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COMMUTE

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EXECUTIVE SUMMARY

COMMUTE was a research project that ran from 1996 to 1999 within the Strategic Research strand of the European Commission Fourth Framework Transport RTD programme. It addressed the definition of a methodology for strategic assessment of the environmental impacts of transport policy options. The methodology was intended to be primarily applicable to policy decision-making at the European level and to cover road, rail, air and waterborne transport modes. Computer software that embodies the main aspects of the methodology was developed and demonstrated within the COMMUTE project.

The main COMMUTE project objectives were as follows:

?? To define a methodology for strategic assessment of the environmental impacts of transport policy options, to support transport policy decision making at the European level.

?? To develop computer software that embodied the main aspects of the methodology and could present the results to users.

?? To demonstrate the use of the main aspects of the methodology and the computer software; in particular in the context of a pilot strategic environmental assessment of the impacts on energy consumption, primary pollutant emissions and safety of plans for the Trans-European Transport Network (TEN-T).

COMMUTE delivered two main end products:

?? The **COMMUTE methodology for SEA** of transport policies, plans and programmes (PPPs), comprising:

- A Framework for SEA covering the basic methodological requirements for SEA of multi-modal transport actions and guidelines on integration methods
- Detailed impact assessment methods for some core impacts such as air pollution emissions, energy consumption, noise and safety

?? The **COMMUTE software tool** allowing assessment of air pollution emissions, energy consumption, noise and safety impacts.

The COMMUTE Framework for SEA provides detailed guidelines for carrying out a strategic environmental assessment (SEA), and sets the use of the COMMUTE software tool in context. The full guidelines run to some 160 pages, and are structured according to the following steps, around which an SEA should be organised from the procedural point of view:

1. Setting of objectives and targets
2. Screening to determine the need for SEA at this stage of the planning process

3. Scoping: identification of:
   - the physical/regional limits;
   - the impacts to be addressed;
   - the alternative actions that need to be assessed.
4. Carrying out of the SEA:
   - measuring/predicting the environmental impact of the action and its alternatives;
   - evaluating the significance of the impact (e.g. through comparison with environmental objectives);
   - proposing recommendations: preferred alternative, mitigation and monitoring measures.
5. Preparation of the decision
6. Taking the decision
7. Making arrangements for monitoring and follow-up
8. Conducting further environmental assessments (at later stages of planning process, e.g. project EIA)

The overall COMMUTE methodology defined a range of environmental indicators for examination within an SEA. The detailed impact assessment methods defined in COMMUTE and incorporated in the software tool cover assessment of air pollution emissions, energy consumption, noise and safety, across four travel modes – road, rail, air and water. These are described in the main body of the report.

Impact assessment methods for other indicators included in the COMMUTE methodology (but not the current software) were described in detail within the COMMUTE Framework guidelines. These could be brought in to the COMMUTE software tool in a future development effort.

The COMMUTE software tool was developed to be primarily applicable to policy decision-making and is targeted primarily on relatively large scale analyses at European, national or regional scales. The tool is network oriented and works on assessments on links and nodes. The impacts are calculated on a link-by-link and node-by node basis and then added together for assessments of networks or corridors comprising a number of links and nodes.

The tool uses a Geographical Information System (GIS) for handling the geographical representation of the network and for performing spatial oriented analysis and for presentation purposes.

The COMMUTE software tool was validated against other comparable data sets, and was demonstrated within the project, particularly through the pilot SEA of plans for the Trans-European Transport Network (TEN-T). This formed a rigorous, highly demanding and large scale demonstration of the capabilities of the COMMUTE software tool and illustrated its interfacing with a complex transport model. The results were sufficiently robust for the study team to conclude that the method would be suitable for a more detailed SEA of the TEN-T.

Overall, the COMMUTE project successfully achieved its main objectives and has clear potential for future exploitation. From the work carried out in COMMUTE, it is clear, however, that further work would be beneficial in a number of areas, including:

- further methodological research to integrate sustainability target setting within the overall SEA process and to improve monitoring and follow-up after implementation of policies, plans and programmes;
- further development of the COMMUTE tool to bring in additional impact areas (particularly through the GIS interface) and accommodate other stages of the overall SEA process;
- further data collection to improve strengthen input and default data across all modes and therefore improve the accuracy and robustness of the COMMUTE tool outputs.

1. INTRODUCTION

1.1 Objectives of the COMMUTE project

COMMUTE was a research project that ran from 1996 to 1999 within the Strategic Research strand of the European Commission Fourth Framework Transport RTD programme. It addressed the definition of a methodology for strategic assessment of the environmental impacts of transport policy options. The methodology was intended to be primarily applicable to policy decision-making at the European level and to cover road, rail, air and waterborne transport modes. Computer software that embodies the main aspects of the methodology was developed and demonstrated within the COMMUTE project.

The main COMMUTE project objectives were as follows:

?? To define a methodology for strategic assessment of the environmental impacts of transport policy options, to support transport policy decision making at the European level.

?? To develop computer software that embodied the main aspects of the methodology and could present the results to users.

?? To demonstrate the use of the main aspects of the methodology and the computer software; in particular in the context of a pilot strategic environmental assessment of the impacts on energy consumption, primary pollutant emissions and safety of plans for the Trans-European Transport Network (TEN-T).

COMMUTE was the only Transport RTD project in the 4th Framework Programme that had environmental issues as its first priority and dealt explicitly with Strategic Environmental Assessment (SEA).

The environmental impacts of the provision of transport infrastructure and its subsequent use are significant in scale and arise throughout the transport sector. However, while general global and national effects of the development of the transport system have been well documented, Environmental Impact Assessment has historically been applied to individual transport infrastructure projects rather than wider policies, plans and programmes (PPPs). As a consequence, the consideration of the environmental effects is usually conducted at a local level.

As a result, there have been parallel moves in many countries towards developing an approach for the environmental assessment of policies, plans and programmes - Strategic Environmental Assessment (SEA). The widespread nature of transport systems and their consequent environmental effects have meant that transport has been a sector where the potential benefits of SEA have been identified.

In this sense, SEA can be seen as the formalised, systematic and comprehensive process of evaluating the environmental impacts of a policy, plan or programme and its alternatives, including the preparation of a written report on the findings of that evaluation and using the findings in publicly accountable decision-making.

1.2 Means used to achieve the objectives

1.2.1 End products and work breakdown structure

The COMMUTE project had two main end products:

?? The **COMMUTE methodology for SEA** of transport policies, plans and programmes (PPPs), including:

- A Framework for SEA covering the basic methodological requirements for SEA of multi-modal transport actions and guidelines on integration methods
- Detailed impact assessment methods for some core impacts such as air pollution emissions, energy consumption, noise and safety

?? The **COMMUTE software tool** allowing assessment of air pollution emissions, energy consumption, noise and safety impacts.

The impact assessment methods for other important impacts (land use and ecological impacts) that need to be considered in conducting a SEA - particularly for PPPs that involve provision of new infrastructure - are defined in outline within the COMMUTE Framework for SEA. The COMMUTE tool can later be expanded to include other impacts like land take, ecological impacts etc.

The process that defined the details of both products was a highly iterative one. Special attention was paid to the issue that the COMMUTE tool will produce outputs, which can be easily fed into SEA and into various assessment methods such as MCA, CBA etc.

COMMUTE was divided into seven work packages. The main focus of each work package was as follows:

WP1: identification of user requirements and review of methodologies and models
WP2: development of the COMMUTE assessment methodology
WP3: development of the COMMUTE computer software tool
WP4: demonstration of the COMMUTE software tool and exploitation planning
WP5: technical liaison with other projects
WP6: project management and dissemination
WP7: pilot SEA

The content of each work package and their constituent activities is summarised briefly below.

WP1: Review

Workpackage 1 represented the basis for the other following technical workpackages. In Activity 1.1, potential end-users were identified and their needs were determined.

Activity 1.2 created a state-of-the-art review of relevant methodologies and models. In addition the availability of data about noise emission and safety was reviewed. The availability of data on pollutant emissions and energy consumption across all transport modes was examined by MEET. The results of both activities contributed directly to methodology development in WP2.

WP2: Methodology

In Activity 2.1 on the basis of the inputs from WP1, an outline methodology was initially defined. This also took account of initial review work on software development under WP3. This outline methodology provided the framework for the other methodological dvelopment activities in WP2.

In Activity 2.2 the COMMUTE framework for SEA was defined. This set out guidelines on how to conduct a strategic environmental assessment of transport plans, policies and programmes, and placed the COMMUTE impact assessment methods and software tool in context.

In Activity 2.3, the final COMMUTE methodology was defined, building on the outline methodology created in Activity 2.1 and the COMMUTE framework for SEA. This included detailed definition of impact assessment methods in the areas of pollutant emissions, energy consumption, noise and safety. This led into the definition of input and output data (Activity 2.4) and formulae and algorithms (Activity 2.5). Both of these activities linked closely into Activity 3.3 - software specification.

WP3: Software development

In Work Package 3, all activities were working towards the creation of the COMMUTE software tool. These involved:

?? A review of relevant current software
?? Definition of software user requirements
?? Definition of software specification
?? Software writing
?? Software testing and refinement

WP4: Exploitation and demonstration

In Work Package 4, the usability and applicability of the COMMUTE tool was demonstrated. This included some sensitivity testing and some illustrative runs of the software on hypothetical transport scenarios. In addition, a hands-on demonstration of the software tool was organised as part of a half-day workshop on the COMMUTE outputs in Rome.

WP4 also involved development of an exploitation plan for COMMUTE. This involved identifying a range of additional future work areas using the products of COMMUTE; and areas for further methodological and technical development. An agreement between partners for future exploitation of the software tool was drawn up and signed as part of this work.

WP5: Technical Liaison

Work Package 5 represented the connection with other relevant Tasks in the Transport RTD programme Strategic Research workplan. Timely and in-depth conversations with consortia involved in the other Tasks ensured that the activities of COMMUTE were in harmony with those of other tasks to meet the higher ranked goals of the Transport Research Programme.

WP6: Management

Project management and dissemination of the results were covered in Workpackage 6. The essential task of the project management involved the consistent coordination and observation of the progress of the project, keeping under consideration the end goals as well as interim goals.

WP7: Pilot SEA

Workpackage 7 represented COMMUTE's role in the pilot SEA of plans for the Trans-European Transport Network (TEN-T), and was the major demonstration of the COMMUTE tool's application. COMMUTE assessed the impacts on energy consumption, primary pollutant emission and safety based on traffic flow and scenario inputs from STREAMS and SCENARIOS projects. COMMUTE performed seven sets of main model runs plus two extra sets of runs for sensitivity tests. The safety impacts were estimated on a national level on the basis of aggregated traffic figures per country and transport mode. The output results were returned to the STREAMS project, which was responsible for the GIS presentation.

1.2.2 Cooperation between COMMUTE and MEET

COMMUTE and MEET were two separate but complementary projects that, taken together, jointly addressed Task 1.2/18 of the Transport RTD Programme. There was therefore a strong interaction between the two projects throughout their duration. The objectives and scope of each project were complementary.

COMMUTE was to define a methodology for strategic assessment of environmental impacts. This focused mainly on pollutant emission, energy consumption, noise emission and safety across road, rail, air and waterborne transport modes. COMMUTE also developed and demonstrated software based on these aspects of the methodology. COMMUTE was driven by user needs and liaised closely with other related tasks within the Strategic Transport research work programme.

MEET provided "bottom-up" input to the methodology development. In particular, it provided input based on the availability of air pollutant emissions and energy consumption data to meet the needs of different methodologies. MEET then compiled an agreed data set that met part of the data requirements of the COMMUTE methodology and model. This covered air pollution emission and energy consumption factors across the four transport modes. It also covered related traffic characteristics for each mode.

The work packages and activity structures and the timetables of each project were defined to ensure that they were complementary and allowed the required interaction between projects. A program of cooperation was agreed between COMMUTE and MEET, which included a number of key milestones concerning cooperation between the two projects.

1.2.3 Cooperation on pilot SEA of the TEN-T

In cooperation with the MEET, STREAMS and SCENARIOS projects, COMMUTE accomplished a pilot strategic assessment of the Trans-European Transport Network (TEN-T). This was a major demonstration of the COMMUTE software tool and methodology. The aim of this work was to obtain an indication of the impacts of plans for the TEN-T, including their broad geographical distributions, in terms of energy consumption, emissions and traffic safety. The pilot demonstrated the feasibility of the developed methods, including the extent to which the approach used in the pilot project would be suitable for a full SEA of the TEN-T.

For successful completion of the pilot SEA a harmonious cooperation between the projects was essential. Therefore a Joint Scientific Committee was established, chaired by representatives of the STREAMS project and containing a representative from each project. Representatives from the Commission and the European Environmental Agency also sat in the Joint Scientific Committee. A cooperation plan was set up to ensure a trouble-free implementation.

The basic allocation of the work was for the STREAMS partners to undertake runs of the STREAMS model, according to reference and Common Transport Policy scenarios as defined (in quantitative terms) by SCENARIOS. The STREAMS transport model outputs were provided to COMMUTE who then used the COMMUTE tool to calculate energy consumption and emissions, with assistance from MEET in terms of the assumptions to be made for the calculation of future emissions, both for road and non-road transport. Estimates of traffic safety impacts were made jointly by STREAMS and COMMUTE.

1.3 Contents of this report

This is the Final Report of the COMMUTE project. As such, it summarises and presents the main results of the project. It is intended to complement a series of reports (deliverables) produced during the course of the project, which contain greater detail on various aspects of the project. These deliverables are mainly publicly available, and can be obtained from the COMMUTE Project Coordinator.

Following this introduction, Chapter 2 of the report summarises the work on user needs carried out early in the project. Chapter 3 presents a summary of the overall COMMUTE methodology and the COMMUTE framework for SEA. Chapters 4 to 9 then describe the detailed impact assessment methods that form part of the COMMUTE methodology and that were developed for incorporation in the COMMUTE software tool.

Chapter 10 of the report describes the COMMUTE software tool itself. Chapter 11 covers its validation and demonstration, including a pilot assessment of the impacts of proposals for the Trans European Network (TEN). Finally, Chapter 12 of the report presents overall conclusions from the COMMUTE project.

2. USER NEEDS

2.1 Introduction

The usefulness of any methodology depends crucially on the extent to which it satisfies the needs of its eventual users. The basic principle of the COMMUTE methodology was to allow the evaluation of large scale transport developments as regards their effect on the environment (noise, air pollution and energy consumption), and on safety. Within this context, an extensive and diverse set of applications was possible.

Not only were there many different types of policy and implementation that could be evaluated, but the effects themselves can act over different distances and time scales, impacts can be on humans, the built environment and the natural environment, effects of different pollutants vary in magnitude and importance, and they differ from those on noise and safety. Priorities of individuals and organisations will also vary, depending on the purpose of their evaluation and on their area of responsibility. Potential users include international, national and local policy developers and implementers, transport planners and providers, technologists and academics.

An important early stage of the COMMUTE project was therefore to survey the needs of potential users so that they could be taken into account in the development of the methodology. The following sections describe the design and conduct of the survey and present and discuss its results.

2.2 Methodology

The survey was carried out using a postal questionnaire. This was piloted in the United Kingdom with the involvement of two Government organisations before the main survey of user needs was undertaken. The items covered were:

?? the general value of strategic environmental assessment to the individual or his organisation,
?? the types of policy of interest,
?? the types of environmental and safety impact of interest,
?? the spatial resolution required,
?? the time resolution required,
?? the form in which the outputs were required,
?? operational requirements (software and hardware compatibility).

At this stage, some attention was also given to the existing information and data that could be useful in the development of the methodology. For example, in the context of spatial resolution, the NUTS classification of the EUROSTAT service was considered because this provides a common European basis for the description of geographical areas. Consequently, the relevant questions were designed with reference to the NUTS levels.

A total of 136 questionnaires to various people and organisations in different European countries and institutions. 67 completed questionnaires were returned, giving a good response rate of about 50%. Most responses were from government bodies (local authorities and national agencies). The second highest number of responses was from institutes (non-government organisations, including international organisations such as the UN ECE, involved in transport research and other related activities). Replies were also received from several Directorates General of the European Commission, and from a few commercial organisations and academics.

2.3 Results and discussion

Concerning the transport mode or modes of interest to the respondent, a large majority were interested in all modes (road, rail, air and shipping). Of the individual modes, road transport was selected by more than twice as many respondents as any of the other three. The dominance of road transport on an individual basis was unsurprising as its extensiveness, and therefore its impacts, easily outweigh the other modes. Nevertheless, it was concluded that most users did not wish non-road transport to be neglected in the COMMUTE methodology.

Most respondents had national responsibilities, with those having European-scale responsibilities second. This finding was borne in mind in the later evaluation of responses on the scale of application for which the COMMUTE methodology was designed.

When asked for expressions of the degree of interest in transport policies of different types, greatest emphasis was given to policies encouraging a shift between transport modes (by implication, a reduction in road transport with corresponding increases elsewhere). But, for all of the policy options mentioned, the greatest number of responses showed them to be of interest: in each case, more than half of the responses placed the level of interest in either category 4 or 5, on the scale of 1 (no interest) to 5 (strong interest). This result implied that the COMMUTE methodology needed to be sufficiently flexible to accommodate as wide as possible a range of policy options.

More detailed questions followed on the types of impact that were of interest to respondents. With regard to air pollution, strong interest was expressed in all of the pollutants mentioned in the questionnaire, and a number of others were mentioned in some replies. Slightly higher levels of interest were shown in NO_X, CO_2 and PM. Noise impacts and fuel/energy consumption were also of interest to most respondents: in fact, none of the replies indicated 'no interest' in noise impacts.

Similarly, safety impacts generally elicited high interest responses, with roughly equal numbers interested in assessments of fatalities, numbers killed or seriously injured (KSI) and of the risk of accidents. Finally, effects on land take, land use, ecology and water pollution were examined, and again most respondents assigned a high level of interest. Comments were invited also on impacts not specifically mentioned in the questionnaire. One aspect mentioned several times here was the assessment of impacts in economic terms.

Only a marginal classification of priorities was possible from these responses. It was, for instance, possible to assign relative levels of importance to different air pollutants (sulphur dioxide appeared to cause less concern than other compounds for example), and perhaps to conclude that water pollution was of less concern than energy consumption or noise impacts. However, the general conclusion was that all of the impacts were seen as important, suggesting again that the COMMUTE methodology had to be flexible and comprehensive.

Respondents were asked to categorise their required forms of presentation of assessment results. The method indicated as most important was an assessment classified by transport mode. This was consistent with the fact that modal shift policies were the type in which greatest interest was expressed. The alternative forms of presentation suggested in the questionnaire also received strong support, and several others were proposed by respondents. Once more, given that all of the ways in which the results could be presented received support from a majority of the respondents, it appeared that the COMMUTE methodology needed to include a wide range of options.

Geographical areas of most interest were major urban areas or transport corridors, and individual countries. Among the NUTS classes, levels of interest were almost equally divided, with around half of the replies assigning interest to the highest two levels in each case. Presentation of results on the scale of the European Union or in terms of a geographical grid received lower levels of support. This order of priority may have been biased by the distribution of respondents' areas of responsibility. It may also have been due to a misunderstanding of the objectives and capabilities of strategic impact assessment methods. The letter accompanying the questionnaires attempted to explain these, and stated that:

"The methodology will be applicable to decision making at a European level and may also be useful to national and regional government organisations".

There is clearly some conflict between that statement and the general requirement for smaller scale evaluations expressed in the questionnaire responses. Nevertheless, it seems overall that potential users wanted a methodology which would be applicable over a wide geographical range from the scale of quite small communities (NUTS level 1 - communities/wards/localities, of which there are almost 100000 within the EU) through to a national and international scale.

The final quantitative question on the structure of the methodology concerned the time scale required for presentation of the results of an assessment. Almost all respondents expressed a strong interest in annual average results. Also regarded as important were seasonal outputs and estimates of worst case events. Of these, the most difficult to achieve satisfactorily are the worst cases. Because these often occur as a result of the combination of a number of rare circumstances, their prediction is uncertain.

Respondents were also asked two questions on the use of strategic environmental assessment tools. The first asked about the need for such tools within their organisation. Almost equal numbers classified their current need in each of the three highest priority levels (of five), while two thirds of replies indicated the top priority level for their need in the future. The second question enquired about the environment in which users would like the methodology to operate, covering compatibility with existing software and hardware and with existing sources of related information such as the NUTS database. Most people wished to use standard hardware and software. The most commonly mentioned hardware system was a personal computer using a DOS or Windows operating system; a minority of responses mentioned other types such as Macintosh and Oracle. Standard database and spreadsheet software (such as Microsoft Access and Excel) was favoured. Regarding compatibility with external databases, a number of replies mentioned ARCINFO, or GIS databases more generally, and a number agreed with the option of using the NUTS database.

3. THE COMMUTE METHODOLOGY AND FRAMEWORK

3.1 Overview of COMMUTE Methodology

The COMMUTE methodology definition task had two main parts. These were:

- definition of an overall **COMMUTE Framework for SEA**; and
- definition of **detailed impact assessment methods** for core impacts that would be included in the COMMUTE software tool.

The overall **COMMUTE Framework for SEA** provides guidelines for carrying out an SEA. It provides on one hand general procedural and methodological requirements for the application of SEA in the transport sector and on the other hand guidelines on integration methods. Furthermore it sets the use of the COMMUTE tool for carrying out SEA in context of the overall process, and illustrates where the COMMUTE tool could be expanded in the future by covering other environmental impacts. The COMMUTE Framework for SEA is described in section 3.2.

