Germany in 1995, whereas TREMOVE comes up with 91% (compared to 9% rail). There is here a difference in average load factors for cars: in TREMOVE is computed to be 1.76 in 1995, staying constant until 2020, whereas in STEEDS is was assumed to be 1.35, which is claimed to be in accordance with published data. This apparent gap explains the difference in passenger-km for cars (741.5 billion km in 1995 for STEEDS, 946.4 billion km in 1995 for TREMOVE). However, the key parameter for emissions implications, vehicle-km, is not affected adversely. Traffic (in vehicle-km) grows in both simulations, with growth tailing off over time, due mainly to the common GDP assumptions underlying the two simulations.

[30] Germany has the highest total transport demand (both passenger and freight) of all the Member States in the EU.

For freight transport, road traffic is growing faster than other modes in STEEDS, up from 220 billion tonne-km in 1995 to 381.4 billion tonne-km in 2020.

Fig. A1.2 Road and rail transport demand (in billion vehicle-km) – STEEDS/TREMOVE base case comparison for Germany



Source: STEEDS, 1999

ANNEX 2 TRANSPORT FORECASTING MODELS AT EUROPEAN SCALE

One of the tasks of the technical assessment project is to explore conditions for a cost-effective interfacing of TREMOVE with European transport models. Indeed, this was one of key recommendations of the model authors in 1999 when they complained about the problems due to the lack of consistency of the transport forecast in the existing version of TREMOVE. In fact, for the modelled countries, TREMOVE currently uses external data collected from a variety of sources at national level, including public organisations, transport authorities, transport ministries, private consultants. This issue is analysed in detail in section XX.X and here a short inventory of strategic transport models covering the EU is reported. An introduction section illustrates the characteristics of strategic transport models and then four transport models are analysed in detail.

A2.1 Strategic transport models of the EU

Transport models are designed to describe the impacts of transport decisions in a simplified representation of the real world. Among the wide range of transport models for different planning purposes, those that can be candidate to be connected with the TREMOVE model belong necessarily to the category of strategic models.

It is required that the spatial scope of these models is consistent to the need of providing European-wide detailed transport data. The models which meet these criteria, and for which information has been found, are:

- The SCENES model;
- The VACLAV-VIA model;
- The NEAC model;
- The EUFRANET model.

The SCENES is the most complete as it covers all trips with all modes of transport for freight and passengers and has a spatial coverage which includes also some Accession countries. The VACLAV-VIA model has a complete coverage of the CEEC countries for both passengers and freight, but its focus is on long distance transport (travels longer than 50 km). The other two models, NEAC and EUFRANET, are long-distance freight transport models.

Box A2.1 MDir: know more about existing transport models

MDir (transport Models Directory) is one key issue of the SPOTLIGHTS Thematic Network (see annex 4)

Mdir is public and is accessible through the project website. The status of MDir is that 222 European transport models have been included in the database, which consists of 57 models characteristics. The characteristics are clustered under 7 main groups: policy relevance, model accessibility, input data, model formulation, model outputs, software & hardware, audits. Notably in the characteristics, the policy relevance of models plays an important role: i.e. what is the transport domain of models (passenger/freight) on what scale do the models operate? As such, the MDir is expected to help policy makers/modellers to learn from past experience.

According to NEA, the partner responsible for the development of the database, about 80% of European models are included in Mdir, even though the information is not complete for all the models. They also state that the difficulties encountered so far in setting up the MDir are:

- to get complete information on a model: the modellers that constructed the model seem to be the only ones that can give the best level of detail in describing the model;
- the maintainability of the Mdir after the SPOTLIGHTS Thematic Network; it is essential that one organisation is harmonising the diffuse information that is filled in;
- the 57 characteristics take time to fill in, if a self-sustaining system is aimed at (see point a) then this could be an obstacle.

A2.2 The SCENES model

SCENES is a strategic multimodal transport model at the European scale dealing with both passenger and freight transport developed within a project funded by the European Commission under the transport RTD Programme of the 4th framework programme (SCENES, 2001). This passenger and freight model is based on the model developed during the preceding STREAMS project.

The model is designed to produce in the first instance European transport forecasts. Comprising as it does, of a wide range of demographic, economic, socio-economic and transport factors, and being built as a 'bottom up' model from the zone level

(with many parameters and data inputs specified at the country level), a much greater level of detail is possible.