The **detailed impact assessment methods** defined in COMMUTE and incorporated in the software tool cover assessment of air pollution emissions, energy consumption, noise and safety, across four travel modes. These are described in subsequent chapters of this report.

The relationship between these two parts is illustrated in Figure 3.1.

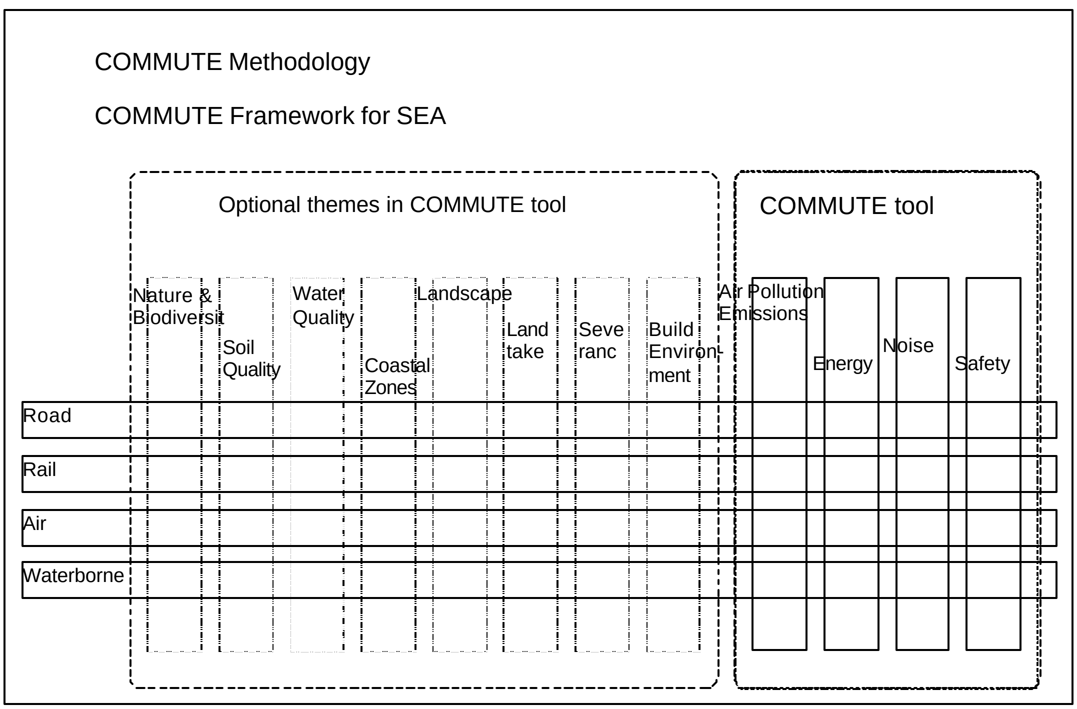


Figure 3.1 The environmental themes in COMMUTE Methodology

A key part of the overall methodology development task involved defining the themes and indicators that would be included within the COMMUTE methodology for strategic environmental assessment. These are presented in Table 3.1.

Table 3.1 SEA indicators in the COMMUTE Methodology

Theme/ Impact (if considered in COMMUTE tool shown darker)		**COMMUTE tool Indicator for road and rail transport, when less detailed geographical representation is used.**	**COMMUTE tool Indicator for air and waterborne transport, when less detailed geographical representation is used.**	**COMMUTE tool additional Indicator, when detailed geographical representation is used**
Global Issues				
	Climate Change	? Emissions of CO_2 (Total tonnes/year, Tonnes/passenger-km, Tota tonnes/year for passenger transport, Total tonnes/ tonne-km, Total tonnes/year for freight transport)	? Emissions of CO_2 (Total tonnes/year)	? Emissions of CO_2 across geographical representation
Air Pollutant Emissions	Acidification	? Gross emissions of SO_2 and NOx (Total tonnes/year, Tonnes/passenger-km, Tota tonnes/year for passenger transport, Total tonnes/ tonne-km, Total tonnes/year for freight transport)	? Gross emissions of SO_2 and NOx (Total tonnes/year)	? Gross emissions of SO_2 and NOx across geographical representation
	Air Quality	?Quantity of emissions of VOC, SO_2, NO_X, particulates , CO, Pb (Total tonnes/year, Tonnes/passenger-km, Tota tonnes/year for passenger transport, Total tonnes/ tonne-km, Total tonnes/year for freight transport)	?Quantity of emissions of VOC, SO_2, NO_X, particulates , CO, Pb (Total tonnes/year)	? Quantity of emissions of VOC, SO_2, NO_X, particulates , CO, Pb across geographical representation
Energy Use		? Primary energy consumption [(Total MJ/year, MJ/passenger-km, Total MJ/year for passenger transport/ Total MJ/year for freight transport), for fuel types: diesel oil, fuel oil, kerosene, gasoline, LPG, CNG, biofuels (Total tonnes/year, Tonnes/passenger-km, Tota tonnes/year for passenger transport, Total tonnes/ tonne-km, Total tonnes/year for freight transport)]	? Primary energy consumption [(MJ/year), for fuel types: diesel oil, fuel oil, kerosene, gasoline, LPG, CNG, biofuels (Tonnes/year)]	? Primary energy consumption across geographical representation

Natural Resources & community issues			
Nature & Biodiversity	? Number of ecologically important areas touched or cut through by transport infrastructure	? Number of ecologically important areas touched or cut through by transport infrastructure	? Size of ecologically important areas taken (km^2) and number of ecologically important areas cut through by transport infrastructure
Soil Quality	? Number of valuable soil zones touched by transport infrastructure	? Number of valuable soil zones touched by transport infrastructure	? Size of valuable soil areas taken by transport infrastructure (km^2)
Water Quality	? Number of stretches of water and ground water protection areas touched by transport infrastructure	? Number of stretches of water and ground water protection areas touched by transport infrastructure	? Size of stretches of water or ground water protection areas taken (km^2)
Coastal Zones	? Number of coastal zones touched by transport infrastructure	? Number of coastal zones touched by transport infrastructure	? Areas of coastal zones affected by transport infrastructure (km^2)
Community Issues			
Noise	? Watts per road or rail transport/link/corridor/km/ passenger or tonne-km ? Sound pressure level at a reference distance in decibels (Laeq) ? Division between night time and day time: [Area affected by noise, which is either greater than 55 dB(A)/ night time or greater than 65 dB(A)/ day time (km^2)]	? Watts per air or waterborne transport/link/corridor/km ? Sound pressure level at a reference distance in decibels (Laeq) ? Division between night time and day time: [Area affected by noise, which is either greater than 55 dB(A)/ night time or greater than 65 dB(A)/ day time (km^2)]	? Population within noise levels greater than 55 dB(A)/ night time and 65 dB(A)/ day time
Traffic safety	?Traffic fatalities/ year	?Traffic fatalities/ year	Traffic fatalities/ year
Landscape	? Number of designated landscape areas touched by transport infrastructure	? Number of designated landscape areas touched by transport infrastructure	? Areas of designated landscape areas touched by transport infrastructure (km^2)
Land take	? Land area required (km^2)	? Land area required (km^2)	? Land area required (km^2)
Severance	? Number of settlements affected by transport infrastructure	? Number of settlements affected by transport infrastructure	? Population in the settlements cut through and area of large undeveloped or undisturbed areas affected by transport infrastructure (km^2)
Build Environment	? Number of designated buildings and conservation areas touched by transport infrastructure	? Number of designated buildings and conservation areas touched by transport infrastructure	? Number of designated buildings and landtake from conservation areas for transport infrastructure (km^2)

3.2 Harmonisation of impact assessment methods within the COMMUTE methodology and tool

The COMMUTE methodology and software tool emphasises the issue of 'harmonisation' of the impact assessment methods across transport modes and across impacts. This twofold harmonisation function was seen as essential by the COMMUTE consortium, particularly to ensure consistency and to minimise data input requirements in the software tool.

Harmonisation was focused on the following aspects:

- spatial distribution both on the horizontal and vertical dimensions;
- time dimensions of the input data and calculation algorithms;
- unified intermodal approach for the estimation of fuel life cycle consumption and emissions;
- representation of the modal fleets (road vehicles, trains, etc.) by means of an adequate number of vehicle classes and sub-classes**.**

The first three of these aspects are discussed in the following paragraphs; while the others are dealt with in the individual descriptions of impact assessment methods in subsequent chapters.

3.2.1 Spatial aspects

The COMMUTE methodology includes two basic ways of describing the transportation system in geographic terms:

- by means of *networks* made up with multimodal transportation *links* (along which traffic flows or vehicle-kms and speed are known, for example), and nodes associated either to transportation activity centres (e.g. cities or airports) or to simple network nodes such as intersections;
- by means of *areas* (such as regions or countries) characterised by known overall levels of transportation activities (expressed - for example - as total vehicle-km for each vehicle class).

Also in this second case, the flexibility of the concept of 'cell' (link or node) will allow an analysis by means of links and/or nodes (e.g. a whole country represented by one node and one link).

Following this approach, the COMMUTE tool calculates the 'link and node' related impacts, and these can then be aggregated in different ways or separated out into urban and 'extra-urban' impacts where this is needed. Moreover the final COMMUTE software will enable the end user to superimpose the impacts with population density distribution (or any other ecological quantity) by using classic GIS functionalities.

The definition of a vertical distribution of impacts addresses the issue of the different altitude at which the different impacts are produced by the four considered modes. It is obvious that it would be not appropriate in general to add emissions from airplanes in flight to the emissions from road vehicles and then draw conclusions on the environmental effects of future policies aiming (for example) at reducing road traffic and increasing air transportation. For a greenhouse gas as CO_2 this would not cause troubles, but for other pollutants such as CO and NOx a distinction on the altitude of emission is needed.

Similarly, in order to address the issue of the overall environmental effects of policies aiming at increasing the number of electric vehicles, it will be necessary to clearly distinguish emissions from car tailpipes and emissions from power plants producing the electricity needed by trains and electric cars. The distance to the receptor is in the two cases extremely different.

The COMMUTE methodology and software tool considers three reference layers defined as follows, offering a good viewpoint for representing impact calculation results:

1) a ground layer, for taking into account pollutant and noise emissions from :

- ?? road non-electric vehicles
- ?? maritime vehicles
- ?? airplanes inside airports (taxi-in and out, plus take-off according to LTO cycle)
- ?? non electric trains

2) an intermediate layer, for considering pollutant and noise emissions from:

- ?? power plants producing electricity
- ?? plants producing fuels (fuel life-cycle emissions)
- ?? airplane emissions during initial climb-out and approach

3) an upper layer, for taking into account pollutant emissions from:

- ?? airplanes in the cruise phase and in the upper phases of climb and descent (for example above the altitude representing the threshold between LTO cycle and cruise).

3.2.2 Time dimensions

In terms of time dimensions, the COMMUTE methodology and software tool needs to allow assessments to be carried out for the impacts of transport plans and policies implemented in the future. The effects of such policies have to be compared with past situations starting from an initial reference year.

These two basic needs imply the definition of a Time Horizon, being the time limits between which calculations will be allowed for a given ‘calculation period’ (see below). Within the tool, future vehicle fleet breakdowns by vehicle class are estimated by the MEET Project for selected years from 1990 up to the year 2020, although scenarios could be examined beyond this if suitable input data were available.

The Calculation Period is the time interval over which a single calculation with the COMMUTE software is performed. COMMUTE tool will consider one year as the usual calculation period, because of normally available data.

Nevertheless, since COMMUTE core models have their calculation period inherently defined by the time dimension of transport input data (e.g. vehicle-km) it must be expected that any calculation period – for which traffic input can be provided – can be considered by the tool (e.g. one season). The Calculation Period will be anyway associated to a Calculation Year, and this one will have to be selected inside the allowed Time Horizon.

3.2.3 Fuel life cycle consumption and emissions

Fuel life cycle (FLC) emissions and consumption are those related to the production and the transportation of the fuel used for the propulsion of the different types of vehicles. The consideration of such a contribution is essential when comparing transportation fleets including electric vehicles because such vehicles virtually emit no pollutant locally (Zero Emitting Vehicles) but need the production of electricity elsewhere, and such a production implies emissions of pollutants that are to be included in an overall balance.

Moreover the production of electricity (and of the 'fuels' in general) requires energy and this must be explicitly considered in a coherent energetic comparison between alternative policies putting more or less stress on electrically powered transport modes (mainly electric trains).

Vehicle life cycle (VLC) emissions and consumption are similarly those due to the usage of the vehicle: vehicles being part of a transportation scenario have to be produced, maintained and (sometimes) dismantled; since all of these activities require the usage of energy and imply the emission of pollutants, a completely exhaustive comparison of multi-modal alternatives would require also the consideration of this term. This contribution is not considered in the COMMUTE tool, because of the extreme complexity of the identification of all the consumption and emission characteristics of the plants and industries involved in the whole life of the vehicle, and because this term is expected to be of lower relevance than the FLC term.

Since emissions due to electricity production will be referred to the 'intermediate layer' defined for the emission vertical distribution model and pollutants emitted at stack height generally are subject to regional dispersion, the emission contribution of electric plants (and similarly of the other fuel plants) can be evenly distributed over the involved countries and regions. This seems to be a good compromise between simplicity and meaningfulness, and would still allow to consider the peculiarities of different countries where the electricity is produced on the basis of rather different mixes of power plants implying very different emission loads.

Within the COMMUTE software tool a consistent FLC emissions and consumption model was incorporated into each of the four "core models" involved in the calculation of consumption and emissions for road, air, water and rail transport (see Chapters 4 to 7). This calculates the emissions of various pollutants from fuel production and transportation for Electricity, Natural Gas, Gasoline, Diesel, LPG, Kerosene, Heavy Fuel Oil, and Bio-diesel from Oilseed Rape, using data from the MEET project. Primary energy consumption associated with fuel production and transportation is also calculated. Once FLC emissions and primary energy consumption have been calculated at cell level, the results can be aggregated by various means including use of GIS software.

3.3 COMMUTE Framework for SEA

The COMMUTE Framework for SEA provides detailed guidelines for carrying out a strategic environmental assessment (SEA), and sets the use of the COMMUTE software tool in context. The full guidelines are set out in COMMUTE Deliverable 2 (Volume 2), and run to some 160 pages. The reader is referred to this document for detailed guidance.

This section of the Final Report provides a very brief summary of the guidelines contained within the COMMUTE Framework for SEA. These are structured according to the following steps, around which an SEA should be organised from the procedural point of view:

1. *Setting of Objectives and Targets (Stocktaking of the Political Environment)*
2. *Screening to determine the need for SEA at this stage of the planning process*
3. *Scoping: identification of:*
   - *the physical/regional limits;*
   - *the impacts to be addressed;*
   - *the alternative actions that need to be assessed.*
4. *Carrying out of the SEA:*
   - *Measuring/predicting the environmental impact of the action and its alternatives;*
   - *Evaluating the significance of the impact (e.g. through comparison with environmental objectives)*
   - *Proposing recommendations: preferred alternative, mitigation and monitoring measures.*
5. *Preparation of the decision*
6. *Taking the decision*
7. *Making arrangements for monitoring and follow-up*
8. *Conducting further environmental assessments (at later stages of planning process, e.g. project EIA*)

Since SEA becomes more efficient and effective when it is carried out on the basis of specified environmental **objectives and targets** an SEA should open with the setting of such objectives and targets. Objectives and targets for SEA can either be identified by content-analysing relevant documents such as laws, regulations, directives, policy papers (white papers), programmes and plans, or by other more interactive objective/target-setting techniques that involve relevant institutions and/or persons. Such interactive techniques are for example structured workshops or interview-based approaches such as the Delphi technique.

The objective and target setting provides a basis for the next step in SEA: **Screening**. Under screening a decision is to be taken on whether

a) a PPP should be rejected because it obviously would cause intolerable environmental impacts,
b) a PPP should be exempted from the need for an SEA since obviously only negligible environmental impacts would be induced, or
c) the need for an SEA can be established.

Case-by-case decisions on the need for an SEA should be taken by one competent institution in order to facilitate quick decision making. Helpful tools for screening are SEA pre-appraisal matrices in which the likeliness of a defined set of impacts can be stated and explained. The outcome of screening should be laid down in a brief report that should be publicly released in order to give the possibility for constructive criticism.

Should the need for an SEA be established by screening the next step to follow is **scoping**, the process leading to the definition of the Terms of Reference of the SEA. Scoping includes the definition of relevant environmental impacts and indicators, the delineation of the study area, the fixing of the time horizon, the choice and composition of suitable tools and methods, as well as the definition of alternatives to be assessed. Scoping is a means of ensuring public participation and acceptance of a PPP. The result of the scoping exercises the scoping report, which should also be publicly released in order to give the possibility for constructive criticism. In contrast to the screening report, the scoping report should be more comprehensive, including also a more detailed description of the PPP, a description of the baseline environmental conditions in the study area and on an assessment of the description of the environmental effects (on a desktop-study level).

For the actual carrying out of an SEA a broad range of **methods and tools** has proven to be applicable under previous SEA studies. The existing methods and tools differ according to their application. A clear distinction between groups of SEA techniques is however difficult to achieve, due to some overlap in their functions. In COMMUTE a distinction was made between assessment, aggregation and other methods. Assessment methods focus on the measurement of single impacts, while aggregation methods are capable of aggregating single measurement results into overall indicators. Under other methods complementary innovative approaches are presented which, if they are integrated into the carrying out of an SEA, can enrich the SEA by life-cycle, cumulative impact and sustainability aspects.

The COMMUTE tool will provide an active support for carrying out an SEA, in the first phase by modelling impacts in the key areas of energy use, emissions, safety and noise and in a future phase reaching across the spectrum of impacts to be considered within an SEA. For the future, the COMMUTE tool envisages integrating different SEA approaches and tools.

Geographical Information Systems (GIS) can be regarded as the most important assessment tools. GIS are predestined for the assessment of impacts with spatial character such as land take in dedicated areas or the number of inhabitants affected by specific noise levels. GIS will form a part of the COMMUTE-tool. For the future an improvement of data availability seems to be a challenging and useful step to be taken.

In order to condense the findings of the environmental assessment into a reduced set of decision criteria which is easy to comprehend one can draw on **aggregation methods** such as **Cost-Benefit-Analysis (CBA) and Multi-Criteria-Analysis (MCA)** or a combination of the two (framework analysis). While the precondition for the use of CBA is the monetisation of the input variables, MCA can cope with input data of the most varied dimensions. Since especially in the environmental field not all impacts can be monetised, an exclusive application of CBA for aggregation purposes is impossible. However CBA can deliver monetised values for environmental impacts where this is widely accepted (e.g. noise in assessments at later states of the planning process, such as tier 4) and feed them into MCA where they can be further aggregated with non-monetisable impacts (Framework Analysis). Simple additive weighting (SAW) is considered here to be the most suitable MCA technique, although the parallel application of other MCA techniques such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for validation purposes seems to be advisable. Besides, sensitivity analyses which assess the impact of modified weights on the final result of an MCA should be conducted in order to test the validity of the result.

Amongst the other methods, **Cumulative Impact Assessment (CIA)** is useful in order to take into account additive, interactive, compounding and synergistic cumulative effects. Impacts on the environment which result from the incremental impact of an action when added to other past, present and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions, are thus covered.

The approach of **Life-Cycle-Analysis (LCA)**, which to a certain extent is already taken into consideration in the COMMUTE tool, permits an enlargement of the environmental assessment to the full product cycle. Accordingly the assessment of energy consumption for example not only takes into account the energy consumed during vehicle operations but also includes e.g., the fuel consumption during the electricity production in power plants.

The third "other method", **Strategic Sustainability Assessment (SSA)**, aims at the integration of sustainability targets into the SEA process. Thus its functions are to identify sustainability targets, e.g. by content analysis of relevant documents, to compare environmental impacts against these targets and if these targets are missed/exceeded to issue a warning to the decision maker and instigate a reconsideration of the PPP.

An issue that should be incorporated iteratively into an SEA is **mitigation**. Having assessed the environmental impacts of a PPP, measures mitigating these impacts should be proposed. Subsequently the need arises to assess both the costs of these mitigation measures as well as their benefits, i.e. their contribution to the reduction of the environmental impact. Obviously costs and benefits have to be taken into account in the overall evaluation.

The integration of the various SEA approaches and methods into an overall approach is demonstrated in Figure 3.2.

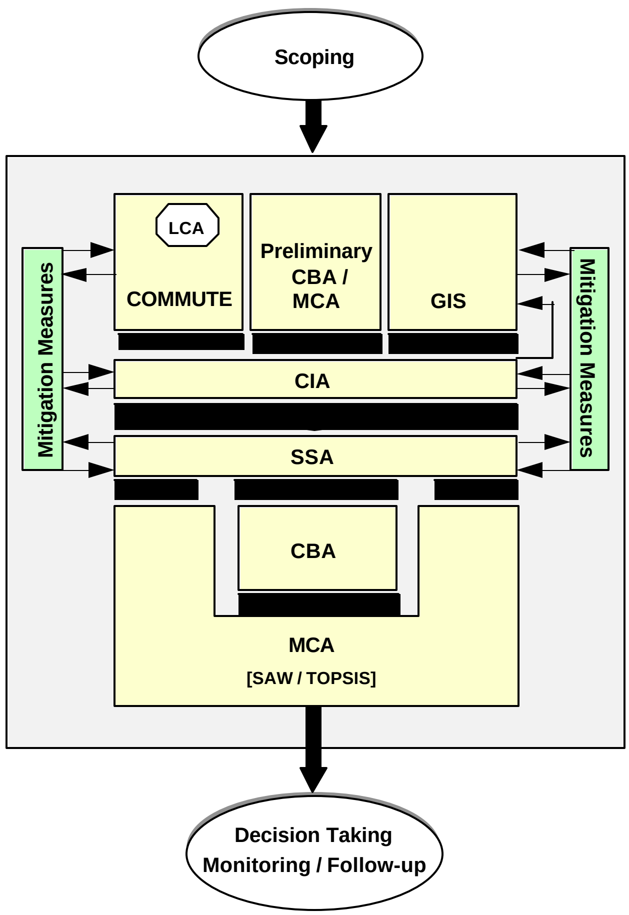


Figure 3.2 Integration of SEA Approaches and Methods.

After the scope of the SEA has been set through scoping, the single impacts which have been identified as relevant are assessed either directly through the COMMUTE-tool or through a GIS which can interface with the COMMUTE-tool (see Figure 3.2). At least for energy consumption LCA also forms an integral part of the COMMUTE-tool. Where convenient, cumulative impacts are assessed subsequently. In principle CIA could also form part of the COMMUTE-tool, e.g. as part of the GIS-module when overlay-techniques are concerned. However, this will need further development of the COMMUTE-tool. The same applies to SSA. Until SSA is integrated into the COMMUTE-tool, it should be applied externally and subsequently to CIA. On all three levels (COMMUTE-tool, CIA, SSA) mitigation measures should be considered and their effects should be fed back into the assessment of single impacts through the COMMUTE-tool. Having passed SSA, the single impacts need to be aggregated which should be done through MCA. Indicators which are suitable for monetisation can be monetised through CBA. However, since not all of the impacts can be monetised, CBA cannot be used as an overall aggregation technique. Therefore also the impacts which have been monetised through CBA need to be fed into MCA in order to be aggregated with the other indicators. The results of the aggregation of impacts through MCA will form the basis for decision making.

The results of carrying out the SEA in its core sense have to be incorporated into an **SEA report**. The forms of presentation should comprise text as well as tables and maps. The findings should additionally to the full report be condensed into a non-technical summary. Information on the findings of the SEA should besides relevant institutions also be made available to the public.

On the basis of the SEA report the decision should be taken by a competent decision maker (e.g. the responsible authority such as the General Directorate or Ministry of the Environment) who should take into consideration the feedback from the broad public, possibly represented through interest/pressure groups. The decision by the decision maker should be presented in a report which also contains a justification of the decision.

In order to ensure that an SEA is not just a proforma exercise designed to secure a development permit rather than a well-considered process to enhance environmental benefits and contribute to environmental sustainability, **follow-up and monitoring** should form an integral part of an SEA. The principal function of follow-up and monitoring can be summarised as follows:

- Inspect and check the implementation of the terms and conditions agreed and approved for the development process;
- review or re-assess the environmental implications of any design changes;
- monitor the actual effects of the activities on the environment and the community;
- monitor the timing, sequence, location and extent of the activities carried out;
- verify the compliance with regulatory requirements and applicable standards or criteria;
- formulate and implement action plans to avoid, reduce, or rectify any adverse impacts;
- verify the accuracy of the predictions made and the effectiveness of mitigation measures;

- provide feedback to policy and planning management control to adjust programming, design or location of activities or the methods and approaches of carrying them out;
- provide feedback to improve impact prediction and mitigation practices;
- provide feedback to future planning and design of development.

As has been presented both the need and the methodological preconditions for the application of SEA in transport exist. Obstacles for this application seem to be at present:

- the lack of a legal basis (enactment of an EU SEA-Directive);
- the lack of an institutional set-up (formal assignment of responsibilities for the various steps under SEA to specific institutions);
- the lack of available data which affects especially the application of GIS.

4. IMPACT ASSESSMENT METHOD FOR ROAD TRANSPORT EMISSIONS AND ENERGY CONSUMPTION

4.1 Overview of method

This chapter of the report describes the detailed impact assessment method for road transport emissions and consumption developed as part of the COMMUTE methodology and included in the COMMUTE software tool. This method draws on the MEET methodology (MEET, 1998) for the calculation of hot running emissions/consumption, road gradient, vehicle load and evaporative correction and the COPERT II methodology (Ahlvik et al., 1997) for cold start excess emissions/consumption.

Among the factors influencing energy and emissions, disaggregation of road travel by vehicle type, vehicle fuel, vehicle engine size and technology is essential for meaningful impact estimates to be made within the COMMUTE methodology for the software tool

After agreement with COMMUTE, the MEET project derived a comprehensive vehicle fleet breakdown for 107 road vehicle categories, according to various base years, both for individual EU countries and for Europe as a whole. The 107 vehicle category distribution takes account of vehicle type, fuel type, vehicle engine size, various European regulations, and current and future technologies. The vehicle fleet distribution is incorporated as a database within the COMMUTE tool.

Within the COMMUTE tool, the user specifies the input traffic data, in terms of vehicle kilometres, at a relatively aggregate level for the 5 major classes:

?? Cars
?? LDV
?? HGV
?? Buses
?? Motorcycles

The tool then distributes the traffic data proportionally according to the disaggregate vehicle fleet distribution defined in the default database for a selected country. The use of this database implies that the fleet distribution is homogenous throughout the country. However, this simplification may not be satisfactory in some applications not involving the entire country (e.g. some areas of the country may be much wealthier than others and have a greater proportion of newer and larger cars than the national average; the percentage of two-wheelers on the highways may be much lower than the national average). Thus, the software allows for the vehicle distribution default database to be replaced by local and more representative data of the study area (link or node), if available.

The road transport emission/consumption impact calculation method is based on the average speed approach (COMMUTE, 1997) where emission and energy functions are speed related. Functions for energy consumption and emissions according to traffic speed have been produced by MEET for each disaggregate vehicle category. These functions, which are not country specific, are applied in the COMMUTE tool. Traffic speed can be either directly defined by the software user or indirectly estimated from road type. Where speed is input by the user, speeds (in km/h) need to be specified for the 5 aggregate vehicle classes described above.

Where speed is estimated from road types, the COMMUTE software will search for the default database of typical average speeds for three different road types (urban, non-urban and motorway).

The following sections outline the assessment method for the point of use emissions/energy consumption calculations.

4.2 Hot running emissions/consumption

Hot emissions are produced when the engine and the pollution control systems of the vehicle have reached their normal operation temperature. They can be calculated if the emission per unit of activity and the total activity over the timescale of the calculation are known, using the formula:

$$E_{hot} = e \cdot m$$

Where:

E_{hot} the emission, in units of mass per unit of time (usually in tonne/year), for each vehicle category
e the hot emission factor in (g/km)
m the activity, in distance travelled per time unit (usually in km/year)

The activity '*m*' required for the emission calculation is defined as:

$$m = n \cdot l$$

Where:

n is the number of vehicles in each category
l is the average distance travelled by the average vehicle of each category over the time unit (in km/year)

It is assumed that the unit of activity is kilometres, i.e. the distance driven by each vehicle, in the time unit. Other forms of activity can be used as well (for example based on the mass of fuel consumed), but the emission factors have to be changed accordingly.

The vehicle average annual distance is different from one country to another. In any case, this distance is distributed over different types of roads. A part of the distance is travelled in urban areas, a part in rural areas and the rest on highways, each type of road having different average speeds, affecting accordingly the emission factors.

The total emissions and fuel consumption on the link or node are calculated by summing the emission/consumption contribution from all vehicle classes. Taking into account the different vehicle categories, the final equation for hot emission estimation can be derived:

$$\mathbf{E_k} = \sum_{i=1}^{i=categories} \left[n_i \cdot l_i \cdot \sum_{j=1}^{j=3} \left(p_{i,j} \cdot e_{i,j,k} \right) \right]$$

Where:

E	basic hot emissions
k	the number of pollutants
i	the number of vehicle categories
j	the number of road types
n_i	the number of vehicles in category i
l_i	the average annual distance travelled by the vehicles of category i
$p_{i,j}$	the percentage of annual distance travelled by the vehicles of category i
$e_{j,k}$	the emission factor of pollutant k corresponding to the average speed on road category j, for the vehicle category i.

4.3 Cold correction

It is essential to take account of cold running in the COMMUTE methodology. This factor has a significant effect on emission rates and consumption, particularly for urban driving conditions where most car trips are short in length and therefore undertaken under cold engine conditions.

E_{cold} is calculated using correction factors for cold start emissions and energy consumption, as provided by COPERT II (Ahlvik et al., 1997). In principle, cold start emissions occur for all vehicle categories. However, emission factors are only available or can only be reasonably estimated for gasoline, diesel and LPG passenger cars and light duty vehicles (assuming that they behave like passenger cars). Moreover, cold start emissions are considered not to be a function of vehicle age.

Cold start emissions are calculated as an extra emission over the emissions that would be expected if all vehicles were only operated with hot engines and warmed-up catalysts. The ratio of cold to hot emissions is used as a correction factor and applied to the fraction of kilometres driven with cold engines. These factors may vary from country to country. Different driving behaviour (varying trip lengths), as well as climate with varying time (and hence distance) required to warm up the engine and/or the catalyst affect the fraction of distance driven with cold engines. These factors can be taken into account, but again information may not be available to do this thoroughly in all countries, so that estimates have to close identified gaps.

The cold emissions are introduced into the calculation as additional emissions per km by using the following formula:

$$E_{cold;i,j} = ?_j \cdot m_j \cdot e^{hot} \cdot (e^{cold} / e^{hot} - 1)$$

where:

$E_{cold, i, j}$ = cold start emissions of the pollutant i (for the reference year), caused by vehicle category j (assumption: all cold start estimates are allocated to urban driving)

$?_j$ = fraction of mileage driven with cold engines or catalyst operated below the light-off temperature

m_j = total annual mileage of the vehicle category j

e^{cold}/e^{hot} = cold to hot ratio of emissions

The parameter ? depends on ambient temperature t_a (for practical reasons the average monthly temperature is proposed to be used) and pattern of vehicle use, in particular the average trip length l_{trip}. However, since information on l_{trip} is not available in many countries for all vehicle classes, some simplifications have been introduced for some vehicle categories.

The ratio e^{cold}/e^{hot} also depends on the ambient temperature and pollutant considered.

4.4 Gradient-load correction

The gradient of a road has the effect of increasing or decreasing the resistance of a vehicle to traction, as the power employed during the driving operation is the decisive parameter for the emissions of a vehicle. Increases or decreases in the load on the engine have a corresponding effect on rates of emission and fuel consumption, but even in the case of large-scale applications, it cannot be assumed that the extra emission when travelling uphill is fully compensated by the reduced emission when travelling downhill.

In principle, the emissions and fuel consumption of both light and heavy duty vehicles are affected by road gradient. However, because of their higher masses, the gradient influence is much more significant in the case of heavy duty vehicles.

The method adopted to allow for the effect of gradient is taken from the MEET methodology (MEET, 1998), which is itself based on the results of the German

Emission Factor programme. Special gradient factors have been introduced, considered to be a function of :

- The technology (for light duty vehicles) or the mass (for heavy duty vehicles)
- The road gradient
- The pollutant
- The mean speed of the vehicle

For each vehicle category, gradient and pollutant, the gradient factor can be calculated as a polynomial function of the vehicle's mean speed:

$$as_{i,j,k} = A6_{i,j,k} \cdot V^{6} + A5_{i,j,k} \cdot V^{5} + A4_{i,j,k} \cdot V^{4} + A3_{i,j,k} \cdot V^{3} + A2_{i,j,k} \cdot V^{2} + A1_{i,j,k} \cdot V + A0$$

where:

$as_{i,j,k}$ is the correction factor
V is the mean speed
$A0_{i,j,k}$... $A6_{i,j,k}$ are constants for each pollutant, vehicle and gradient class

Hence, it is proposed to correct the emission factor calculated for vehicle's use on a flat road according to the following equation, in order to incorporate the influence of the road gradient:

$$ec_{hot,i,j,k} = as_{i,j,k} \cdot e_{hot,i,j,k}$$

where:

$ec_{hot,i,j,k}$ is the corrected emission factor of the pollutant *i*, in g/km, of the vehicle of category *j* driven on roads of type *k* with hot engines
$e_{hot,i,j,k}$ is the emission factor of the pollutant *i,* in g/km, of the vehicle of category *j* driven with hot engines on roads of type *k* with zero gradient
$as_{i,j,k}$ is the gradient correction factor of the pollutant *i* of the vehicle of category *j* driven on roads of type *k* for the appropriate gradient class, gradient classes are 0%, 2%, 4%, 6%, -2%, -4% and -6%.

The driving resistance of a vehicle is also influenced by vehicle mass, i.e. higher vehicle mass requires higher power from the engine during driving, especially in acceleration modes. Due to the fact that emissions and fuel consumption are proportional to the engine power, the calculations also have to take into account vehicle load.

Emissions from passenger cars are conventionally measured on a chassis dynamometer. The load setting of the dynamometer normally corresponds to the weight of the vehicle in running order, and including the driver, which is quite typical of normal use. In addition, the influence of load on emissions and consumption is small because the load range of a passenger car is small, in comparison with heavy duty vehicles. So it can be stated that the load influence is sufficiently covered for this vehicle category via the standard hot emission factors.

In the case of heavy duty vehicles the vehicle load has an important influence on emissions and fuel consumption as the load can contribute significantly to the total weight of the vehicle.

Functions to correct for load have been determined for goods vehicles so that:

$$?_l ?? ?_u ?? (? , v)$$

where:

$?_l$	is the emission factor when loaded in g/km
$?_u$	is the emission factor when unloaded in g/km
$? (?, v)$	is the load correction factor function
$?$	is the gradient in percent
v	is the mean velocity of the vehicle in km/h

Load correction factor functions ($? \ (?, v)$) are of the form:

$$? \ (? , v) ?? \ ? n ? ? p ?^2 ? q ?^3 ? rv ? sv^2 ? tv^3 ? \frac{u}{v}$$

where:

$?$	is a constant
n - u	are coefficients

For urban buses and coaches, the basic functions provide estimates of emissions for the vehicle with a mean load, rather than no load. The load correction functions described above are not applicable for these vehicle types.

4.5 Evaporative correction

Evaporative emissions/consumption occur as a result of fuel volatility, combined with the variation of ambient temperature or temperature changes in the vehicle's fuel system which occur during normal driving procedures (variation of temperature because of heat transfer from the vehicle's engine to all the components of the fuel system).

The evaporative emissions/consumption represent a significant proportion of the VOC emitted or consumed by petrol powered vehicles (evaporative emissions and consumption from diesel fuel are negligible). Thus, E_{evap} is calculated only for petrol fuelled vehicles for the pollutant VOC.

Functions for calculating these indicators, as provided by MEET (MEET 1998), take account of the ambient temperature and the trip length distribution. Ambient temperature can be defined by the user, estimated via GIS or taken from a database with typical annual figures for each European country. Average trip length can also be defined by the user. However, default values for each European country are present in the COMMUTE database.

MEET adopted the CORINAIR methodology for the estimation of evaporative emissions (and fuel consumption). According to this methodology (MEET 1998) there are three sources of vehicle evaporative emissions:

- Diurnal emissions
- Hot soak emissions
- Running losses

All three types of evaporative emissions are significantly affected by the volatility of the gasoline being used, the absolute ambient temperature and temperature changes, and vehicle design characteristics. For hot soak emissions and running losses the driving pattern is also of importance. The main equation for estimating the evaporative emissions is:

$$E_{evap,voc,j} ? 365 ? a_j ? (e^d ? S^c ? S^{fi}) ? R$$

where:

$E_{evap,voc,j}$ are the VOC emissions due to evaporative losses caused by vehicle category *j*

a_j is the number of gasoline vehicles of category *j*

e^d is the mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation, and fuel volatility (RVP)

S^c is the average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor

S^{fi} is the average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection

R are the hot and warm running losses

and:

$$S^c ? (1 ? q) ? (pxe^{s,hot} ? wxe^{s,warm})$$

$$S^{fi} ? qe^{fi} x$$

$$R ? m_j ? (pe^{r,hot} ? we^{r,warm})$$

where:

q is the fraction of gasoline powered vehicles equipped with fuel injection

p is the fraction of trips finished with a hot engine (dependent on the average monthly ambient temperature)

w is the fraction of trips finished with a cold or warm engine (shorter trips) or with the catalyst below its light-off temperature

x is the mean number of trips per vehicle per day, averaged over the year, or shorter time period

$e^{s,hot}$ is the mean emission factor for hot soak emissions (which is dependent on fuel volatility RVP)

$e^{s,warm}$ is the mean emission factor for cold and warm soak emissions (which is dependent on fuel volatility RVP and average monthly ambient temperature)

e^{fi} is the mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection

$e^{r,hot}$ is the average emission factor for hot running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature)

$e^{r,warm}$ is the average emission factor for warm running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature)

m_j is the total annual mileage of gasoline powered vehicles of category j

5. IMPACT ASSESSMENT METHOD FOR RAIL TRANSPORT EMISSIONS AND ENERGY CONSUMPTION

5.1 Overview

In contrast to the estimation of emissions from the road transport sector, the COMMUTE impact assessment method for rail involves an initial estimation of the energy consumption required to move the specific train from its origin to destination. This energy consumption is subsequently converted into emissions, dependent on the fuel type under which the individual locomotive is operating. For multiple rail operations on specific links or over a designated network, these emission estimates are summated to determining the total emissions from the activity.

The rail methodology approach is described below:

- Calculation of the energy consumption to move the train, over a given operating cycle.
- Derivation of the emissions from the primary power generating source - diesel or electric power plant.
- Emission factors combined with the energy consumption are used to derive the fuel consumption and emissions associated with the specific activities
- Future energy and emissions are derived from a combination of future energy consumption values and future emission factors associated with the locomotive type.
- In both existing and future scenarios, the emissions associated with diesel and electric train operation are calculated separately, and summated over the network under study.

The following algorithm is incorporated into the COMMUTE tool to allow the estimation of the energy consumption.

$$E' = \frac{(N+1)}{L}\frac{v_{max}^2}{2} + B_0 + B_1 \cdot v_{ave} + B_2 \cdot v_{ave}^2 + g\frac{\Delta h}{L}$$

Where:

E’	the energy consumption in KJ/tonne-km
L	trip length (km)
Δh	change in height (gradient) (m)
N	number of intermediate stops
V_{ave}	average speed (m/s)
V_{max}	maximum speed (m/s)
g	gravitational constant
B_0	constant - equating to rolling resistance
B_1	constant - equating to friction resistance
B_2	constant - equating to cross sectional aerodynamic resistance

The calculation of rail transport emissions from the energy consumption figures is based on values defined by the MEET project. Future year values assume a linear trend towards lower emissions, although it is recognised that this is likely to be an oversimplification of the real world situation. The reductions in estimated emissions from the electricity sector will be dominated by a stepwise introduction of new generating plant (inherently cleaner fuels and generating technologies), but supplemented by the use of relatively old plant during periods of high demand (winter and holidays) or peak diurnal periods.

The use of the COMMUTE tool requires a series of characteristics to be provided by the end user for the specific network of rail links under study. These characteristics describe both the link in terms of distance and elevation, but also the type and operational class of the locomotive. For greatest accuracy these inputs must be defined by the end user, but where data availability is problematic, default values are contained within the COMMUTE tool and may be adopted, as outlined in the following section.

5.2 Input data and default values

The COMMUTE tool is designed to estimate emissions from the present day extending to 2020. The COMMUTE tool default values therefore incorporate this time basis, and where appropriate, the defaults are subject to stepwise or linear changes to incorporate the expected changes in nation and European electricity generational mix, the introduction of new locomotives and rolling stock and the upgrading of tracks, junctions and existing network capacity problem areas.

The existing configuration of the COMMUTE tool contains the structure for the inclusion of four train types. However, the tool architecture is designed to allow for the easy inclusion of additional train categories.

The following default values are used within the COMMUTE tool. Where site or route specific data exist, these data should always be used in favour of these supplied defaults.

Table 5.1 Energy consumption constants

Train type	B_0	B_1	B_2
High speed train – passenger	16.6	36.6×10^{-2}	26.0×10^{-3}
Urban train – passenger	16.0	0	22.5×10^{-3}
Regional train – passenger	18.3	0.097	0.0413
Freight	24.7	0	84.5×10^{-3}

No data is currently available on the likely changes to the energy consumption defaults for future years. This is accepted as a simplification of the likely future conditions, considering the potential improvements in aerodynamic drag, and track and suspension design. As such these default values remain the same for future years.

Table 5.2 Train characteristics

Train type	Occupancy (%)	total number of seats	weight (tonnes)
High speed train - passenger	60	300 - 800	300 - 800
Urban train – passenger	35	290	120
Regional train – passenger	40	250	290

Table 5.3 Train loading ratio

Train type	1998	2020
High speed	1.0 tonnes/seat	0.4 tonnes/seat
Urban	0.4 tonnes/seat	0.3 tonnes/seat
Regional	0.4 tonnes/seat	0.3 tonnes/seat
Freight (loading ratio)	0.27	0.22

Train weight will reduce in future years through the use of lighter materials and improvements in construction techniques. This may be seen today with the tonne/seat value for an existing high speed TGV train, at approximately 0.7, which is still high in comparison with the most advanced and recently introduced high speed train in current use, the Japanese 3000, with a tonnes/seat value of 0.49. For freight trains it is expected that the ratio of the tare weight of the cars to the maximum total loaded weight will decrease from the current level of about 0.27 to a value of about 0.22 in 2022.