Base and forecast year

The base year of the SCENES model is 1995. Forecasts are provided for year 2020.

Geographical scope and zoning system

The SCENES model is an extension of the STREAMS model, which concentrated on the EU countries, and hence had the EU area as internal zones. The new internal countries of the SCENES model in the CEEC area are Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, and Slovenia.
The zoning system includes 244 internal zones (205 in the EU area built on NUTS II[31] regions and 39 in the CEEC area), and 21 external zones. The latter are used to ensure that the traffic leaving or coming to the internal SCENES model area goes in the correct general direction.

Virtual zones are used to simulate local (intra-zonal) trips.

Network

The SCENES model uses a multimodal network. The road, rail and inland waterway networks of the SCENES model are based on IRPUD's (Institute of Spatial Planning, University of Dortmund) so-called 'base networks' and their detail is high; for instance there are about 5000 road links and 2000 rail links. The rail "shuttle" services are modelled explicitly in terms of path, frequency, timetable. Pipelines, sea shipping and air network are less detailed. Road network includes capacity of links.

Traffic categories

The SCENES model simulates both passengers and freight traffic to, from and between the 244 internal zones. An innovative treatment of intra-zonal travel for both passengers and freight allows the characteristics of even the shortest trips to be represented.

Concerning passengers, the model deals with all trips, including not motorised ones. On the freight side, data used to calibrate the model does not include traffic performed by road vehicles with a payload lower than 3.5 tonnes.

15 different passenger flows, according to purpose and length, and 13 freight flows are simulated.

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[31] NUTS (Nomenclature of Territorial Units for Statistics) is the classification of EU regions used by EUROSTAT to provide regional data.

Modes of transport

A very detailed set of modes is considered in SCENES. On the passenger side, slow modes, personal car, business car, local bus, coach, train, high speed rail, air are used. On the freight side, modes are: light goods vehicles, heavy goods vehicles, conventional train, combined transport, sea shipping, inland navigation, air freight and pipelines.

Different phases of trips are modelled by means of suitable "network modes". For instance, mode "ship" includes "ship in navigation", "ship in port", "loading/unloading" as well as the part of trip by land modes when origin and/or destination is in a region without a port.

Algorithms

The generation phase is very different in passenger and freight model. On the passenger side, trip rates by different population groups are used. On the freight side, a spatial adaptation of Input-Output matrices is used to simulate economic trades which are translated into traffic flows..

The distribution of passenger trips is governed by published data on the spread of trips / person / year over different distance bands. The distribution of freight trips derives from the trade matrix.

The mode choice phase is performed according to a hierarchical logit formula for each Origin-Destination pair. The disutility of each mode is computed as generalised cost plus suitable modal constants.

The assignment phase uses a Stochastic User Equilibrium (SUE) algorithm to split trips among alternative paths according to a logit formula. Generalised cost (only perceived monetary costs are used) is computed in the logit model.

The modal choice phase take place simultaneously to assignment so that they affect each other. Equilibrium is reached after iterations.

Applications

The SCENES project ended in late 2001. Currently the model is being applied in the TIPMAC project.

The SCENES project builds closely on the work undertaken by the STREAMS project. 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.

A2.3 The VACLAV-VIA model

The VACLAV-VIA model (Schoch, 2000) is built on the classic four-step approach of trip generation, trip distribution, mode choice and trip assignment and is the result of the joint application of two complementary models. It is based on the VACLAV model for Germany developed by IWW and enlarged to a Europe-wide forecast model for long distance passenger traffic and the VIA model, developed by Mkmetric, which deals with the generation and distribution steps.

Base and forecast year

The base year of the model is 1995. Forecasts are produced for year 2020.

Geographical scope and zoning system

The geographical area covered by VACLAV comprises the whole Europe. The zoning system is based on the NUTSIII nomenclature within the European Union. Due to differences on the data availability the zoning in the CEE-countries ranges from NUTSIII to NUTS0. In total, the zoning system used by VACLAV comprises 1200 regions.

Network

The network includes road, rail and air links.

The road network is very detailed and is the result of the merging of different GIS road networks. NEA has supplied the network parts for Belgium, the Netherlands, Luxembourg, Great Britain and Ireland. INRETS provided the network information for France, Spain, Portugal and Italy whereas the IWW covered Germany, the Scandinavian and Alpine countries, Greece as well as the Central and Eastern European countries. In total, the road network now comprises about 20.000 undirected links and 10.000 nodes.

The rail network was built mainly from timetable evaluations, for a total of some 150,000 km of railway lines in Europe. In total, the network comprises about 3.800 links that connect 3.200 nodes or stations. Several attributes are associated to the links including those required for the assessment of capacities.

The Air Network is coded in the form of a matrix showing the connections between 400 airports. These connections consist not only of the available non-stop flights, also transfer connections using two or more non-stop flights are included. Airports are connected to the road and/or railway network, but not directly to the regions, as access and egress using non-air modes is necessary. In total the network consists of about 400 airports and about 2.500 non-stop-flights representing the mode air transport.

Traffic categories

VACLAV covers all inter-zonal long distance trips (trips length at least 50km). The demand is segmented by three trip purposes.

Although the main purpose of VACLAV is the forecast of passenger demand, also models for freight forecasts are included especially the road freight assignment step is well developed and compatible to the NEAC model (Common assignment of freight and passenger road vehicles).

Modes of transport

The modal choice set comprises four means of transport: Car, Railway, Air, Coach (Eastern-European model only).

Algorithms

For each origin-destination pair *ij*, the modal split model estimates the probability of selecting a modal alternative *m* according to a non-linear logit function is used.

In the assignment phase generalised users costs are calculated (derived from the utility functions in the mode choice model) for every link in the network and shortest path algorithms are applied. Speeds on road links (and therefore their contribution to user costs) depend on the traffic load situation.

Applications

The main applications of VACLAV-VIA are:

- STEMM (Strategic European Multi Modal Modeling)
- PETS (Pricing European Transport Systems)
- Traffic Forecast for the Ten "Helsinki" PAN-European Corridors
- European Transport Forecast 2020 (Forecast 2020)

A2.4 The NEAC model

The NEAC model[32] was first developed in the mid eighties for freight and passenger transport. In the early nineties the transport chain principle was included in the freight model and in 1999 the model has been extended to include Central and Eastern Europe, improving the quality of transport forecasts and transport flow analysis.

[32] http://www.nea.nl/neac/

The NEAC model provides transport forecasting of goods and passengers including corridor analysis and Policy impact analysis.

Base and forecast year

The base year of the NEAC database is 1995 for Western Europe, 1996 for Eastern Europe except Russian Federation database whose base year is 1998.

Estimations are provided yearly from base year to 1999 and forecasts are produced for years 2005, 2010, 2015 and 2020.

Geographical scope and zoning system

The model covers Western Europe (EU15 countries plus Norway and Switzerland) with a detail of more than 200 zones based on NUTS II and 13 Eastern Europe PHARE countries (Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovak Republic, Hungary, Romania, Slovenia, Bosnia & Hecegowina, Albania, Macedonia and Bulgaria) with a detail of more than 100 zones. Russian Federation is represented with 89 regions.

Network

No details are provided in the web site.

Traffic categories

The freight side of the NEAC model distinguishes 11 commodity groups, that is the 10 NST/R[33] Chapters with Crude Oil separated.

One of the main features of the NEAC model is the distinction between trade flows and transport. The construction of the database is carried out by describing, as accurately as possible, the trade between the regions of origin and destination of a commodity including as much as possible information on the route followed resulting therefore in transport information.

Modes of transport

Four alternatives of transport are modelled explicitly: road, rail, inland navigation and sea. Other alternatives are collected into a “rest” mode.

Algorithms

For the estimation process of the trade flows a gravity model is used in which the trade between countries/regions is explained by the supply factors of the exporting

[33] NST/R (Standard Goods Classification for Transport Statistics/Revised) is the classification of goods used for EUROSTAT data.

country/region and the demand factors of the importing country/region. The underlying theory is that trade is the result of the specialisation of countries/regions.

The distance between the countries/regions in the analysis is used as a proxy for a 'resistance' on the trade between countries. The effects of specific circumstances like economic co-operation in a free trade zone are captured by a dummy variable.