Freight train occupancy

Occupancy levels on freight services are characteristically low, and are unlikely to exceed an estimated 60%. Although high occupancies may be achieved on outbound journeys, on the return journeys, many of the specialist wagons (auto-carriers, tankers etc) are routinely run empty.

Table 5.4 Train speed characteristics

Train type	Average speed (km/h)	maximum speed (km/h)	Average number of stops per 100 km
High speed train - passenger	105	250 - 300	2
Urban train – passenger	62	85	11
Regional train – passenger	74	100	4
Freight	50	90	10

Table 5.5 Future train speeds

Train type	2000	2005	2010	2015	2020
High speed trains	105	110	116	122	128
Regional trains	74	75	75	76	77
Urban trains	62	62	63	63	63
Freight	50	51	53	54	55

Under the timeframe to 2020, it may be assumed that the maximum train speeds remain the same for all classes, although it may be expected that the relative proportion of high speed services are likely to increase.

Degree of electrification

Where the percentage of electric to diesel operation is unknown, default values may be used which are based upon the degree of electrification of the network. As a European average this represents a value of between 65 and 70%. However, this degree of electrification relates to the track network and not therefore to the operational characteristics of the locomotives on that network. As such, in many countries this electrification default would introduce considerable errors.

For example in the United Kingdom and Greece, the degree of electrification is considerably lower, at some 5 to 15%, and in the Netherlands the existing level of electrification already exceeds 80%. The following table provides defaults for the degree of electrification, extrapolated to 2020, on the assumption that the majority of European countries are likely to reach a value of 90% by 2020.

Table 5.6 Degree of electrification

Country	1990	1995	2000	2005	2010	2015	2020
Austria	58	63	69	74	79	85	90
Belgium	63	68	72	77	81	86	90
Denmark	10	13	17	20	23	27	30
Finland	30	40	50	60	70	80	90
France	40	48	57	65	73	82	90
Germany	35	44	53	63	72	81	90
Great Britain	15	18	20	23	25	28	30
Greece	5	9	13	18	22	26	30
Ireland	2	7	11	16	21	25	30
Italy	56	62	67	73	79	84	90
Luxembourg	81	83	84	86	87	89	90
Netherlands	72	75	78	81	84	87	90
Portugal	0	5	10	15	20	25	30
Spain	52	58	65	71	77	84	90
Sweden	70	73	77	80	83	87	90

With respect to the allocation of generating power supply for freight services, it is likely (partially due to the long service life of the existing freight fleet), that the proportion of electrification will be considerably lower for freight than passenger services. This situation is unlikely to show significant changes in the immediate future.

6. IMPACT ASSESSMENT METHOD FOR AIR TRANSPORT EMISSIONS AND ENERGY CONSUMPTION

6.1 Overview

The main features of the COMMUTE method for the calculation of air transport emissions and fuel consumption are as follows:

?? The assessment of energy consumption and pollutant emission is based on the standardised operating conditions for air traffic (see Fig. 6.1 below).
?? The method allows the assessment of emissions of Nitrogen oxides (NO_X), Carbon monoxide (CO) and Hydrocarbons (HC) as well as fuel consumption and Carbon dioxide (CO_2).
?? The method distinguishes between short, medium and long distance flights.
?? The method distinguishes between emissions in the vicinity of an airport and in flight conditions.
?? The method distinguishes between emissions on three vertical levels (see section 3.2).
?? In combination with the GIS and with the knowledge of flight routes a link - connection will be possible.

The calculation of emissions and fuel consumption for instrument flights (IFR-flights) from civilian aviation is based on the methodology described in detail in COMMUTE Deliverable 2, Volume 3. The special feature for air transport is the 3D-emission source, bearing in mind the typical transport mission, which can be divided in the standardised operating conditions. These are Taxi - out, Take - off, Climb - out, Climb, Cruise, Descent, Approach and Taxi – in, as illustrated in Figure 6.1.

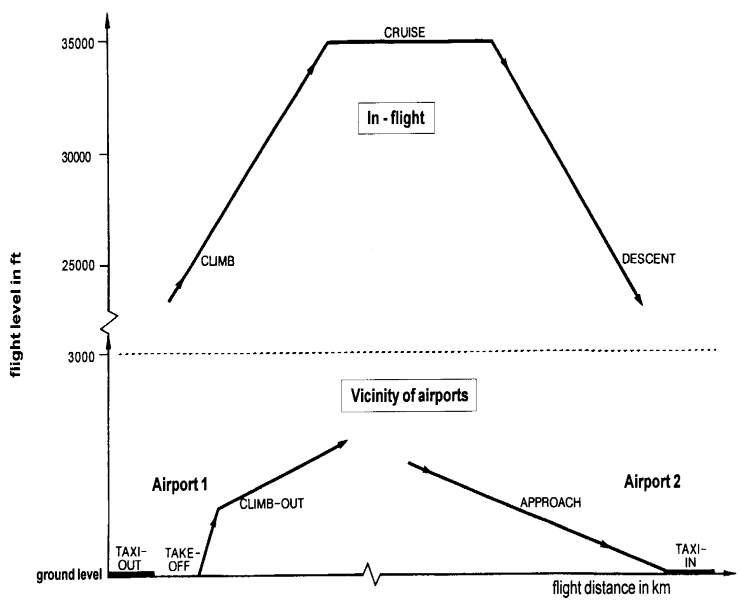


Figure 6.1 Standardised operating conditions for air traffic

The calculation process starts with disaggregated emission factors and traffic data. The model provides emission factors for a fleet of 30 different types of aircraft/engine combinations. This fleet is sufficient to describe the European aircraft fleet. In addition emission factors for short-, medium- and long distances aircrafts have been aggregated. These emission factors are available for all phases of the standardised operation conditions of a transport mission, as illustrated in the above figure. Table 6.1 describes the structure of the emission factors. A table of this structure for each emission component to be calculated and for each of the section length (flight distance categories) is embedded in the COMMUTE software tool.

Table 6.1 Generic structure for fuel consumption and emission factors in relationship to aircraft types and flight distance classifications

Aircraft Type				**Standardised Operating conditions [1)]**				
		Vicinity of airport 1 (Departure, <3.000 feet)		**In-flight**			**Vicinity of airport 2 (Arrival, <3.000 feet)**	
	Taxi out	Take off	Climb out	Climb	Cruise	Descent	Approach	Tax in
B737	xx	Xx	xx	xx	xx	xx	xx	xx
B727	xx	Xx	xx	xx	xx	xx	xx	xx
A300	xx	Xx	xx	xx	xx	xx	xx	xx
DC8	.	.	.	.	.	.	.	.
Generic I Generic II	. .	. .	. .	. .	. .	. .	. .	. .
Generic III	.	.	.	.	.	.	.	.

1) Data available will be given for the section lengths 250 km, 500 km, 750 km, 1.000 km, 2.000 km, 4.000 km, 7.000 km, 10.000 km

This approach makes it possible to distinguish between emissions in the vicinity of the airports under consideration (nodes), In-flight conditions (links) and to summarise these - for complete flight missions and for the whole area under consideration. Thus taking the standardised operations conditions into account information about emissions and fuel consumption for the following three vertical levels is available through a aggregation process.

Ground level:	0	-	1499	feet
Intermediate level:	1500	-	2999	feet
High level:	3000	-	35999	feet

To calculate the fuel consumption and the emissions for the area under consideration, the number of flights for real distances per aircraft type are necessary as input data. The method then uses the following formulae:

$$TE_p \; ? \; \underset{r}{?} \; \underset{j}{?} \; SE_{j,p,r} \; ? N_{j,r}$$

$$TF \; ? \; \underset{r}{?} \; \underset{j}{?} \; SF_{j,r} \; ? N_{j,r}$$

$$SE_{j,p,r} = \underset{k}{S}\underset{i}{S} \; EF_{j,p,i,k,r} * D_{i,k,j}$$

$$SF_{j,r} = \underset{k}{S}\underset{i}{S} \; FC_{j,i,k,r} * D_{i,k,j}$$

TE	Total emission [kg]
TF	Total fuel consumption [kg]
SE	Specific emission [kg]
SF	Specific fuel consumption [kg]
EF	Emission factor [kg/km]
FC	Fuel consumption factor [kg/km]
D	Flight distance [km]
N	Number of aircraft
i,k	Operating condition
j	Aircraft type
p	Pollutant
r	Route from airport 1 to airport 2

6.2 Future emissions

In order to take future emissions and fuel consumptions into account the method and COMMUTE software tool uses reduction factors derived from various optons provided by the MEET project on future non-road transport emissions. The following factors currently applied are as follows:

Table 6.2 Reduction factors for air transport

Year	Fuel	CO2	Nox	CO	HC	SO2
1995	1.00	1.00	1.00	1.00	1.00	1.00
2000	0.94	0.94	0.91	0.92	0.92	0.94
2010	0.84	0.84	0.76	0.79	0.78	0.84
2015	0.79	0.79	0.67	0.66	0.67	0.79
2020	0.75	0.75	0.60	0.54	0.57	0.75

As with all default data in the model these figures may be modified by the end user or as soon as new information is available.

7. IMPACT ASSESSMENT METHOD FOR WATERBORNE TRANSPORT EMISSIONS AND ENERGY CONSUMPTION

7.1 Overview

There are significant data availability problems with assessment of the impacts of waterborne transport. However, a practical impact assessment method was developed within COMMUTE and implemented in the software tool using the data available from ports. The available data are:

- some particulars of the ship, mainly size.
- the ship's next call

The particulars registered for the ships vary between ports and administrations. However, in general the Gross Tonnage (GT) is registered. The GT is an internationally ratified measurement that gives a fair value of the ship's size. Most of the ships' duties are based on the GT.

By knowing the GT of a ship and the type of vessel it is possible to build an empirical function that gives the ship's fuel consumption and/or installed power. This is an approximate method but it is built on the available information and based on a fairly large number of ships. Known individual ships or ship types with a large impact on the result may be treated separately.

7.2 Input data, default values and calculation method

The specification of the fleet composition has to be part of the user input to the COMMUTE tool. The tool supplies a set of Default Type Ships categorised by type and size. In addition the user is able to define ships with different characteristics as Custom Type Ships.

The user input to the waterborne transportation part of the COMMUTE tool can be divided into two parts:

?? Compulsory input of traffic data by Ship type, Size and Frequency
?? Optional input of Custom Type Ships.

For every link in the network the user has to enter a database of ship movements. The ships are divided into Default Type Ships, and Custom Type Ships. The former are characterised only by ship type and size in GT while the latter demand more detailed information on the ships' properties and/or emission characteristics.

The traffic data input to the COMMUTE tool is attached to links. Normally a link connects two ports but it can also connect two regions with unspecified ports. For each Link and Ship Type category the user has to provide the total number of vessel movements during the chosen time interval.

In addition to the link traffic, the number of port calls should be entered at the nodes that represent a port. This is to enable the calculation of port emissions. Ports are normally situated near populated and trafficked areas. Note the difference between the number of port calls and the number of movements. Each port call normally, but not necessarily, adds two movements to the link attached to the port. Also the "average port lay time" has to be entered by the user.

The Default Type Ships follow the data structure supplied by the MEET project, as shown in Table 7.1.

Table 7.1 Default Type Ships

DEFAULT TYPE SHIPS	
01	Solid Bulk
02	Liquid Bulk
03	General Cargo
04 05	Container Passenger/Ro-Ro/Cargo
06	Passenger
07	High Speed Ferry
08	Inland Cargo
10	Other

Ship movements are grouped into eight size classes into a database <u>for each link</u> with the structure shown in Table 7.2.

Table 7.2 Ship size classes

A LINK		SIZE CLASS	1	2	3	4	5	6	7	8
		GT	<300	300-1000	1000-2500	2500-4500	4500-8000	8000-12000	12000-21000	> 21000
DEFAULT TYPE SHIPS		SHIP MOVEMENTS								
01	Solid Bulk									
02	Liquid Bulk									
03	General Cargo									
04	Container									
05	Passenger/Ro-Ro/Cargo									
06	Passenger									
07	High Speed Ferry									
08	Inland Cargo									
10	Other									

The ports have a similar structure except that they refer to ship calls instead of ship movements.

Emission and consumption parameters are supplied in the COMMUTE tool for each Default Type Ship and Size Class, as shown in Table 7.3. These are then used with the input ship traffic data to calculate emissions and consumption. These parameters are primary input requirements for the Custom Type Ships.

The tool calculates the energy consumption and the emissions along the links and in the ports. The life cycle emissions of the fuel are also calculated. The output from the waterborne transport part of the COMMUTE tool is common with the other modes in structure.

Table 7.3 Emission and consumption parameters included in the COMMUTE tool

Variable	Unit
Operating speed	Knots
Fuel consumption, HFO	Kg/h
Fuel consumption, Marine Diesel	Kg/h
Fuel consumption, port	Kg/h
Emission factor Carbon monoxide, CO	g/kg fuel
Emission factor Carbon dioxide, CO_2	g/kg fuel
Emission factor Volatile Organic Compounds, VOC	g/kg fuel
Emission factor Nitrogen oxides NO_x	g/kg fuel
Emission factor Particulate, PM	g/kg fuel
HFO sulphur content	%
Marine Diesel sulphur content	%

8. SAFETY IMPACT ASSESSMENT METHOD

8.1 Overview

The COMMUTE tool has two safety impact assessment method options – a single risk method and a multiple risk method. Both methods use traffic exposure (e.g. vehicle mileage) as input data and produce traffic fatality numbers as output data. The single risk method should be used when the user wants to have absolute values with good or poor disaggregated data. The multiple risk method needs more accurate and aggregated data and it can be used for more sophisticated studies, when the user wants to see the relative traffic safety changes between different traffic scenarios. The absolute values are not so accurate as in the single risk method.

Both methods use a fatality risk database, which is built into the COMMUTE tool. All the risk values are national values. Values may have been aggregated e.g. to different vehicle and road types, but they always represent the whole country.

8.2 Single risk method

The single risk method is very simple. It uses the linear formula:

F = E*R, where:

F = amount of traffic fatalities (output)
E = traffic exposure (input)
R = risk (amount of fatalities/ certain traffic exposure)

The model has certain characteristics depending on the traffic mode. These are described below:

Road traffic

The road traffic safety assessment in the COMMUTE safety tool has been separated to three road types and five user groups. The road types are urban roads, non-urban roads and motorways. The user groups include pedestrians and bicycles, mopeds and motorcycles, passenger cars, buses and lorries. The output, the fatalities, are presented by user group. The tool doesn't need the passenger and bicycle exposure from the user, because this exposure has been estimated in the basis of total traffic input in urban areas or in non-urban areas. This estimation process is based on national pedestrian and bicycle traffic surveys.

The demands on the risk database are rather heavy. When compiling the data, all of the road fatalities and all road traffic exposure has been separated into fourteen sub-groups (*3 road types * 5 user groups* without the pedestrians and bicycles in motorways). This kind of separation is not available in every country in Europe and therefore some national proportions and relations (e.g. dividing the exposure along different road types in the basis of road type length) has been used more globally to estimate the corresponding numbers in other European countries.

Rail traffic

In rail traffic the nodes are the urban areas and links are the non-urban areas. In the international statistics the rail traffic fatalities have not been separated to freight train accidents and passenger train accidents. In the COMMUTE safety risk database the separation is made on the basis of some detailed national studies. The relation (passenger train accident fatalities/ freight train accident fatalities) has been used then globally.

Air traffic

The COMMUTE GIS-method means that all the traffic routes have been divided into nodes and links. In air traffic the airports represent the nodes. The safety model is only studying the nodes because the air traffic safety depends more on the amount of landings and take offs (the most crucial moments of flights) than vehicle kilometres between airports. Therefore air traffic is using amounts of landings as an exposure.

In the COMMUTE safety tool a distinction has been made - in every mode - between passenger traffic and freight traffic. Because the air traffic safety statistics don't include this kind of distinction it has been made by assuming that the accident risk is the same for passenger and freight planes, but because the average number of people in a passenger plane is higher than in the freight plane, the fatality risk in passenger planes is also higher. Therefore the relationship between *passenger plane fatality risk/ freight plane fatality risk* is as big as the *average amount of crew and passengers in passenger planes/ crew in freight planes*.

Water traffic

In water traffic the harbours represent the nodes and water routes are the links. According to the model, the risk of fatalities is concentrated totally on the links.

In all water traffic, statistics on exposure data is very inaccurate and accidents are very unpredictable and on a small scale (geographically). Therefore it has not been possible to create country wide risk databases as in other modes. The water traffic safety tool is using European wide risk estimates.

The estimation between passenger ship fatality risk/ freight ship fatality risk has been assessed on the same basis as for air traffic (by comparing the amount of humans on the ship).

8.3 Multiple risk method

As written earlier, the multiple risk method is for more sophisticated studies, when the user wants to see the relative traffic safety changes between different traffic scenarios. In the multiple risk method, the fatality risk of the user group (vehicle group) has been separated to single risk and to meeting accident risks against other user groups in the same traffic network. Therefore the fatality risk of e.g. mopeds and motorcycles in the urban area is:

$R_{mopurb} = R_{mopsingurb} + R_{mopapedurb} + R_{mopamopurb} + R_{mopacarurb} + R_{mopabusurb} + R_{mopalorurb}$, where,

R_{mopurb} = Fatality risk for mopeds and motorcycles in urban areas
$R_{mopsingurb}$ = Single accident fatality risk for mopeds and motorcycles in urban areas
$R_{mopapedurb}$ = Meeting accident fatality risk against pedestrians and bicycles for mopeds and motorcycles in urban areas
$R_{mopamopurb}$ = Meeting accident fatality risk against mopeds and motorcycles for mopeds and motorcycles in urban areas
$R_{mopacarurb}$ = Meeting accident fatality risk against passenger cars for mopeds and motorcycles in urban areas
$R_{mopabusurb}$ = Meeting accident fatality risk against buses for mopeds and motorcycles in urban areas
$R_{mopalorurb}$ = Meeting accident fatality risk against lorries for mopeds and motorcycles in urban areas

As can be imagined, when estimating the single accident fatalities for mopeds and motorcycles in urban areas, we can use the linear model we presented in the context of the single risk model: F = E*R. That means, the fatalities arising from e.g. off-road accidents are only dependent of the exposure of mopeds and motorcycles and the corresponding risk.

But the situation is rather different when we consider the accident fatality risk against other user groups. It's now not only a question of the exposure of mopeds and motorcycles, because the amount of other possible obstacles (other user groups) will highly affect the risk of meeting them. Therefore we must use a formula, when we also take account of the exposure of the meeting party to adopt the meeting accident risk.

The estimation procedure

The multiple risk method becomes more complex when we understand, that before we can start to adopt the risk of meeting an accident, we must now examine the exposure conditions, where the original risk was born. When the single risk model needed only risk values in the database, the multiple risk model also needs an exposure database. Because it was not possible to feed every exposure from every link and node in the European traffic network into the database, these exposures are only countrywide as are the risk values. When the user wants to study a certain area or link, these exposures are converted to corresponding exposure levels on the basis of the total exposure of the area or link. That means these reference exposures describe more the exposure relations between different user groups than the absolute values.

The first estimation procedure is therefore based partially on the reference exposures, but when the user makes more estimations/calculations he can later start using the exposures he fed in the first calculation. Figure 8.1 describes the possible process of several calculations. Because the absolute values are primarily based on the database exposures, which doesn't describe the local conditions very well, the absolute values are not so reliable. But when the user starts to make comparisons, he can see very interesting and meaningful changes in fatality levels, in the way which takes account of the whole vehicle fleet in a manner, which was not possible in the single risk method.

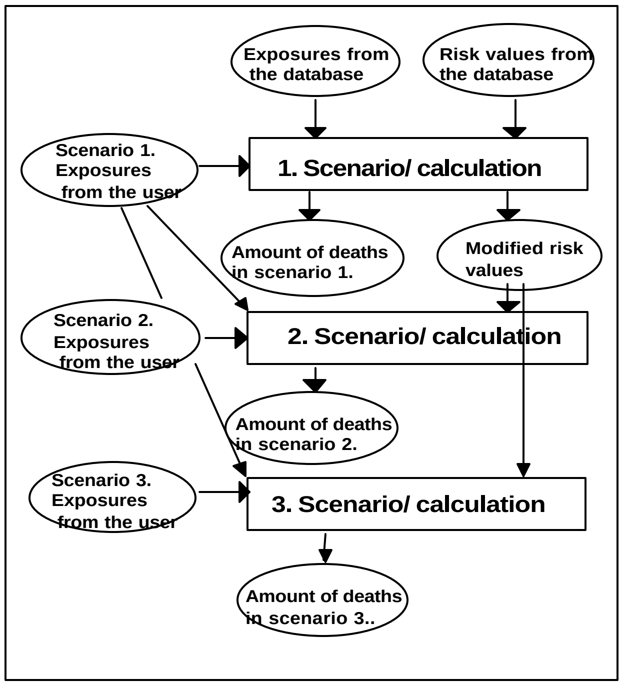


Figure 8.1 Multiple risk method assessment process

Elasticity factors

Because the multiple risk method is able to study the changes in exposure levels, it is also able to re-estimate the linear model between fatalities and exposure: F = E*R. As some studies has shown, the amount of fatalities doesn't necessarily always reach this level when the exposure is growing or changing. The theories have presented both the linear correction factor (K in the picture) or the exponential correction factor (e in Figure 8.2). These correction factors are called elasticity factors. The safety multiple risk method is using linear elasticity factor.

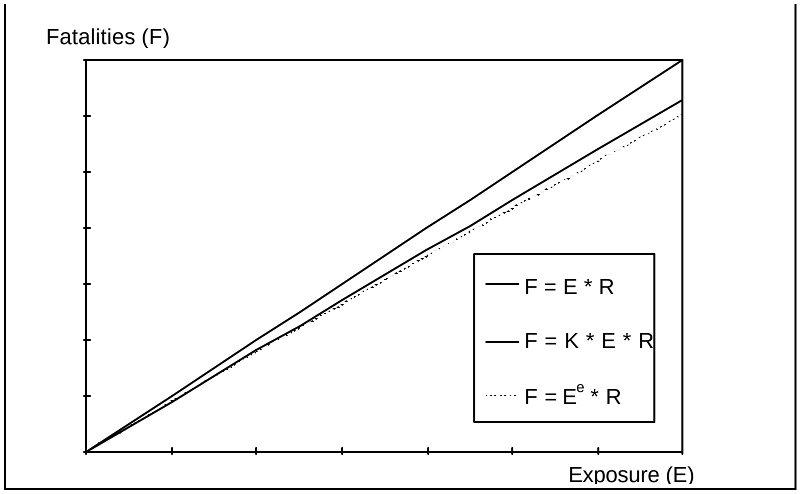


Figure 8.2 An example of flexibility factors K (K<1) and e (e<1)

9. NOISE IMPACT ASSESSMENT METHOD

Available strategic noise assessment methodologies can be classified into four methodological categories ranging from models of noise emitted at source to models of aggregate noise effects. The COMMUTE core noise calculation modules operate within the first methodological category (noise emitted at source), but an option of additional models is left open.

The noise module of the COMMUTE software tool provides outputs for strategic comparisons of aggregate sound power emitted by each noise source or sub-category of noise source considered. Additional conversions to equivalent sound level at stated reference distances are provided for guidance. Full details are given in COMMUTE Deliverable 2, Volume 3.

The primary output data, aggregate sound power, from the COMMUTE core noise calculation module is the sound power per metre length or total sound power for each defined link or the total sound power for each defined node. For links, the total sound power is calculated by multiplying the sound power per metre by the length of the link in metres, or by multiplying the sound power per vehicle by the proportionate time spent traversing the link. Nodes which are defined simply as points at the end of one or more links do not generate any sound power at all. Nodes which are defined as centres of activity considered to act at a point will generate sound power according to the amount of activity taking place within them.

The core noise calculation module is based on default hourly average sound powers per vehicle, as derived from existing European data. For road and rail traffic, the default values relate to a single vehicle per hour per metre of route (road or railway track). There are different defaults for different classes of vehicle under different operating conditions. For air traffic, since all noise is assumed to be emitted at a single node, the default sound powers relate to single vehicle operations.

The aggregation of total sound power at source is then a simple multiplication by numbers of vehicles and length of route (where appropriate). Aggregate sound power can then finally be converted to equivalent sound levels at stated reference distances for guidance, bearing in mind that this final stage of the calculation cannot take local topography or other local circumstances into account.

10. THE COMMUTE SOFTWARE TOOL

10.1 Introduction

The COMMUTE software tool embodies the impact assessment methods for the primary pollutant emissions, energy consumption, noise and safety across the transport modes road, rail, air and waterborne transport, as described in Chapters 4 to 9. However, it is also designed for future expansion to cover other important land use and ecological impacts.

The COMMUTE software is primarily applicable to policy decision-making and it is based on relatively large scale spatial resolutions. The tool focuses on assessing the environmental impacts of Programmes, Policies and Plans (PPPs) at:

- European level (i.e. assessing impacts of PPPs for the whole of the EU)
- National level (i.e. assessing impacts of PPPs for individual countries)
- Regional level (i.e. assessing impacts of PPPs for large administrative regions (e.g. NUTS 2) or for regional scale corridors)

The tool is network oriented and works on assessments on links and nodes. The impacts are calculated on a link-by-link and node-by node basis and then added together for assessments of networks or corridors comprising a number of links and nodes. In this context urban areas, harbours and airports are represented as nodes in the network. These nodes could then each have traffic flow data associated with them within the tool that would cover the whole area (e.g. vehicle-km figures and an average speed for a whole city in the case of road transport).

This approach does not include explicit representation of the urban transport network within each urban area. It therefore allows assessment of policies that have an impact in urban areas (e.g. policies that encourage modal shift for urban travel) but would not be suitable for assessment of urban infrastructure programmes. Such assessments would need to be conducted using a more detailed urban scale model.

The tool uses a Geographical Information System (GIS) for handling the geographical representation of the network and for performing spatial oriented analysis and presentation purposes.

The finest level of temporal resolution that the tool will focus on is provision of seasonal impacts, with the main emphasis being on calculating and presenting annual impacts.

The final version of the COMMUTE tool includes a life cycle analysis approach in so far as emissions of harmful substances and energy consumption from power stations and refineries will be considered additionally to those from vehicle operation.

For the different impacts across transport modes a specific module or model has been designed, but each module is independent and separated from the others.

The software is modular and the database has not only the function of storing the data but also of integrating the models.

The user interfaces the program through the Human Machine Interface which has been developed using a commercial Geographical Information System.

10.2 System Architecture

To achieve user-friendliness, the COMMUTE software was developed in the well known Windows 95 environment. Wherever possible, well known commercial tools were used instead of developing new and proprietary codes.

The architecture of the software was designed to be flexible, easy to maintain and capable of accommodating future development. In fact the software has a modular structure.

For the different impacts across transport modes a specific model and module has been designed (ACCESS BASIC). Each module (model) is independent and the integration is made through the database (ACCESS) and the Human Machine Interface (ACCESS BASIC).

MAPINFO has been selected as the Geographical Information System, because of its quality to be one of the most used and inexpensive GIS and because it is integrated with Microsoft and offers a simple toolkit in Basic (MapBasic).

It is essential to be able to add or change models without changing the overall architecture or the existing modules.

The software structure consists of six parts:

1. The HMI (human machine interface) which allows the user to interface with the tool
2. The GIS which represents the data (input and output) in a geo-referenced form
3. The DATA MANAGER which manages the database and provides the input-output functions
4. The different MODELS/modules which provide the environmental results
5. The CONFIGURATION MANAGER which allows the user to configure the scenarios (year..)
6. The MANAGER OF MODELS which schedules the run of the different modules

Each model, such as the 'road emission and consumption' or the 'rail safety' etc., is a separate module and it has a proprietary code written in a collective language.

The modular structure of the software together with the fact that a standard commercial database management system has been used allows the user to interface the data also with other tools such as Excel or ARCINFO.

Each model is composed of two main parts: the calculus itself that comprises the reading and writing of the database data, and the configuration that requires an HMI to interface with the user in order to assess the configuration of the scenario that the model will run.

Figure 10.1 shows that the model takes the inputs as they are in the database and prepares the data as required by the "core model" which is the calculator module that assesses the environment. The post module takes the outputs as they are calculated by the "core model" and aggregates or desegregates them as they will be shown to the user of the program.

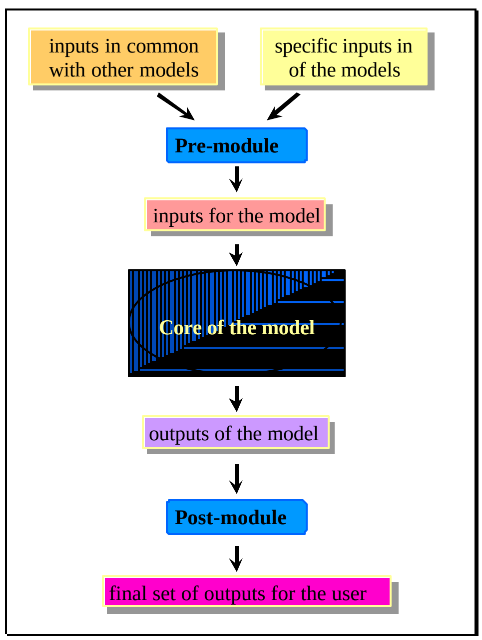


Figure 10.1 Structure of each model

Both input and output data are contained in the database. The user has the option to create scenarios and to compare calculation results with the a priori information.

10.3 The Database

According to the software architecture the database is *integrated*. Wherever possible the model uses the same data, so that some data of the database is common, while some data is specific to each of the models. The common data is really important for the harmonisation and integration of the models.

The COMMUTE database is organised in Microsoft ACCESS tables in order to allow the user to analyse results in an easy-to-use and flexible environment. To perform the calculations for the different impacts across the transport modes, the COMMUTE software tool needs several types of tables which are classified according to the source and nature of the data they contain. The tables can be categorised as either input tables which contain all the data necessary for the calculation of the results, or output tables which contain the results of the software elaboration.

The same tables can be also divided as follows:

COMMUTE tables

These contain data provided by the tool:

?? The **general tables** contain classifications and codes used in the other tables; they are generally provided by the COMMUTE tool. They are an integral part of the COMMUTE software.

?? **Default tables** are tables that the COMMUTE tool provides to enable calculations if the user cannot provide sufficient data to fill in the optional input user data tables; the default tables are usually based on historical average data. Examples of this type of data include road vehicle fleet compositions for all EU countries or data on electricity production emissions. This data is provided as default data with the model.

?? The **coefficient tables** contain constants or factors used in the formulas (e.g. emission factors) for the calculation of the outputs; they are extracted from scientific literature or from the results of other European Projects (i.e. MEET Project).

User tables

These contain data which depend on the user:

?? The **mandatory user input tables** are the ones that the user must fill in to define a scenario; they generally contain traffic data and network data. The GIS can support the user to fill in these tables.

?? The **optional user input tables** are tables which the user should fill to have more accurate results, but where this is not mandatory. If the user doesn’t insert these data, the tool uses the default values.

?? **Output tables** contain all the results the COMMUTE tool can provide. COMMUTE produces output tables for emissions, fuel consumption, energy consumption, noise and safety for the user defined scenario.

enerally the output data provided is disaggregated for each link/node and per vehicle category as well as aggregated for countries and per vehicle macro-category.

10.4 The menu screen and use of the software

The “COMMUTE main menu” screen presents the software tool user with three different sections, as shown in Figure 10.2.

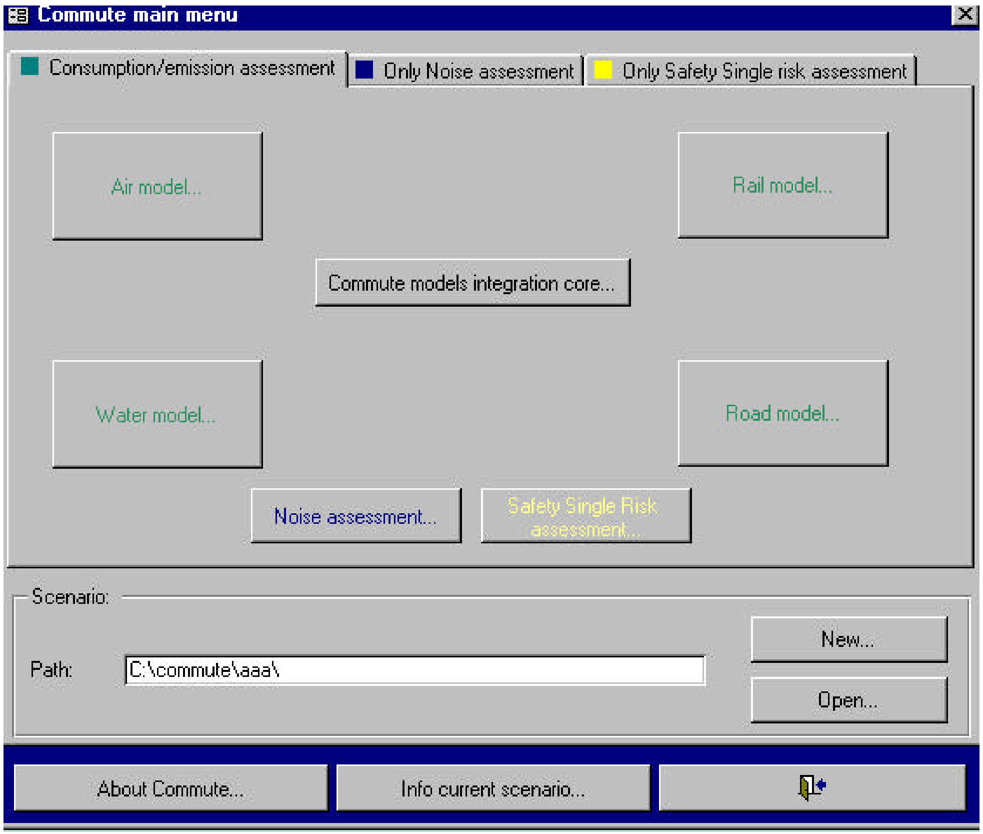


Figure 10.2 The COMMUTE main menu screen

The first section is for **calculation** and reflects the approach of the COMMUTE methodology. The main subdivision is for impacts: emission & consumption, noise, safety. Each impact is calculated for the different modes of transport: air, road, rail, and water.

All the calculation modules are integrated and the commonalties are grouped in an integration core which consists of the common shared set of classification tables (i.e. the list of the countries, the list of the fuels considered etc.) and coefficient tables (i.e. the calorific power of the fuels).

This allows a comparison of results among different modes on a user defined multi-modal network scenario.

The second section is allocated below the calculation one and it allows the user to define (create or open) a **scenario**: the network traffic/transport case that he/she want to assess.

The third section, at the bottom, contains mainly buttons to access **information** about the COMMUTE Tool, the COMMUTE Project and the scenarios selected by the user through the scenario section.

10.4.1 The calculation section

This section occupies the upper part of the menu screen. The different impacts are represented in separated sheets. Each sheet is associated to one colour (a coloured square on the sheet's flap) and embodies the four mode buttons. It is possible to distinguish the following sheets:

?? The first sheet is for the EMISSION & CONSUMPTION function: the associated colour is GREEN
?? The second sheet is for the NOISE assessment only and it is associated to the colour BLUE
?? The third sheet is for the SAFETY SINGLE RISK assessment only and it is associated to the colour YELLOW

It is important to know that the emission and consumption impact evaluation requires more detailed data than the noise and the safety impact. Then, if the user wants to assess *all the impacts* for a certain scenario, he has to begin with the Emission & Consumption Assessment Sheet. That is because in this way the inputs for the Noise and the Safety Assessments will be obtained as a copy or an aggregation of the Emission & Consumption inputs. Otherwise, if the user wants to evaluate only the Noise Impact or only the Safety Assessment, he should select the “Only Noise” sheet or the “Only Safety” sheet which require less detailed data. However, it has to be clear that, in this case, he/she cannot assess the Emission and consumption impacts.

In the centre of each sheet there is a button called "COMMUTE models integration core" which allows the user to view the list of the common tables (countries, fuels, pollutants…..) belonging to the “COMMUTE integration core”.

The emission & consumption sheet

The emission and consumption sheet provides the more comprehensive evaluation on the same defined network (emission & consumption, noise and safety). In order to help the user in terms of the priorities in assessing the impacts, the Human Machine Interface gives a hierarchy in using the models. The hierarchy of the tool is as follows:

1. Emission and consumption impacts
2. Noise and Safety impacts

When pushing one mode button, for example the rail one, the user can insert data, run the application and obtain first the emission/consumption results. This sheet embodies also the modules for the evaluation of NOISE and SAFETY assessment: at the bottom you can see the two relative buttons. As it was described above, the emission/consumption model needs all the data (generally more detailed) necessary also for the calculation of the NOISE and SAFETY assessments.

In other words, if for a mode, the user inserts the network and traffic flow data for the emission/consumption assessment and he/she runs the model, the interface allows the user to select also the buttons to obtain the NOISE and SAFETY results about the same test. The aggregations of the input data of the emission model are made automatically to get the input data for the NOISE/SAFETY scenarios.

Beside each mode button can appear three coloured little squares, one green , one blue, one yellow they relate to a test for which runs have effectively been undertaken. For example: if, for the rail mode, you have already pushed the run button for the emission/consumption and for the noise evaluations, beside the rail button you will see the green and the blue squares.

The noise assessment sheet

If you want to obtain *only* the noise assessment of a network, you should choose this sheet, but be careful: it will not then be possible to obtain other impact results for the same network. In fact, the noise assessment needs less detailed user input data compared with the emission and consumption model, so, if you start the evaluation from this poin,t and you insert network and traffic data requested for the noise assessment, *it will not be possible to obtain other impact results* for the same network. For each transport mode you can insert data *independently* to the other sheets and if you make a run, a *blue* square will appear beside the mode.

The safety single risk sheet

As for the noise assessment, if you want to obtain *only* the *safety* assessment of a network, you should choose this sheet, but be careful: *it is not possible to obtain other impact results* for the same network. For each transport mode you can insert data *independently* to the other sheets and if you make a run, a *yellow* square will appear beside the mode.

10.4.2 The scenario section

At the bottom of the COMMUTE tool main menu the user finds a box for the configuration of the scenario which is the network traffic/transport case that the user want to assess. The user can use the COMMUTE tool to evaluate the environmental impacts of different scenario policies. The COMMUTE scenario is a comprehensive user configuration of the network and of the traffic flows for all the transport modes, but of course the user can also define and make evaluations on a single mode network.

The user has two options:

- ?? to *create a new scenario* pressing the "New…" button and selecting a directory and its name
- ?? to *open an existing scenario* pushing "Open…" and selecting an already existing scenario.

The first time the user works on the COMMUTE Tool he/she has to create a new scenario: this operation prepares the background where the tool can be used. From this point on, the user can decide either to create a new scenario again or to use the existing one (by opening it) that has already been prepared. In particular, each time the user creates a new scenario the tool creates a new directory and prepares a database in this directory. This database contains the *COMMUTE data* (defaults, and general data) and the empty structure of the tables that will contain the user input and the results. Once the user inserts the input data and commands the application to run, the database is filled with the relative results.

10.4.3 The information section

At the bottom of the menu screen there is:

1. a button called “About COMMUTE” showing general information about the COMMUTE tool and the COMMUTE Project
2. a button named “ Info current scenario” which contains information about the state and the setting up of whole current scenario
3. a button for the exit from the program.

11. VALIDATION AND DEMONSTRATION OF THE COMMUTE SOFTWARE TOOL

This chapter of the report covers validation and demonstration of the COMMUTE software tool. The tool (with the exception of the noise module) was tested and validated during the course of the project by comparing outputs from model runs with broadly comparable data sets from other sources. These validation tests show the software tool's credibility and are reported in section 11.1.

The main demonstration of the application of the COMMUTE software tool was the pilot strategic environmental assessment of the Trans European Network (TEN), carried out in Work Package 7 of COMMUTE. This is reported in section 11.2.

Additional demonstration activities were also undertaken within COMMUTE Work Package 4, in terms of sensitivity testing and additional illustrative model runs on different hypothetical policy scenarios. These are reported in COMMUTE Deliverable 5 (Demonstration and Exploitation) – to which the reader is referred.

11.1 Validation of the COMMUTE software tool

11.1.1 Road emissions and consumption

Efforts were made to compare the COMMUTE model and the results gained in the framework of the Pilot SEA against other models and data. This was done on three different levels. The following sections describe the approaches and results of these comparisons and aim at explaining the differences both in a qualitative and quantitative way.

Comparison with JET model

In order to compare the COMMUTE road transport model, it was agreed to use the JET model from the JUPITER project. JET (Jupiter Energetics in Transport) is a spreadsheet model which has been developed by Transport and Travel Research Limited (TTR) within the JUPITER project as a tool to estimate the changes in energy and emissions from road transport measures. JUPITER (Joint Urban Project In Transport Energy Reduction) is a Thermie Targeted Transport Project involving a range of integrated transport management measures designed to achieve energy savings and environmental improvements in the partner cities of Aalborg (Denmark), Bilbao (Spain), Florence (Italy), Gent (Belgium), Liverpool (United Kingdom) and Patra (Greece). However, JET can be applied to any other area or city provided the relevant data can be provided.

Now the COMMUTE tool can be used to calculate the effect of hot, cold start and evaporative emissions. At the time that the comparison of the COMMUTE road transport model was carried out however, the software (COMMUTE Version 1.4) only included emission factors to calculate hot emissions. The

JET model also has a facility to calculate hot emissions separately and therefore provides a basis for a comparison with the current version of the COMMUTE road transport model. It was therefore possible to compare the outputs of the JET model and the COMMUTE road model using the same input data.

In order to compare the COMMUTE road model with the JET model, it was decided to use input information from three of the six JUPITER cities, Bilbao (Spain), Florence (Italy) and Gent (Belgium). The JET model provided input information for the relevant cities for average speeds of passenger cars and buses and the length of the road network in each city. As a simple comparison exercise, a figure of 1 million annual vehicle kilometres was also input for each mode. Table 11.1 below illustrates the inputs used in the comparison process which were common to the two models:

Table 11.1 Common inputs to the COMMUTE and JET models

City	**Countr y**	**Length of road network (km)**	**Average speed (km/h)**		**Annual vehicle kilometres (x 1000)**	
1.1	1.2		**Cars**	**Buses**	**Cars**	**Buses**
1.3 BILB AO	*1.4 SP AIN*	135	17.2	11.5	1,000	1,000
Florence	Italy	702	23	17	1,000	1,000
Gent	Belgium	199	25	14	1,000	1,000

Using these inputs, the COMMUTE model was then run for the year 1995, the year closest to the date in which the latest version of JET was created (March 1997). Tables 11.2 to 11.4 below illustrate the results of the comparison in terms of hot emissions, hot energy consumption, and hot fuel consumption for the three selected cities.