The modal-split model determines new market shares of different transport alternatives based on changes in cost and time. Depending on the commodity groups distance and total tonnage on relations transported, several segments have been identified; within each segment of the market the development of the modal-split is dependent on the transport time and the cost of transport of each mode in relation to other modes (cross elasticities). The coefficients for the elasticities of time and cost in the model are significant among the segments that differ significantly from each other.

The modal split model is adapted in such a way that it can handle transport chains, it gives forecasts for the shares before and after transhipment. The competition between sea and inland modes is restricted.

It is possible to make assignments of the total trade in weight (volumes), it is also possible to make assignments of transport units (trucks, inland waterway ships, trains, sea-going vessels). Different kinds of assignments can be made, varying from simple all or nothing assignments to intermodal multiple-route assignments.

Applications

The NEAC model has been used in several projects at regional, national and international level. Among the most recent projects there are:

- forecasts for the 10 Helsinki pan-European transport corridors (EU Commission, PHARE, DG I, 1999);
- Transport forecasting goods and passengers, horizon 2020 (EU Commission, DG VII, 1999)
- THINK UP – Thematic network for understanding mobility predictions (5th Framework Programme EU Commission, 2000);
- INFREDAT (4th Framework Programme EU Commission, 2000) A methodology for collecting INtermodal FREight Transport DATa.;
- CONCERTO, Concertation action for European transport information systems (4th Framework Programme EU Commission, 2000). The main objectives of the CONCERTO project are the promotion of the development of a European Transport policy Information System (so-called ETIS).

A2.5 The EUFRANET model

The EUFRANET project (1997-1999) was funded by the European Commission under the transport RTD Programme of the 4th framework programme (EUFRANET, 1999). One of the main objectives of the EUFRANET project was the evaluation of different strategies for the development and operation of an efficient and competitive trans-European freight railway network. Basis for this evaluation is the calculation of market response of rail freight as a function of the new quality levels defined in the different strategies.

Therefore one of the main tasks in the EUFRANET project was the provision of the origin-destination freight transport flows and an appropriate modal split-model.

Base and forecast year

The model was built on the basis of the NEAC data base of the year 1992. Forecasts are provided for year 2020.

Geographical scope and zoning system

The data was complete concerning EU countries excluding Sweden and Finland (which were not part of EU in 1992, Austria also was out of EU at that time, but it is included in the model) plus Switzerland. For the other countries only the flows in relation with these 14 countries was available.

The zoning system includes 158 regions mainly based on NUTS II.

Network

Even if the model does not deal with the assignment phase a network is used to assess quality level of modes, although a rail network is not present and quality level for such a mode is provided by a train simulation program from IVE (Hannover).

The road network includes more than 7.500 nodes and nearly 12.000 links. The Inland Navigation networks consists of 376 nodes and 437 links

Traffic categories

The model considers 11 freight flows correspondent to the commodity groups of the NEAC database, i.e. the 10 NST/R chapters with crude oil separated.

The modal split phase is applied only to inter-zonal traffic.

Modes of transport

Four modes are considered in the modal split phase: road, rail conventional, combined transport and inland navigation.

Algorithms

The idea of the freight transport demand model is to explain the production and consumption of goods as a function of the socio-economic variables of the regions. A stepwise procedure is used. In a first step the demand by country and direction (national, export and import) is projected. In the following working steps this demand is disaggregated by commodities and regions. Finally the regional distribution of the transport flows is done.

In the modal split-model a hierarchical logit model is used with a nonlinear (Box-Cox) transformation of the variables price and time in the utility functions.

For road and inland navigation, the level of service is determined. The transport time of road between two zones is calculated by searching the fastest route in the network and adding resting time for the drivers and loading/unloading time. For inland navigation time consists of access/egress on road and the shipping time on the network including waiting time for the locks and resting time. For the transport price average price functions are used.

Applications

No applications outside of the EUFRANET project.

ANNEX 3 DATA REQUIRED BY TREMOVE

This annex summarises the main data required by the TREMOVE model. Focusing on the data requirement was intended primarily in the light of the aim of extending its scope to non-EU countries. However, the extension of the scope of TREMOVE according to the proposed developments implies the availability of additional data also for EU countries. Two groups of data are identified: information used in the current structure of TREMOVE (table A3.1) and information required for an improved version of TREMOVE (table A3.2).