Clearly there are no gross errors in the outputs produced by the COMMUTE road model. All of the COMMUTE model outputs are of the same order of magnitude as those produced by the JET model. The difference between the outputs produced is never greater than an overestimation of 21% (CO emissions for Bilbao) or an underestimation of 22% (hot energy consumption for Florence) as calculated by the COMMUTE model.

It would be unlikely to achieve a closer match between the two sets of outputs owing to the fact that there are differences in the fleet compositions for each city/country between JET and the COMMUTE model. In addition, the COMMUTE model uses more up to date emission factors than the JET model which also has an effect on the outputs produced.

Table 11.2 Hot emissions (tons) from the COMMUTE and JET models

City	Pollutant	COMMUTE (1995)	JET (1997)	Difference (+/-)	Difference %
Bilbao	CO	30.89	24.25	+ 6.64	+ 21%
	CO_2	1,691.52	1,884.53	- 193.01	- 11%
	1.5 VOC	6.18	5.70	+ 0.48	+ 8%
	NOX	26.19	24.71	+ 1.48	+ 6%
	PM	1.48	1.49	- 0.01	- 1%
Florence	CO	23.94	21.26	+ 2.68	+ 11%
	CO_2	1,436.71	1,554.25	- 117.54	- 8%
	1.6 VOC	4.54	4.43	+ 0.11	+ 2%
	NOX	22.28	20.50	+ 1.78	+ 8%
	PM	1.06	1.04	+ 0.02	+ 2%
Gent	CO CO_2	20.55 1,567.99	21.48 1,683.52	- 0.93 - 115.53	- 5% - 7%
	1.7 VOC	5.12	4.91	+ 0.21	+ 4%
	NOX	25.66	22.53	+ 3.13	+ 2%
	PM	1.46	1.25	+ 0.21	+ 14%

Table 11.3 Hot energy consumption (MJ) from the COMMUTE and JET models

City	COMMUTE (1995)	JET (1997)	Difference (+/-)	Difference %
Bilbao	23,698,710	27,363,026	- 3,664,316	- 15%
Florence	18,486,590	22,582,062	- 4,095,472	- 22%
Gent	22,404,980	24,449,575	- 2,044,595	- 9%

Table 11.4 Hot fuel consumption (tons) from the COMMUTE and JET models

City	COMMUTE (1995)	JET (1997)	Difference (+/-)	Difference %
Bilbao	553.31	600.04	- 46.73	- 8%
Florence	430.45	494.47	- 64.02	- 15%
Gent	523.67	535.94	- 12.27	- 2%

Comparison with EEA/CORINAIR data for road transport in 1994

Table 11.5 below compares total CO, CO_2, HC and NOx road transport emissions calculated by the COMMUTE model for 1994 with the EEA Statistical Compendium CORINAIR data for road transport for the same year. The COMMUTE data includes hot emissions, cold emissions and evaporative emissions. The effects of cold- and evaporative emissions are calculated as outlined below. This table gives a breakdown of emissions by country and for the EU as a whole. PM emissions are excluded from the analysis because although particulate emissions were calculated by the COMMUTE model, there was no EEA/CORINAIR data available on PM emissions with which to compare the COMMUTE output.

Table 11.5 Comparison of COMMUTE road transport model emissions and EEA/CORINAIR data for road transport in 1994

Country	CO ('000 tonnes)			CO_2 (M-tonnes)			HC ('000 tonnes)			NOx ('000 tonnes)		
	1.8 COMMUTE	**Corinair**	**Commute/ Corinair**	**Commute**	**Corinair**	**Commute/ Corinair**	**Commute**	**Corinair**	**Commute/ Corinair**	**Commute**	**Corinair**	**Commute/ Corinair**
Austria	215	364	**0.59**	10.4	14.9	**0.70**	38	76	**0.50**	62	96	**0.64**
Belgium	258	995	**0.26**	14.2	23.9	**0.59**	58	186	**0.31**	110	214	**0.51**
Denmark	289	413	**0.70**	5.9	9.4	**0.63**	55	76	**0.72**	53	88	**0.60**
Finland	352	311	**1.13**	7.7	9.5	**0.81**	69	55	**1.25**	73	135	**0.54**
France	2440	6045	**0.40**	84.7	121.3	**0.70**	530	1145	**0.46**	717	1047	**0.68**
Germany	2613	3953	**0.66**	122	159.4	**0.77**	418	713	**0.59**	750	1046	**0.72**
Greece	527	979	**0.54**	10.2	13.3	**0.77**	96	224	**0.43**	90	129	**0.70**
Ireland	138	261	**0.53**	3.6	5.5	**0.65**	27	59	**0.45**	26	44	**0.59**
Italy	3055	5507	**0.55**	72.7	100.1	**0.73**	611	1125	**0.54**	669	947	**0.71**
Luxembourg	10	44	**0.23**	0.7	1.1	**0.65**	2	9	**0.24**	4	10	**0.40**
Netherlands	510	516	**0.98**	17.7	27.1	**0.65**	94	143	**0.66**	137	247	**0.55**
Portugal	476	733	**0.65**	12.0	11.4	**1.05**	96	105	**0.91**	100	135	**0.74**
Spain	1713	2739	**0.62**	44.3	50.2	**0.88**	437	512	**0.85**	383	528	**0.72**
Sweden	674	1164	**0.58**	13.7	16.3	**0.84**	128	158	**0.81**	143	166	**0.86**
UK	2237	4472	**0.50**	70.6	110.8	**0.64**	511	786	**0.59**	624	1139	**0.55**
Total EU	**15506**	**28496**	**0.54**	**491.0**	**674.2**	**0.73**	**3171**	**5372**	**0.59**	**3942**	**5971**	**0.66**

Table 11.6 shows the total traffic data in vehicle kilometres for EU 15 both for COMMUTE/STREAMS and for COPERT. Although the comparison for EU 15 shows very good correspondence (the difference is only 3%), larger differences for certain countries can be observed. The factors range from 0.72 for Luxembourg to 1.26 for Netherlands.

Table 11.7 shows the disaggregated traffic figures used by COMMUTE/STREAMS and for CORINAIR/COPERT for the four EU Countries; France, Italy, Germany and United Kingdom. Even though the total traffic figures are nearly equal there are extremely high differences in heavy- and light duty vehicles mileage. The figures for these vehicle categories from STREAMS and used by COMMUTE are significantly lower than those from CORINAIR.

Table 11.6 Aggregated traffic data for EU 15

Country	MVekm		
	COMMUTE/ STREAMS	COPERT	**COMMUTE/ COPERT**
Austria	51,376	62,565	**0.82**
Belgium	77,164	89,082	**0.87**
Denmark	29,972	40,064	**0.75**
Finland	36,548	46,007	**0.79**
France	431,770	412,176	**1.05**
Germany	590,529	605,449	**0.98**
Greece	55,344	50,397	**1.10**
Ireland	19,361	22,573	**0.86**
Italy	356,617	391,974	**0.91**
Luxembourg	4,141	5,730	**0.72**
Netherlands	96,867	76,582	**1.26**
Portugal	62,360	50,982	**1.22**
Spain	232,427	245,863	**0.95**
Sweden	64,475	66,151	**0.97**
UK	372,240	375,423	**0.99**
Total EU	**2,461,948**	**2,541,018**	**0.97**

Table 11.7 Traffic data by vehicle classes for four EU countries

	Vehkm [millions]		
	COMMUTE /STREAMS	**COPERT**	**Ratio COMMUTE/COPERT**
France			
Buses	3,097	3,143	0.99
Heavy duty vehicles	14,188	39,743	**0.36**
Light duty vehicles	4,196	76,899	**0.05**
Passenger cars	410,289	292,390	1.40
Total	431,770	412,176	1.05
Germany			
Buses	4,747	4,503	1.05
Heavy duty vehicles	17,135	66,565	**0.26**
Light duty vehicles	10,843	25,853	**0.42**
Passenger cars	557,804	508,529	1.10
Total	590,529	605,449	0.98
Italy			
Buses	4,130	3,386	1.22
Heavy duty vehicles	9,534	44,571	**0.21**
Light duty vehicles	3,573	33,738	**0.11**
Passenger cars	339,380	310,280	1.09
Total	356,617	391,974	0.91
UK			
Buses	2,787	4,770	0.58
Heavy duty vehicles	10,155	31,085	**0.33**
Light duty vehicles	7,873	34,731	**0.23**
Passenger cars	351,426	304,837	1.15
Total	372,240	375,423	0.99

There are a number of differences in the data shown in Table 11.5. The COMMUTE model is based on a series of assumptions relating to road type, fleet composition, traffic input and traffic speeds. Clearly these assumptions will have an impact on the differences reported above. All COMMUTE estimates are lower than those from CORINAIR and the greatest differences for each country are shown in CO and HC emissions. For the EU15 as a whole the CO and HC emissions calculated by the COMMUTE model are just over half those listed in the EEA/CORINAIR data.

These differences derive to a large extent from the vehicle speed predicted by the STREAMS model for the intra-zonal traffic and how this is used by COMMUTE. The STREAMS intrazonal model speeds vary by the type of zone and are an average for that zone. The average speeds for intrazonal traffic of passenger cars across countries is in the range of 45 Km/hrs. They are not intended to be simply 'urban' speeds as many zones do not cover mainly urban areas. There is no direct connection in principle between this approach and the approach taken in the COMMUTE software.

The underestimation of NO_X emissions from COMMUTE tool are mainly caused by the large differences in light-and heavy duty (see Table 11.6) since these vehicles are the highest NO_X emitters.

Comparison with Auto-Oil II

The Auto-Oil II road transport base case is a year by year qualitative and quantitative description of road traffic, vehicle stocks and polluting emissions and their expected evolutions up to 2020 (the time horizon of Auto-Oil II), including the impact of all Auto-Oil I measures. This base case will be used in the Auto-Oil Programme as a reference, a benchmark, to which a number of policy scenarios will be compared, in terms of impact on the environment and of cost to society. The emissions have been assessed using the COPERT II methodology.

The traffic data from Auto-Oil II for the nine countries have been used to compare the COMMUTE model with Auto-Oil II and COPERT II respectively for the year 1995. To do so Auto-Oil II has provided vehicle kilometres for passenger cars, buses, light- and heavy duty vehicles and two-wheelers for urban roads, rural road and highways. Data on vehicle speeds and trip length were not available. These disaggregated figures have been aggregated to make them compatible with the COMMUTE input data structure. No data on vehicle speeds and trip length across road-and vehicle types were available from Auto-Oil II. The COMMUTE/MEET default data has been used in the emission calculation. Total emissions for CO, CO_2, NO_X and HC have then been calculated with the COMMUTE model using the Auto-Oil traffic figures as input data. The emissions calculated with the COMMUTE tool have been compared against the Auto-Oil II results. In contrast to the comparisons reported above this activity was done with the final version of the COMMUTE tool which includes the methods for cold start- and evaporative emissions.

Table 11.8 hows the comparison of emission results generated with the COMMUTE tool using Auto-Oil II transport figures against the emission results from Auto-Oil II.

Table 11.8: Comparison of results COMMUTE/Auto-Oil II

Country	CO (000 tonnes)			CO2`(M-tonnes)			HC (000 tonnes)			Nox (000 tonnes)		
	COMMUTE	Auto-Oil II	COMMUTE/ Auto-oil	COMMUTE	Auto-Oil II	COMMUTE/ Auto-oil	COMMUTE	Auto-Oil II	COMMUTE/ Auto-oil	COMMUTE	Auto-Oil II	COMMUTE/ Auto-oil
Finland	520	445	**1.17**	9.4	9.6	**.98**	69	78	**.88**	94	96	**0.98**
France	3,806	4,679	**.81**	104.7	116.3	**.90**	620	856	**.72**	796	923	**0.86**
Germany	4,056	5,610	**.72**	142.2	166.9	**.85**	572	723	**.79**	886	1,047	**0.85**
Greece	794	608	**1.31**	13.9	13.6	**1.02**	133	119	**1.12**	104	104	**1.00**
Ireland	149	169	**.88**	4.0	4.4	**.92**	20	35	**.58**	32	37	**0.85**
Italy	5,361	4,128	**1.30**	96.8	95.0	**1.02**	762	809	**.94**	757	771	**0.98**
Netherlands	1,059	840	**1.26**	24.6	24.2	**1.01**	145	124	**1.17**	183	180	**1.02**
Spain	2,475	2,114	**1.17**	58.9	59.1	**1.00**	402	453	**.89**	483	555	**0.87**
United Kingdom	3,706	5,016	**.74**	99.5	99.9	**1.00**	499	905	**.55**	896	877	**1.02**
Totals	**21,927**	**23,608**	**.93**	**554**	**589**	**.94**	**3,222**	**4,101**	**.79**	**4,231**	**4,591**	**0.92**

Table 11.9: Traffic data in vehicle kilometres from Auto-Oil II

		Country									
Type of vehicle	Road type	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Spain	UK	**Totals**
PC	Urban	10,622	120,415	174,836	14,708	2,879	126,593	26,329	50,856	148,180	**675,417**
	Rural	21,234	191,881	212,487	11,259	8,965	115,763	33,847	50,894	157,945	**804,275**
	Motorway	3,538	57,588	138,130	3,740	3,260	85,674	26,098	64,783	39,525	**422,336**
	Subtotals	**35,395**	**369,885**	**525,453**	**29,706**	**15,104**	**328,029**	**86,273**	**166,532**	**345,650**	**1,902,028**
LDV	Urban	938	23,583	11,866	3,590	406	11,718	4,296	10,108	15,466	**81,972**
	Rural	1,875	39,837	15,161	3,427	1,316	10,904	3,511	2,659	18,597	**97,287**
	Motorway	313	11,999	10,998	1,142	585	10,378	2,672	3,101	4,264	**45,451**
	Subtotals	**3,126**	**75,420**	**38,025**	**8,159**	**2,308**	**33,000**	**10,478**	**15,868**	**38,327**	**224,710**
HGV	Urban	373	2,980	10,758	1,580	185	8,488	1,784	7,463	8,495	**42,107**
	Rural	1,949	14,117	15,800	2,466	614	7,899	2,169	8,346	13,592	**66,952**
	Motorway	258	11,906	22,672	2,367	335	7,518	2,529	14,212	7,503	**69,300**
	Subtotals	**2,580**	**29,002**	**49,230**	**6,414**	**1,133**	**23,905**	**6,482**	**30,022**	**29,590**	**178,359**
Buses	Urban	315	1,527	1,458	199	55	758	369	585	2,844	**8,109**
	Rural	158	586	1,415	153	87	1,392	123	1,677	664	**6,254**
	Motorway	158	586	979	153	87	1,392	123	1,677	1,219	**6,372**
	Subtotals	**630**	**2,699**	**3,853**	**504**	**228**	**3,542**	**615**	**3,938**	**4,726**	**20,735**
	Totals	**41,731**	**477,006**	**616,561**	**44,783**	**18,773**	**388,476**	**103,848**	**216,361**	**418,293**	**2,325,833**

Table 11.9 shows the vehicle kilometres as they have formed the input for COMMUTE tool. The table shows the traffic data for the vehicle types passenger car, light duty vehicle, heavy duty vehicle and buses each for the road types urban, rural and motorway.

The comparison of total emission results for the nine countries in Table 11.8 shows a good correspondence for CO, CO_2 and NO_X. COMMUTE underestimates CO by 7 %, CO_2 by 6 % and NO_X by 8 %. The HC emissions show a significant underestimation of 21 %. Comparing the results per pollutant and country CO_2 shows the best comparison. The factors range from 0.85 to 1.02 which can be considered as a good comparison. Larger differences can be found for the other pollutants as for CO where factors from 0.72 to 1.30 are shown. The likely reasons for the differences encountered are the assumptions on vehicle speeds and trip length which have been used as well as possible differences in the fleet composition data in COMMUTE and COPERT II. The COMMUTE model uses the latest fleet compositions data which were available from MEET deliverable 16.

11.1.2 Rail emissions and consumption

Because of limited data availability for comparison purposes the rail model could not validated as stringently as other parts of COMMUTE tool. As such it is only possible to assess the method qualitatively.

The estimation of the emissions associated with rail transport varies from the other transport modes, as the methodology comprises a two step approach, whereby the energy consumption associated with the train operation is initially determined and subsequently converted into associated exhaust emissions.

The methodology relies upon an expression developed by Jorgensen and Sorenson, and included within Deliverable 17 of the MEET project.

$$E' ? \frac{(N ? 1)}{L} \frac{V\max^2}{2} ? B_0 ? B_1 Vave ? B_2 Vave^2 ? g\frac{?h}{L}$$

It is important to note that this formula is based upon the theoretical energy consumption required to move an object. The first part of this algorithm describes the route, expressed in terms of the distance travelled and the number of stops along the route. The second part of the expression ($Vmax^2/2$) equates to the theoretical expression for kinetic energy ($1/2mv^2$). The 'B' constants relate to the aerodynamic resistances opposing the forward movement of the train and the final parameter (g.h/l) relates to the potential energy associated with changes in gradient (mgh).

The methodology assumes that a train moves from stationary and accelerates to a constant cruise speed. This speed is then maintained until the train approaches a station, at which point the train decelerates and stops. This is obviously an oversimplification of those conditions that actually occur during a train journey. The true operation of a train is dependant on the specification of the train and the type of operation to which it is put. Although these operations are routinely timetabled, the precise journey characteristics are further influenced by a range of factors, including the condition of the track, weather, activity and location of other trains, priority given to other services and passenger delays. Each of these parameters will influence the number and degree of acceleration, deceleration and stationary phases along any specific route. As such under real world operating conditions, trains are unlikely to maintain this idealised operating profile and are likely to be subject to a range of additional transient operational phases. It is under these phases that energy consumption is greatest, and as such this idealised methodology is likely to underestimate real world energy consumption. It has been predicted that this underestimation is of the order of 20%.

The COMMUTE methodology adopts this approach and has developed a series of default values (number of stops, train weights, average and maximum speeds, level of network electrification) for five predefined train types. These train types are high speed, regional, urban and freight. The generation of default values will undoubtedly introduce errors into the derivation of energy consumption and emissions associated with any specific route. In addition to the potential underestimation of rail energy consumption, the emission factors employed to derive the rail emissions are also subject to error. This error is estimated to range from about 30% for SO_2 and CO_2, to 100% for the other pollutants. Available data on the energy consumption and emissions associated with rail transport are limited, and thus an assessment of the magnitude of potential errors may only be cursory.

In summary the COMMUTE tool provides an estimation method for the energy consumption and exhaust emissions associated with both diesel and electric trains. It is recognised that this procedure will provide a ‘broad brush’ estimation method and will be of greater uncertainty when compared to other transport modes.

11.1.3 Air transport emissions and consumption

Comparison of the COMMUTE air transport model has been undertaken on different levels and for different variables in order to enable best possible verification of COMMUTE outputs.

First, according to different flight distances and a sample of different routes COMMUTE results have been compared with results for selected areas in Germany, calculated with the TUEV Rheinland Air Traffic Emissions Model (TATE).

Second, for specific aircraft and for selected transport missions COMMUTE results have been checked with results from a Flight Plan Altitude (FPA) model, assuming that CRUISE will take place on a constant Flight Level (COMMUTE) or on the idealised Flight Plan Altitude (FPA) respectively.

Third, on the basis of fuel consumption data, emission factors used within the COMMUTE air transport model have been compared with those from other authoritative sources like ICAO and DLR.

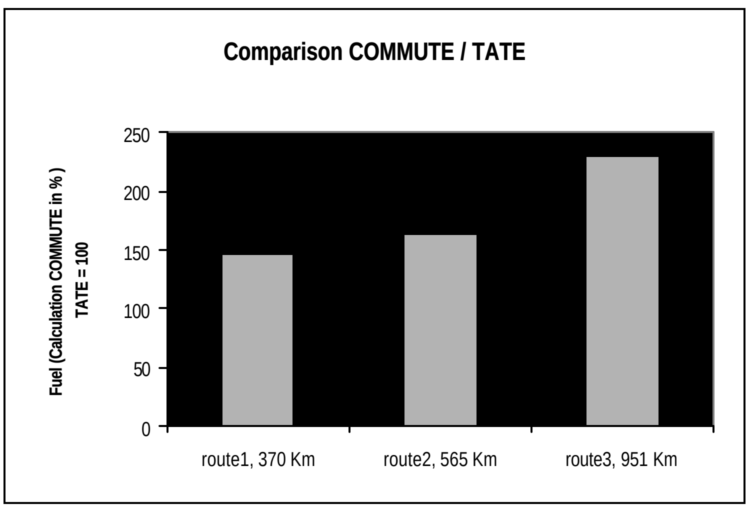
Comparison according to flight distance - COMMUTE/TATE

To check the plausibility of outputs from COMMUTE calculations, data on German domestic air traffic - calculated with TATE - have been used. The reference data include emission figures for all standardised operating conditions (Taxi out/airport A to Taxi in/airport B) and thus correspond with the calculation methodology applied in the COMMUTE model.

Based on the integral fuel consumption results of the Flight Distance Classes >500 km, 500-800 km and >800 km, a sample of three flight routes with the distances 370 km, 565 km and 951 km has been drawn. The route lengths represent the mean values in the respective distance classes. Data on flight movements for these routes have been used as input to COMMUTE air transport model.