Within each group, data is classified according to its relevance for the calibration of the model:

- *Essential*: data is strictly required to build the model, alternative estimates are not feasible of reliable;

- *Important*: estimates can be used, but the quality of the model would be undermined;

- *Useful*: estimates can be used without big problems in the model.

A contribution from a the Accession countries experts of the Contact Group was requested to fill in the final column in the table to verify the availability of data for non EU country. The results of the survey is reported in tables A3.1 and A3.2, which also include the content of the "*Statistical yearbook on candidate and South-East European Countries – data 1995-1999*" issued by EUROSTAT (2001).

It should be noted that some data included in the tables is not country-dependent (e.g. emissions factors) and can be provided by single source (e.g. the ARTEMIS project about emissions). Such a data is reported in *Italics* in the tables below.

Tab. A3.1 Current version of TREMOVE – Accession countries data requirements

Data	Essential	Important	Useful	Accession countries availability				
				CZ	HUN	POL	SLO	SY
Demand								
Volume of passenger demand by mode (pass and pass*km)	X			FA	FA	FA	EA	PA
Volume of freight demand by mode (tons and tons*km)	X			FA	FA	FA	EA	PA
Data for splitting traffic between urban and non-urban, commuters and inhabitants		X		FA	UA	FA	PA	NA
Substitution elasticities by demand category			X	FA	NA	EA	NA	NA
Value of time by demand category and mode			X	NA	EA	FA	NA	NA
Average trip length		X		FA	EA	NA	NA	NA
Costs								
Production costs by mode		X		EA	PA	FA	EA	NA
Tax and subsidies affecting user costs		X		FA	PA	FA	FA	NA
Fleet								
Number of existing vehicles by type and age	X			FA	PA	PA	FA	PA
Annual number of new vehicles by type and technology	X			FA	PA	FA	FA	PA
Annual number of scrapped vehicles by type and technology	X			FA	PA	PA	EA	NA
Annual mileage of vehicles by type			X	EA	EA	PA	FA	NA
Trend of annual mileage of vehicles			X	EA	EA	PA	EA	NA
Occupancy rate/load factor of vehicles by type and class demand (i.e. urban, non-urban, peak, off-peak, etc.)		X		EA	EA	PA	FA	NA
Fuel price (yearly average)		X		FA	FA	FA	FA	NA
Vehicle purchase costs by type of vehicle			X	FA	PA	FA	FA	NA
Macroeconomic data								
Forecasts of GDP by year		X		FA	FA	FA	FA	NA
Forecasts of population by year		X		FA	FA	FA	FA	NA
Disposable income		X		FA	FA	FA	FA	EA
Private consumption		X		FA	FA	FA	FA	EA
Environmental data								
Emission factors by pollutant and road class	*X*			-	-	-	-	-
Fuel consumption by vehicle type, technology and age			*X*	-	-	-	-	-
Average temperature by month			X	FA	FA	FA	FA	NA

Key: FA = Full availability; PA = Partial availability (e.g. coarse classification); EA = Availability from estimations; UA = Uncertain availability; NA = Not available

SY = EUROSTAT, "*Statistical Yearbook On Candidate And South-East European Countries – data 1995-1999", Luxemburg, 2001*

Tab. A3.2 Enhanced version of TREMOVE (option 3) – Accession countries data requirements

Data	Essential	Important	Useful	Accession countries availability				
Demand				**CZ**	**HUN**	**POL**	**SLO**	**SY**
Volume of passenger demand **by trip purpose** and by mode **including air** (pass and pass*km)	**X**			FA	NA	FA	PA	PA
Volume of freight demand **by freight type** and by mode **including ship** (tons and tons*km)	**X**			FA	PA	FA	PA	PA
Data for splitting traffic **between shorter and longer distance**		**X**		NA	EA	FA	PA	NA
Substitution elasticities by demand category **by country, by trip purpose and by distance**			**X**	NA	NA	NA	NA	NA
Value of time by demand category **by country, by trip purpose and by distance**			**X**	NA	NA	FA	NA	NA
Costs								
Production costs by mode **including air and ship**		**X**		EA	PA	FA	FA	NA
Representative **tariffs by mode, by trip purpose and by country**		**X**		NA	NA	FA	FA	NA
Fleet								
Number of vehicles equipped with mobile conditioning devices		**X**		NA	NA	NA	EA	NA
Annual number of new vehicles equipped with mobile conditioning devices				NA	NA	NA	EA	NA
Annual number of new innovative vehicles (i.e. new fuel technologies) by type and technology			**X**	NA	NA	PA	EA	NA
Number of rail tractors by type (electric, diesel),				NA	NA	FA	NA	NA
Number of aircraft by type				NA	NA	FA	NA	PA
Number of vessels by type				NA	NA	FA	NA	PA
Environmental data								
Emission factors of road vehicles by pollutant and road class ***for new pollutants and new fuel technologies***	***X***			-	-	-	-	-
Fuel consumption of road vehicles by vehicle type, technology and age ***including new fuel technologies***	***X***			-	-	-	-	-
Emission factors for non-road vehicles	***X***			-	-	-	-	-
Fuel consumption of non-road vehicles	***X***			-	-	-	-	-
Location of power plants by country and by type of plant		**X**		FA	FA	FA	FA	NA