Figure 11.1 illustrates the comparison of the fuel consumption calculation in TATE and COMMUTE. It can be clearly seen, that COMMUTE overestimates (in relation to TATE) fuel consumption and thus emissions in the test run.

Figure 11.2 Calculation of Fuel Consumption from Air Traffic (TATE/COMMUTE)



Overestimates for fuel consumption as core data range from 46% (Route 1) to 130% (Route 3). Correspondingly, COMMUTE calculations for associated emissions of CO, HC and NO_X exceed TATE figures, partly below and partly above overestimation rates for fuel consumption.

Interpreting the comparison findings it can be stated that the overestimation by COMMUTE seems plausible due to the following factors:

?? unlike the TATE model, in which the real share of aircraft types is taken into consideration, COMMUTE uses for calculation a modelled average aircraft, which has been derived from weighted share of the European aircraft stock.

?? the representative aircraft fleet for European air traffic (as used in COMMUTE) differs from the German domestic fleet (as used in TATE) in that it includes a substantially higher number of wide-body aircraft. Fleet compositions could not have been made consistent.

?? the aircraft and engine type distributions in TATE and COMMUTE vary because COMMUTE uses only aircraft with turbofan propulsion (Jets). It takes neither turboprop aircraft into consideration nor small business aircraft which have a significant share of domestic air traffic in Germany.

Comparison of aircraft specific data - COMMUTE/FPA

Comparative calculations of fuel consumption and emissions of aircraft types B 747, A 310 and A 320 have been carried out for sample routes with COMMUTE, TATE and with the Idealised Flight Plan Altitude Model (FPA).

The FPA model calculates - for certain flight routes/links and under idealised framework conditions - integral figures for complete flight emissions. Framework conditions are idealised in so far as for flight altitude/flight level is not the altitude actually achieved but the Flight Plan Altitude which has to be declared by the pilot upon preparation of the flight plan prior to the flight. Under such conditions, deviations of the FPA calculations from the aggregated data of COMMUTE are inevitable.

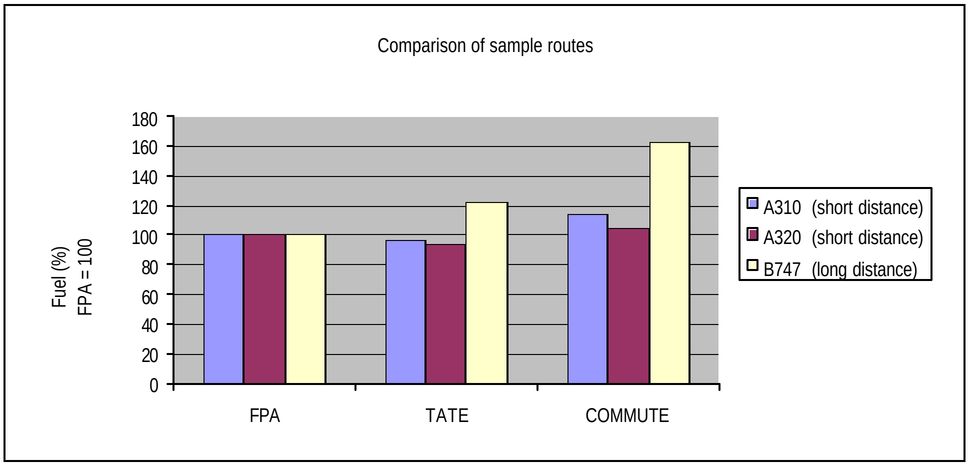
Table 11.10 and Figure 11.2 depict deviations in the calculations. Similarly to the above results, COMMUTE overestimates fuel consumption and emissions in comparison to FPA and also to TATE data.

However, because of the above mentioned different model framework conditions, the overestimation of fuel consumption and emissions through the COMMUTE air transport model seem credible.

Table 11.10 Fuel consumption of three aircraft types for sample routes

Aircraft type	Fuel consumption as a percentage of FPA		
	FPA	TATE	COMMUTE
A310 (short distance)	100	96	115
A320 (short distance)	100	94	105
B747 (long distance)	100	122	163

Figure 11.2 Deviations in calculation of fuel consumption (FPA/TATE/COMMUTE)



Comparison of emission factors - COMMUTE/ICAO/DLR

To validate the emission factors defined in COMMUTE/MEET, they have been compared with the respective factors from ICAO and DLR sources for a sample of four aircraft types.

Table 11.11 shows the comparison results for fuel consumption of aircraft types B737, B757, A310 and A320 respectively.

Table 11.11 Fuel consumption factors for different aircraft from different sources

	B737			B757			A310			A320		
	COMMUTE	DLR	ICAO	COMMUTE	DLR	ICAO	COMMUTE	DLR	ICAO	COMMUTE	DLR	ICAO
	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km
Taxi out	30933		26264	39900		38050	44772		39576	25620		23668
Take off	54515	39513	48572	83700	63287	81460	93895	82855	96522	52965	38697	50793
Climb	25447	20011	42716	44242	30806	70928	36038	42481	84740	20285	22959	44347
Climb out	12521	7343	-	20406	10603	-	18085	14138	-	9709	7239	-
Cruise	4184	3661	-	8040	5369	-	8254	6554	-	4533	3423	-
Descent	3740	2436	-	5595	3327	-	6750	4149	-	3251	2024	-
Approach	3184	2087	8255	5388	2676	13893	6470	3407	15246	2878	1812	8212
Taxi in	30933	-	26264	39900	-	38050	44772	-	39576	25620	-	23668

The figures above show similar fuel consumption distributions for all four sample aircraft. COMMUTE tends to overestimate in comparison to available DLR data. In relation to ICAO figures, COMMUTE data are higher for operating conditions Taxi-In, Take-Off and Taxi-Out while they are lower for Climb and Approach.

Conclusions

The comparison of the air transport model described above has shown that the COMMUTE model generally overestimates fuel consumption and pollutant emissions in comparison to other studies and available models. The overestimation can be explained by two main reasons. Firstly, it is a question of emission factors and secondly, it is a question of different fleet compositions used in different studies. As for emission factors, there is ongoing research to which the emission factors developed by MEET and applied by COMMUTE will provide useful input.

However, because of the above mentioned differences in emission factors and model framework conditions, the overestimation of fuel consumption and emissions through the COMMUTE air transport model seem credible.

11.1.4 Waterborne emissions and consumption

The aim of the comparison was to verify the individual calculations within the COMMUTE tool and to compare the results with a case from another study. Differences would be expected to occur owing to differing simplifications in the two models. The differences should however be small or have satisfactory explanations.

The comparison of the COMMUTE tool module for waterborne transportation has been undertaken on an actual case model previously used for environmental impact assessments in the Oresund region (Miljokonsekvensbeskrivning for Oresundsforbindelsen, SVEDAB, Malmo, 1992). The model system consists of 18 links and 14 nodes, six of which are actual ports while the rest are branching points for the virtual sea lanes.

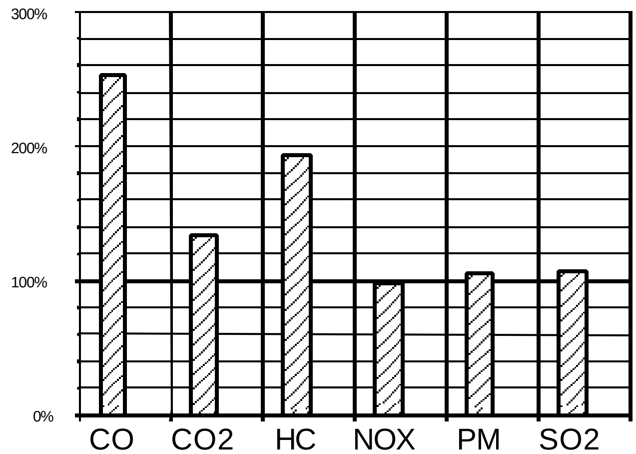
The available traffic figures came from detailed knowledge of ferry lines down to individual ships and more generalised data on all other traffic. The latter includes size distribution in Gross Tonnage that varies for the different routes.

The comparison process turned up a few errors both in the identification of output values and in the default values used by the tool. After the correction of these errors the COMMUTE tool was shown to give comparable results to the method previously used for the Oresund case.

Figure 11.3 shows how the emission totals of the COMMUTE tool compared with the totals of the Oresund case. In Figure 11.3, 100 percent indicates an exact match between the two methods.

The two methods give comparable results for CO_2, NOx, particulates and SO_2. The COMMUTE tool calculates relatively much higher emissions of CO and HC. This is almost entirely due to differences in the default emission factors. The calculations from 1992 used emission data from a small number of emission measurements while the emission factors from MEET, as used by COMMUTE, are based on a much larger sample and should therefore be more accurate.

Figure 11.3 Differences in emissions between comparison case and COMMUTE tool



11.1.5 Safety model

The COMMUTE safety model is defined for the estimation of the amount of traffic fatalities. Traffic exposure is the input data.

The purpose of the comparison was to analyse the reliability of the safety model by comparing the COMMUTE safety model results to other studies, where the relation between exposure and traffic fatalities have been analysed.

All these kind of studies are however based on the same kind of data as the safety model: the best available data of traffic exposure and traffic fatalities in certain districts. The main question is whether a relationship between traffic exposure and traffic fatalities had been found in a time period in a traffic district can be applied elsewhere.

There are no major studies which have been based on an empirically analysed relationship between traffic exposure and traffic safety. Increased traffic exposure can only occur by making changes to the link geometry or traffic system. The only relevant comparison reference material is, therefore, traffic safety statistics.

Air and waterborne traffic

The nature of air and waterborne accidents makes the comparison very difficult. Accidents are rare but disastrous. For example, in 1985-1994 there were only six reported fatal passenger ferry accidents in European waters, but these accounted for 1408 fatalities. The exposure/fatality relation (=risk) is based on the exposure and accident history of all European waters and it is obvious, that when comparing COMMUTE safety estimations and real accident data history, we will have large variations. For example:

?? in the United Kingdom in 1986, the real data has 0 fatalities, COMMUTE estimation (single risk model): 22.8 fatalities,

?? in the UK in 1987, the real data has 189 fatalities (The 'Herald of Free Enterprise' accident), COMMUTE estimation (single risk model) 22.8 fatalities.

These kind of variations cannot be considered as a weakness of the model but the final users of the model should be informed of the nature of the estimation reliability.

Rail traffic

Rail traffic accidents are more common than air and waterborne accidents, but the relatively large fatality numbers of catastrophic accidents makes reliable estimation difficult. Certain link or rail traffic regions inside a country does not necessarily reflect the overall risk for the remainder of the country. If we consider countries as a whole we can see subsequent variations in rail traffic risk in Table 11.12 below.

Table 11.12 Rail traffic risk 1991-1994 (risk of death/ 100 million train-kilometres)

Country	1991	1992	1993	1994	Variation
United Kingdom	0.0107	0.0055	0.0024	0.0047	446%
Germany	0.0079	0.0098	0.0071	0.0048	204%
France	0.0121	0.0090	0.0088	0.0041	295%

Road traffic

Road traffic accidents represent the most prevalent accident type. Some national links and road traffic areas in Finland have been compared with the COMMUTE assessment output of 1996 in Figure 11.4. The comparison has been made by vehicle type (Ped = pedestrians and bicycles; Mop = mopeds and motorcycles; Car = passenger cars; Lor = lorries). Buses have not been illustrated, because there were no bus fatalities in 1996 and because the accident history is also very good. The COMMUTE assessment output is near zero.

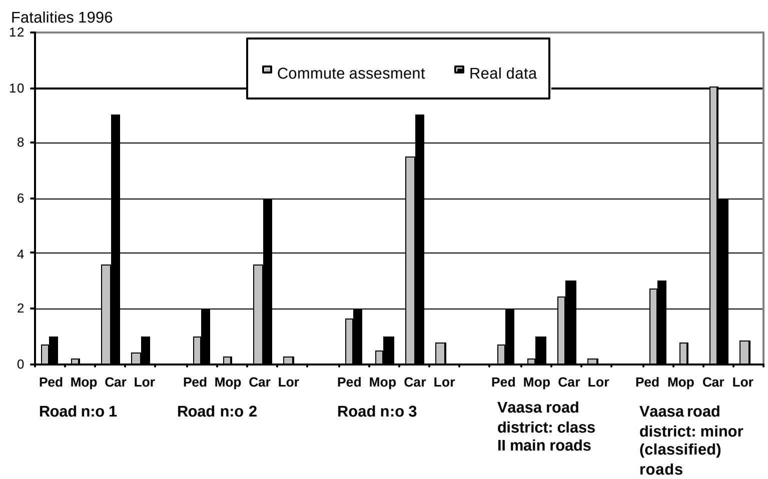
It should be noted that COMMUTE assessment is based on the national statistics and those main Roads 1 to 3 represent only 1-3% of the Finnish total road traffic exposure each. The Finnish road network consists of nine administrative road districts, Vaasa road district being one of them. All the class II main roads in the Vaasa road district represent only 0.7 % of the Finnish total traffic exposure, and all minor roads in Vaasa district represent 2.9 % of the national total.

The COMMUTE safety assessment method includes the separation of three road classes: motorways, urban roads and non-urban roads. The Finnish Roads 1 and 3 are classified partly as motorways and partly as non-urban roads, but all other roads and road areas are classified as non-urban roads.

The amount of fatalities from the observed data are slightly higher on major non-urban roads, but smaller in minor non-urban roads compared to the COMMUTE assessment (see Figure 11.4). An increase in the number of road classes could make the assessment more accurate, but data availability and non-uniformity prevent this.

However, the example in Figure 11.4 covers only one year (1996), and yearly variations affects the result. For example, the average passenger car fatalities in years 1993-1996 were: Road 1: 4,8 fatalities, Road 2: 5 fatalities, Road 3: 7,8 fatalities. These figures are higher than those for Road 1 and Road 2 than the data for 1996 alone.

Figure 11.4 Real and estimated (COMMUTE single risk model) fatalities for selected roads and road districts in Finland in 1996



11.2 Pilot Strategic Environmental Assessment of the TEN-T Proposals

The main demonstration of the application of COMMUTE tool involved the cooperative strategic environmental assessment of plans for the whole Trans-European Transport Network (TEN-T). The Commission wanted to carry out a pilot SEA of the TEN-T to assess its impact on the transport system and on emission levels. The project had two aims. First, to provide an initial attempt at quantifying the impacts of the TEN-T, in terms of travel patterns, energy consumption, emissions and transport safety. Second, to demonstrate the feasibility of certain methods, including the extent to which the approach used in the pilot would be suitable for a full SEA of the TEN-T.

When setting up the project the Commission wanted to draw on its latest research and to bring together researchers from different disciplines. A new consortium was formed, within the structure of the EU Fourth Framework research programme, to carry out the work. This consortium involved four existing research projects, SCENARIOS, STREAMS, MEET and COMMUTE.

The pilot SEA constituted a rigorous and large-scale demonstration of the COMMUTE tool. The multi modal network used for the exercise consisted of approximately:

?? 7000 links for road
?? 1300 links for air transport
?? 2400 links for rail
?? 2900 links for waterborne transport

For the pilot SEA, only part of the SEA processes included in the COMMUTE Framework for SEA needed to be considered. The wider issues surrounding the development of the TEN-T were not relevant to this study, where the emphasis was on impact assessment. The approach used in the pilot SEA was to undertake an impact assessment of the TEN-T by comparing transport scenarios, forecasting travel patterns, and focussing on the emissions (using the COMMUTE software) generated by these alternative scenarios.

11.2.1 COMMUTE tool in pilot SEA

Because of constraints on the timing of the pilot SEA project, it was necessary to prepare an intermediate version of the COMMUTE tool which embodied the main parts of the impact assessment methods. However not all modules of the full final version of COMMUTE tool were included in this interim version. The following main differences in functionality between the intermediate and full version of the tool occurred (there were also other minor differences, for example that the impact of road gradients was not considered):

?? safety assessment was limited to the single risk method
?? cold start and evaporative emissions for road transport were calculated outside the COMMUTE model using approximate correction factors
?? no noise assessment was included - noise was not part of the Commission's pilot SEA requirements
?? only one 'generic' aircraft type was used

11.2.2 STREAMS/COMMUTE Interface

The combination of the STREAMS and COMMUTE methodologies for the pilot SEA project brought a requirement to find a consistent and manageable approach for the exchange of data between these two main elements of the project. The fundamental interface was between the output of the STREAMS transport model which in turn forms the input to the COMMUTE/pilot SEA methodology for determining energy, emissions and safety levels.

Agreement was required between the two projects regarding the categorisation and definitions of the transport data transferred to COMMUTE. For example, there are different categories within each mode of transport in the two projects. The task was therefore to reconcile the two and determine a set of definitions which were consistent with the two projects, and this was achieved.

A number of modifications were required to the STREAMS model in order to allow the COMMUTE methodology to be successfully applied for pilot SEA. This principally affected the form of the model output, and the processing of output outside the modelling environment.

11.2.3 Scenarios tested

In the context of the SEA work, a transport scenario defines the main inputs needed for the STREAMS transport model forecasts. The policy scenarios determine the changes in transport costs and prices for each mode between 1994 and 2010. They are made up of three policy phases:

?? ***Liberalisation***: relating to the current policy trends (the '**reference**' situation).

?? ***Harmonisation***: concerning the impact of the **Common Transport Policy (CTP)**, principally in terms of harmonisation including the internalisation of externalities.

?? ***TEN-T Infrastructure and Policy***: relating to the promotion of intermodality, interconnectivity and interoperability for the TEN-T. The policy changes are only introduced in tests which have the TEN-T in the forecast year network.

A number of possible options were considered before arriving at the following tests combining the reference, CTP and TEN-T policy and infrastructure components defined above:

1 Base year - 1994
2 No TEN-T for reference scenario 2010
3 No TEN-T for CTP 2010
4 All TEN-T policy and infrastructure for CTP 2010
5 Rail only TEN-T policy and rail infrastructure for CTP 2010

Each of the future year tests therefore contain some combination of the three policy phases (liberalisation, harmonisation and TEN-T policy and infrastructure) as shown in Table 11.13 below.

Table 11.13 Components of the SEA tests

Options to be tested	Reference (liberalisation)	CTP (harmonisation)	TEN policy and infrastructure
1. Base year – 1994			
2. 'Reference Scenario' No TEN-T for reference scenario 2010	X		
3. 'CTP Only' No TEN-T for CTP test 2010	X	X	
4. 'All TEN-T CTP' All TEN-T for CTP test 2010	X	X	X
5. 'Rail TEN-T CTP' Rail only for CTP test 2010	X	X	X (rail only)

11.2.4 Results

The main results of the pilot SEA exercise are summarised in this section, from the full report prepared jointly by the STREAMS and COMMUTE projects. These include the transport model outputs from STREAMS, as well as the COMMUTE software tool outputs. The full results are presented in the STREAMS/COMMUTE Pilot SEA Deliverable 4.

The key findings of the transport and emission forecasts are shown in Figures 11.5 and 11.6 and Tables 11.14 to 11.18 inclusive.

Tables 11.14 and 11.15 show the annual percentage changes in person-kilometres and tonne-kilometres by mode from 1994 to 2010 for each scenario, while Tables 11.16 and 11.17 show the percentage changes between each of the scenarios and the 2010 'Reference Scenario'.

Figure 11.5 shows the change in vehicle-kilometres, energy and emissions for each test relative to 1994; while Figure 11.6 shows changes for three tests relative to the 2010 'Reference Scenario'. Table 11.18 shows total vehicle emissions (in thousands of tonnes) and energy consumption (TJ) for the various scenarios.

Table 11.19 at the end of this chapter illustrates the key findings of the safety forecasts, showing the percentage changes in road, rail, waterborne and air fatalities between each of the scenarios and the 2010 'Reference Scenario'.

In addition to these Tables and Figures Annex 1 of this report presents some examples of thematic maps produced by using the MapInfo GIS. These maps provide an overview about the possibilities of a detailed spatial analysis of traffic and emission data as they were produced in the Pilot Strategic Environmental Assessment of the TEN-T.

Taking the transport impacts first, in the 2010 'Reference Scenario' there is an increase in overall passenger travel demand compared to the base for all modes except slow modes and freight rail, driven partly by the falling cost of travel relative to incomes.

Moving to the impact of the policies, the effect of the 'CTP Only' compared to the 'Reference Scenario' was:

?? a significant overall reduction in passenger and freight travel, more so for freight
?? rising rail demand and falling car, truck, air and water use
?? a reduction in road network congestion
?? the 'CTP Only' scenario therefore succeeds in reducing road and air travel and boosting rail.

Then, introducing all the TEN-T infrastructure and related policies led to:

?? increased overall passenger and freight travel demand relative to the 'CTP Only' scenario (although it is still lower than in the 'Reference Scenario' for passengers)
?? a significant effect on mode split as rail (particularly high speed rail) travel increases compared to the 'CTP Only' scenario and road travel falls further
?? further reduction in road network congestion
?? the TEN-T infrastructure and related policies scenario therefore strengthens the effects of the CTP.

By introducing only rail TEN-T infrastructure but with related TEN-T policies on intermodality, interoperability and connections to ports, rail's gains are increased, although at the cost of a significant increase in road congestion.

It is also significant that the most important factor in encouraging freight mode shift to rail is the expanded rail network. The effects of this are large, with or without the road TEN-T.