Key: FA = Full availability; PA = Partial availability (e.g. coarse classification); EA = Availability from estimations; UA = Uncertain availability; NA = Not available
SY = EUROSTAT, "*Statistical Yearbook On Candidate And South-East European Countries – data 1995-1999", Luxemburg, 2001*

From the responses received, it seems that most of the data required for extending the current version of TREMOVE to the Accession countries should be available though a significant part would require some estimations and only a partial coverage of the information would be assured. It was also stressed that collection of information could be demanding in term of time.

Problems concern especially with fleet data, where the level of detail request by the fleet module of TREMOVE might not be satisfied and additional estimations might be required. Also specific parameters like elasticities, values of travel time are mentioned as not available, but most of this elements can be integrated by external sources.

When the additional details for an improved version of TREMOVE are required, more problems are reported. Passenger demand data by trip purpose is generally not available. Also freight traffic by commodity type is not available or not very reliable. SCENES or other models should be the reference source, probably. Also additional details on fleet (e.g. non-road vehicles, vehicles equipped with mobile conditioning devices) are generally not available.

ANNEX 4 MAIN PROJECTS AND PROGRAMMES LINKED TO TREMOVE

The following is a list of the main projects and programmes which have or could have linkages with the TREMOVE model.

ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) - DG TREN

A project of four years started in 2000 with 35 partners led by TRL dealing with emissions from all modes of transport – two wheelers, cars, light duty vehicles, heavy duty vehicles, rail, air and maritime. The project considers also the life cycle assessment and takes into account also the non-regulated pollutants and the influences of auxiliary equipment (air conditioners). ARTEMIS is developed in close co-operation with Member States and the EEA. The European Transport Emissions Review Group (ETERG) has been formed as part of this project. ETERG includes representatives of the EU and Member States, and provides a convenient avenue for the transmission of data and information to and from the project and the national representatives. ARTEMIS' results should represent the advanced version of COPERT methodology (COPERT IV) and could represent the source of emission functions for the advanced version of TREMOVE.

www.trl.co.uk/artemis/introduction.htm

ASTRA (Assessment of Transport Strategies) – DGVII Transport

The ASTRA objective was the development of a tool that analyses the long-term effect of the EU Common Transport Policy (CTP) not only for the transport system but also for the most important connected systems. The tool was developed analysing synergies between different policy measures or policy bundles and considering feedbacks of transport policies with other related policy fields and other real systems. The integrated ASTRA model was based on a set of reliable and already existing models from different scientific disciplines. The implemented tool, the ASTRA System Dynamics model platform (ASP), can be categorised as System Dynamics model for integrated long-term assessment of the European transport policy with a spatial representation on a functional basis. The ASP integrates the macroeconomic sub-module (MAC), regional economics and land use sub-module (REM), the transport sub-module (TRA) and the environment sub-module (ENV) into one

model. The establishment of interfaces between these originally separate models is one of the added values of the ASTRA project.

http://www.iww.uni-karlsruhe.de/ASTRA/summary.html

ATOM (Access TO Model) – DG TREN

The ATOM project has been set up to provide recommendations on how the Commission can improve the use it makes of transport models. The study is part of a group of projects that are investigating the development of a European Transport Information System (ETIS) for the Commission. The project started in 1999 and it is still proceeding.

http://fpiv.meap.co.uk/fpiv/ATOM.htm

AUTO-OIL II – European Commission DG Environment

The second European Auto Oil Programme (AOPII) was established in the spring of 1997. It was designed to provide the technical input for the Commission's work on future vehicle emission limit values, fuel quality standards and related measures. It was specifically intended to satisfy the requirements of Articles 3 and 9 of the proposed Directives, which established the mandate for AOPII. These articles referred to the need to come forward with an updated strategy to meet the requirements of the Community air quality standards and related objectives by 2010 at least cost. In order to design and implement AOPII, a number of Commission services started to draft a preliminary work programme and organisational structure. Seven working groups have been established, each of which operating on the basis of its individual terms of reference.

http://forum.europa.eu.int/Public/irc/env/aop2wg7/library

CAFE (Clean Air for Europe) - DG ENV

This is programme launched last May by DG ENV on air quality by the year 2004. In some way it follows the lines of the Auto Oil programmes but with a wider scope and includes air quality (standards for concentrations), national emissions guidelines, sector specifications. The programme will also introduce the integrated assessment of the initiatives under study.

http://europa.eu.int/comm/environment/air/cafe.htm

COWI Model - DG ENV

It estimates the effect of fiscal measures on CO2 emissions from new passenger cars. This is done by calculating the demand for passenger cars in each of the 15 EU Member States. A detailed car choice framework is the core of the model with elasticities of demand with respect to several attributes. Elasticities were calibrated on a full-scale database of new cars registration on Denmark.

ETIS research programme - DG TREN

This is an area of research managed by DG TREN with the aim to offer decision-makers with a modelling service in support of transport policy making. One of the actions undertaken concerns a common baseline for transport models and databases. The active projects are DATALINE (a pan-European long distance passenger mobility survey) and SPOTLIGHTS (a thematic network for European transport modellers to explore ways for advanced transport models fully transparent to end-users, open and more into policy-making processes). A third project about the definition of the ETIS interface is going to be launched.

ExternE (Externalities of Energy) - DG RESEARCH

The ExternE project is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles. Starting from a core group of five European teams in 1991, participation in the project has grown to over 50 teams from 15 countries. The total value of the ExternE Phase III has been around 5 MECU with the European Commission's JOULE III Non Nuclear Energy Programme contributing around 3 MECU.

http://externe.jrc.es/

PARTICULATES (Improving Understanding and Measurement of Automotive Particulates and Emission Models) - DG TREN.

The three-year research project is aimed at a further characterisation of exhaust particulate emissions from road vehicles. Together with ARTEMIS, PARTICULATES have been set up in order to achieve harmonisation of transport emissions and emission models in Europe.

www.vergina.eng.auth.gr/mech/lat/particulates/

PREMTECH II – DG RESEARCH

It is a network which joins together 40 projects dealing with the intelligent thermal engine in order to ensure that its development is well defined and suited to the targeted objectives of the industry. The major developmental areas concern, Otto cycle engines running on gasoline or alternative fuels such as natural gas, Diesel cycle engines both for light- and heavy-duty applications, Control strategies of internal combustion engines and after treatment technologies of exhaust emissions. The work includes a comparative assessment of technologies: modelling projections will result in virtual demonstrators of CO2, NOx and PM reduction potential achieved by different technological options. It uses data from TREMOVE with some new features taking into account specific inputs for regulated pollutant and CO2 emissions.

PRIMES

The development of the PRIMES energy system model has been supported by a series of research programmes of the European Commission. Its construction started in 1993. During 1998-1999 period, version 2 of PRIMES has been used to prepare the European Union Energy and Emission Outlook for the Shared Analysis project of the European Commission, DG Transport and Energy. It has also extensively used for DG Environment. PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the EU member states. It is conceived for forecasting, scenario construction and policy impact analysis, covering a medium to long-term horizon. Demand is evaluated at a national level in different sectors: residential, commercial, industry, transport. At the moment there is no exchange of input and output between PRIMES and TREMOVE, nevertheless the transport components have many points in common. A new version of PRIMES transport module is being developed by the TREMOVE modellers.

http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf

RAINS - IIASA

The model is conceived for the integrated assessment of options to control air pollution in Europe. It is a tool for analysing alternative strategies to reduce acidification, eutrophication and ground-level ozone in Europe. The model combines a variety of information relevant for the development of cost-effective emission control strategies in Europe: projections of future economic, agricultural and energy development in 38 European countries, the present and future emissions of SO2,

NOx, VOC and NH3 resulting from these activities, the options for reducing emissions and the costs of these measures, the atmospheric dispersion characteristics of sulphur and nitrogen compounds and the formation of ground-level ozone, and the environmental sensitivities of ecosystems towards acidification, eutrophication.and ground-level ozone. Its first version is dated 1985. RAINS includes modules for emission generation (with databases on current and future economic activities, energy consumption levels, fuel characteristics, etc.), for emission control options and costs, for atmospheric dispersion of pollutants and for environmental sensitivities. The RAINS model currently uses the results produced by TREMOVE, in particular, the RAINS model uses the cost of policies produced by TREMOVE.

www.iiasa.ac.at/~rains/home.html

SCENES (European Transport Forecasting Model Specification)

The research project has been completed in 2001 producing a strategic transport forecasting model of EU 15. The model is quite detailed as it deals with all modes of transport and all trips, including short distance mobility on slow modes. The model is now being linked with E3ME an econometric model of Europe in the TIPMAC project to assess the impact of transport policies and investments in the macroeconomic sector (in parallel with SCENES-E3ME, the system dynamics ASTRA model of Europe will also be used and the two results will be compared). SCENES is also used in EXPEDITE (interaction between different demand segments in Europe), SUMMA (development of indicators for social and environmental sustainability for transport policies), SPECTRUM (use of models to look at the impact of policies on the welfare).

www.iww.uni-karlsruhe.de/SCENES/#deliverables

SPOTLIGHTS

The main objective of the projects is developing and achieving an agreement within the European Modelling community "to bring advanced models to lights". The long-term ambition of SPOTLIGHTS is helping policy makers and experts ("end-users" of scientific models) to make an effective use of advanced scientific models. The project runs from January 2000 to February 2002

http://www.mcrit.com/SPOTLIGHTS/index.htm

STEEDS (Scenario-based framework for modelling transport technology deployment: energy-environment decision support)

The main objective of the **STEEDS** project was to build and validate a Strategic Transport-Energy-Environment Decision Support System, as a new approach to policy analysis in the transport sector. The software assists users in exploring options for influencing the choice and use of different vehicles for environmental benefits, in the face of uncertainty and competing policy objectives. The innovation in **STEEDS** lies in its concept as a *decision support system (DSS)* which provides three relevant elements. First, the first *user-friendly* system for *evaluating* (as well as calculating the effects of) options in the transport sector. Second, the first system with a fully *integrated set of models and external scenarios* to cover the range of transport-energy-environment issues and uncertainties, from socio-economic and policy influences on demand through to costs of externalities. Third, the first system to allow the *full environmental consequences* of demand for the *wide range of new propulsion technology options* to be addressed in detail. For example, it includes the calculation of fuel and vehicle life-cycle emissions as well as external costs.

TRENDS (Transport and Environmental Database System)

The programme is managed by EUROSTAT and DG TREN and it is a centralised application of harmonised (MEET) methodologies with time series, high temporal and spatial resolution, attribution to transport activities (first time a link with statistics). The TRENDS methodology builds on a base case transport scenario developed according to the statistics database of EUROSTAT. “Central” estimates should be consistent with national data regarding: vehicle fleets and distributions, vehicle mileage, statistical fuel consumptions and reported emission estimates for the past. It considers also the life cycle analysis of transport (from the production of vehicles and fuel to the scrapping phase). The vehicle stocks of the different transport modes are treated with great care (the car module is a dynamic model developed on the basis of FOREMOVE project). It provides emission forecasts for the future years, but it doesn’t have neither cost or behavioural components embedded in and therefore it doesn’t simulate policy impacts. The TRENDS project incorporates data from COPERT III and EUROSTAT and is ready to include as well the emission functions from the ARTEMIS project, whose focus is on non road modes of transport.

www.forum.europa.eu.int/Public/irc/dsis/pip/library?l=/environment_trends

UNITE (UNIfication of accounts and marginal costs for Transport Efficiency)

The research project is developing a pilot transport accounts of social costs and revenues of transport in Europe with forecasts to the year 2005. In parallel, 30 case studies on marginal cost of transport will be analysed and eventually a integration of the two approaches will be produced.

http://www.its.leeds.ac.uk/projects/unite/