The key findings of the emission forecasts using the COMMUTE tool, by mode, are:

For road: Tighter road vehicle emission standards and improved technology outweigh the growth in road travel, such that all emissions except CO_2 fall in all four tests compared to the base year. The differences between tests are relatively small illustrating the dominance of changes in non-traffic factors. The tests do not include the impact of the car manufacturers' voluntary agreement on CO_2, hence they may overestimate the increase in CO_2 emissions;

For rail: Between 1994 and 2010 all non CO_2 emissions fall, reflecting technical change and a shift from diesel to electric power. For the tests, the changes in emissions mirror the changes in train-kilometres;

For air: All emissions rise in all tests relative to the base year and there are some differences between tests reflecting the changes in the amount of passenger air travel. Hence emissions are closely correlated with the level of air travel (unlike the case for cars). Although there are technological improvements in aircraft technology the key effect appears to be a growth in shorter distance air travel between the base and forecast years; as relatively more fuel is used in the take-off, climb and climb-out phases of the flight compared with cruising, this has a disproportionate impact;

For water: All emissions rise for each test relative to the base year. The IMO limits on exhaust emissions for new engines are not expected to result in any large changes before 2010, because of the slow turnover of the fleet. Hence emissions are closely correlated with the level of waterborne freight

Table 11.18 summarises the emissions results by showing aggregated figures for all road, rail, water and air modes. Overall, because emissions from road travel are so dominant for certain emissions such as CO, aggregate emissions for these pollutants follow the changes in road emissions. The main conclusions by emission are:

For CO_2: Tonnes of CO_2 rise between 1994 and the 2010 'Reference Scenario', but the 'CTP Only' and both TEN-T scenarios reduce CO_2 compared to the reference;

For CO and HC: These emissions derive mainly from road vehicles. The 2010 'Reference Scenario' emissions are lower than 1994, and the alternative tests show further reductions. The 'Rail TEN-T CTP' test shows the greatest reductions since the road TEN-T is not implemented;

For SO_2: 2010 'Reference Scenario' emissions are higher than 1994 and the alternative tests reduce these levels. Emissions of SO_2 are considered only for the non-road modes;

For NOx and PM: The emission levels in 1994 were largely dominated by the road modes. There are substantial reductions in 2010 arising from the reductions in the road modes which more than compensate for increases in other modes. The percentage contribution from the road modes in 2010 is greatly reduced and there is a dramatic growth in emissions from waterborne travel.

The key findings of the safety forecasts using the COMMUTE tool, by mode, are:

For road: The All-TEN CTP scenario seems to affect traffic safety most positively. The Rail TEN-T CTP scenario also has positive effects, but the CTP only scenario seems to have a negative affect on traffic safety.

For rail: The risk level increases at a faster rate than for road traffic but, from the STREAMS output, the traffic growth for the rail modes is relatively strong and especially so with the new rail infrastructure. Each test shows a predicted clear increase of fatalities compared to the 'Reference Scenario'.

For both air and water: The All TEN-T CTP test shows the highest decrease in traffic fatalities of all the four tests.

11.2.5 Conclusions

The pilot SEA study broke new ground in the analysis of EU transport demand and emissions outputs. It formed a rigorous, highly demanding and large scale demonstration of the capabilities of the COMMUTE software tool and illustrated its interfacing with a complex transport model.

The pilot SEA approach provided the first comprehensive, quantified forecasts of the impacts of TEN-T policies and infrastructure, on travel demand and emissions, at the EU level. Hence the first objective of the project was met. The results were sufficiently robust for the study team to conclude that the method would be suitable for a more detailed SEA of the TEN-T.

A more detailed study could take various forms. One option would be to undertake a more sophisticated study with the same scope. More ambitiously, the scope could be widened to, say, include other traffic related impacts such as noise, and by establishing a link to the EEA study on spatial impacts. The range of the assessment could also be widened to include a full cost benefit / multi criteria analysis

Table 11.14: Annual percentage change in EU15 passenger travel (person-kilometres) compared to the 1994 Base

Mode	'Reference Scenario'	'CTP Only'	'All TEN-T CTP'	'Rail TEN-T CTP'
Air	6.34	5.84	5.80	5.82
Car	0.88	0.30	0.14	0.09
Coach	1.04	1.05	1.17	1.02
Rail	2.93	4.48	7.26	7.39
Slow	-0.51	-0.32	-0.34	-0.34
ALL	1.34	1.01	1.20	1.18

Table 11.15: Annual percentage change in EU15 freight demand (tonne-kilometres) compared to the 1994 Base

Mode	'Reference Scenario'	'CTP only'	'All TEN-T CTP'	'Rail TEN-T CTP'
Truck	2.92	2.19	2.59	2.54
Rail	-1.39	-0.67	5.00	5.15
IWW	0.09	0.16	0.75	0.69
Ship	2.33	1.42	2.33	2.15
Air	1.57	1.04	-0.74	-0.74
ALL	2.20	1.52	2.64	2.57

Table 11.16: Percentage change in EU15 passenger travel (person-kilometres) compared to the 2010 'Reference Scenario'

Mode	'CTP Only'	'All TEN-T CTP'	'Rail TEN-T CTP'
Air	-7.3	-7.9	-7.6
Car	-8.8	-11.2	-11.9
Coach	0.2	2.1	-0.3
Rail	27.1	93.4	97.3
Slow	3.1	2.8	2.8
ALL	-5.1	-2.2	-2.5

Table 11.17: Percentage change in EU15 freight demand (tonne-kilometres) compared to the 2010 'Reference Scenario'

Mode	'CTP only'	'All TEN-T CTP'	'Rail TEN-T CTP'
Truck	-10.9	-5.1	-5.8
Rail	12.4	173.2	179.6
IWW	1.1	11	10.1
Ship	-13.2	0.1	-2.7
Air	-8.1	-30.8	-30.8
ALL	-10.1	7.0	5.8

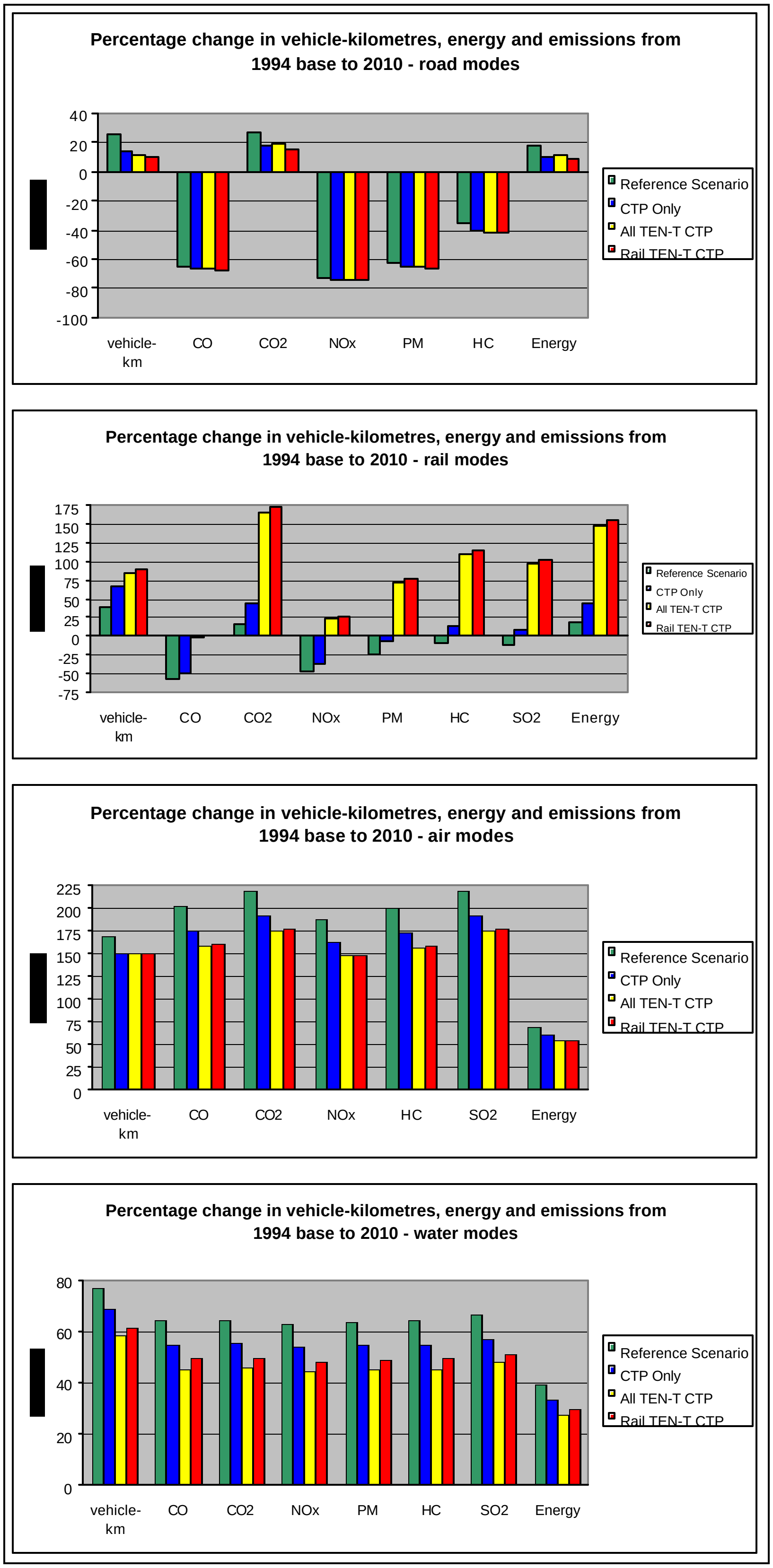


Figure 11.5: Percentage change in vehicle-kilometres and emissions relative to 1994 Base

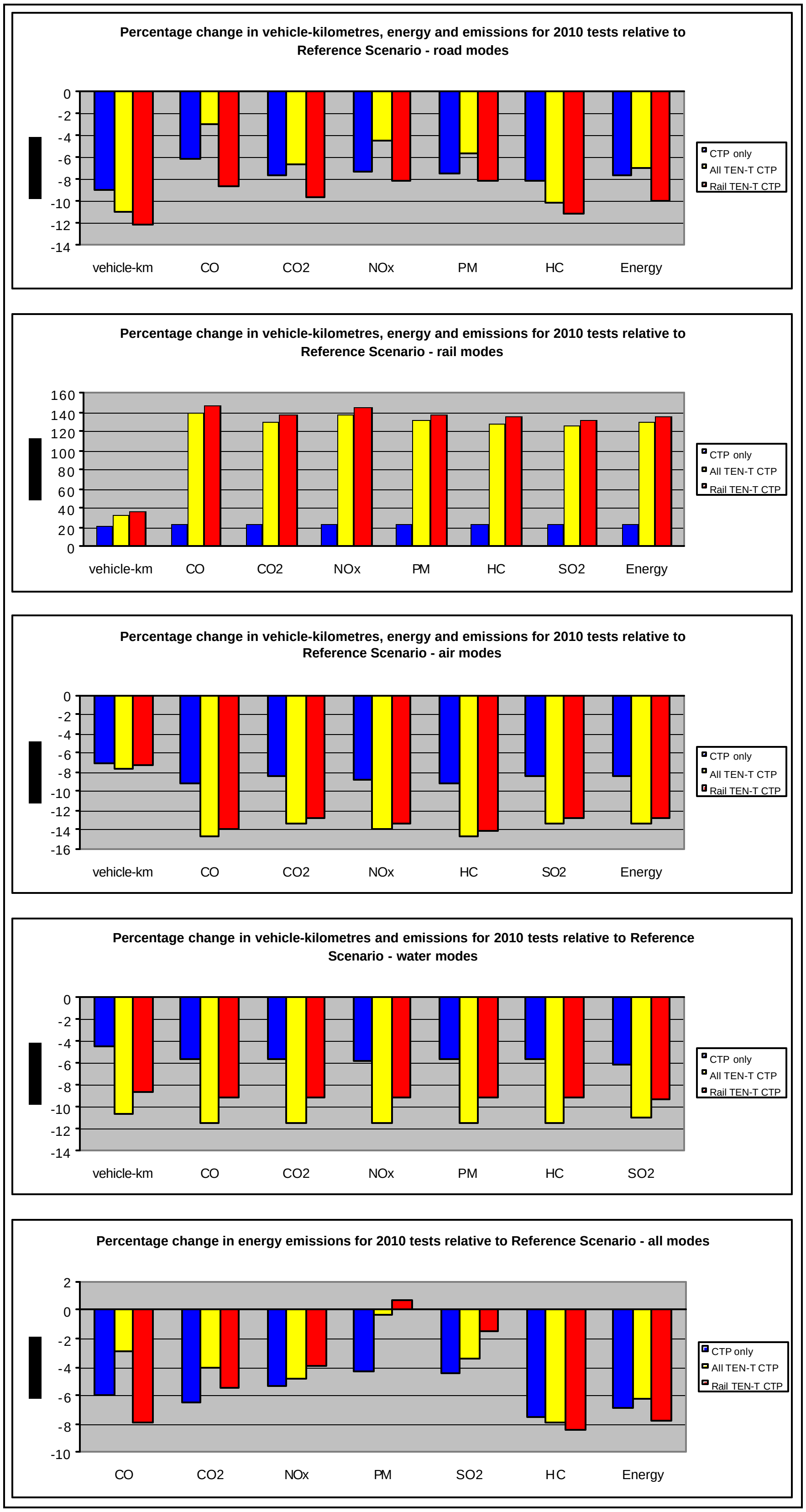


Figure 11.6: Percentage change in vehicle-kilometres and emissions relative to 2010 Reference Scenario

Table 11.18: Comparison of total vehicle emissions ('000 tonnes) and energy consumption (TJ) by scenario for 1994 and 2010 SEA tests

Emission type	Base Year	'2010 Reference'	'CTP Only'	'All TEN-T CTP'	'Rail TEN-T CTP'	Contributing modes
CO	15,864	5,998	5,639	5,820	5,522	All modes
CO_2	636,446	895,395	837,606	859,469	846,130	All modes
NOx	6,012	4,271	4,041	4,065	4,104	All modes
PM	131	96	92	96	97	Road, rail & water
SO_2	758	1,216	1,162	1,174	1,198	Air, rail & water
HC	3,307	2,274	2,103	2,094	2,082	All modes
Energy	8,366,627	11,496,241	10,704,798	10,775,115	10,603,741	All modes
Percentage change		**from 1994**	**from Reference**	**from Reference**	**from Reference**	
CO		-62	-6	-3	-8	All modes
CO_2		41	-6	-4	-6	All modes
Nox		-29	-5	-5	-4	All modes
PM		-26	-4	0	1	Road, rail & water
SO_2		60	-4	-3	-1	Air, rail & water
HC		-31	-8	-8	-8	All modes
Energy		37	-7	-6	-8	All modes

Table 11.19: Percentage change in EU15 road, rail, air and waterborne fatalities compared to the 2010 'Reference Scenario'

Mode	'CTP only'	'All TEN-T CTP'	'Rail TEN-T CTP'
Road	9.9	-26.6	-12.8
Rail	22.2	27.6	31.5
Air	-9.0	-12.6	-12.1
Water	-5.9	-24.5	-14.7

12. CONCLUSIONS

COMMUTE was a research project that ran from 1996 to 1999 within the Strategic Research strand of the European Commission Fourth Framework Transport RTD programme. It addressed the definition of a methodology for strategic assessment of the environmental impacts of transport policy options. The methodology was intended to be primarily applicable to policy decision-making at the European level and to cover road, rail, air and waterborne transport modes. Computer software that embodies the main aspects of the methodology was developed and demonstrated within the COMMUTE project.

The main COMMUTE project objectives were as follows:

?? To define a methodology for strategic assessment of the environmental impacts of transport policy options, to support transport policy decision making at the European level.

?? To develop computer software that embodied the main aspects of the methodology and could present the results to users.

?? To demonstrate the use of the main aspects of the methodology and the computer software; in particular in the context of a pilot strategic environmental assessment of the impacts on energy consumption, primary pollutant emissions and safety of plans for the Trans-European Transport Network (TEN-T).

COMMUTE successfully achieved its objectives, delivering two main end products:

?? The **COMMUTE methodology for SEA** of transport policies, plans and programmes (PPPs), comprising:

  – A Framework for SEA covering the basic methodological requirements for SEA of multi-modal transport actions and guidelines on integration methods
  – Detailed impact assessment methods for some core impacts such as air pollution emissions, energy consumption, noise and safety

?? The **COMMUTE software tool** allowing assessment of air pollution emissions, energy consumption, noise and safety impacts.

The COMMUTE software tool was validated against other comparable data sets, and was demonstrated, particularly through the pilot SEA of plans for the Trans-European Transport Network (TEN-T). This formed a rigorous, highly demanding and large scale demonstration of the capabilities of the COMMUTE software tool and illustrated its interfacing with a complex transport model. The results were sufficiently robust for the study team to conclude that the method would be suitable for a more detailed SEA of the TEN-T.

From the work carried out in COMMUTE, it is clear, however, that further work would be beneficial in a number of areas, including:

- further methodological research to integrate sustainability target setting within the overall SEA process and to improve monitoring and follow-up after implementation of policies, plans and programmes;
- further development of the COMMUTE tool to bring in additional impact areas (particularly through the GIS interface) and accommodate other stages of the overall SEA process;
- further data collection to improve strengthen input and default data across all modes and therefore improve the accuracy and robustness of the COMMUTE tool outputs.

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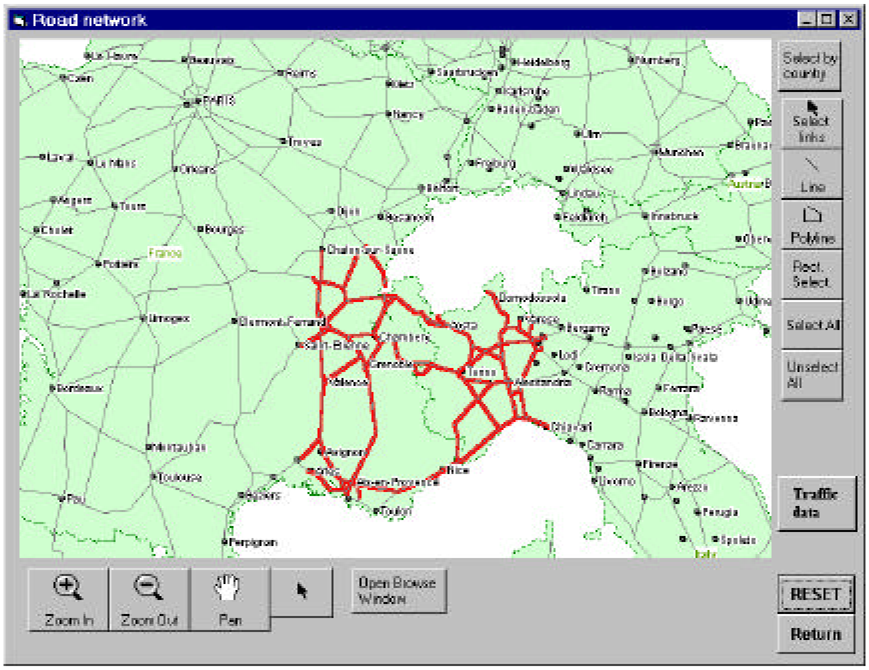
ANNEX 1 – EXAMPLES OF MAPS PRODUCED WITH COMMUTE TOOL AND MAPINFO

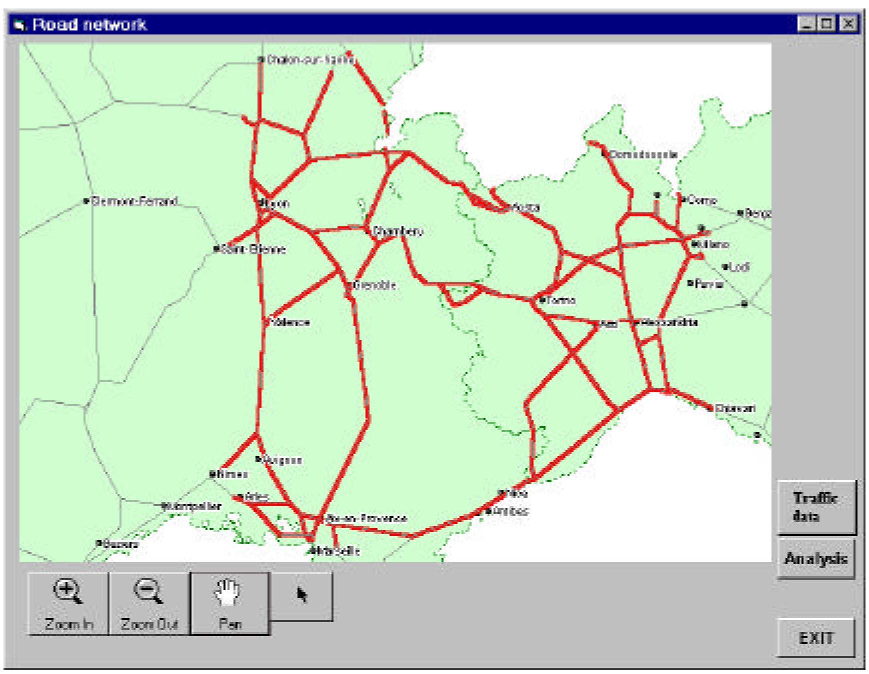
COMMUTE tool : interface with MapInfo GIS

Selection of a part of road network for calculation

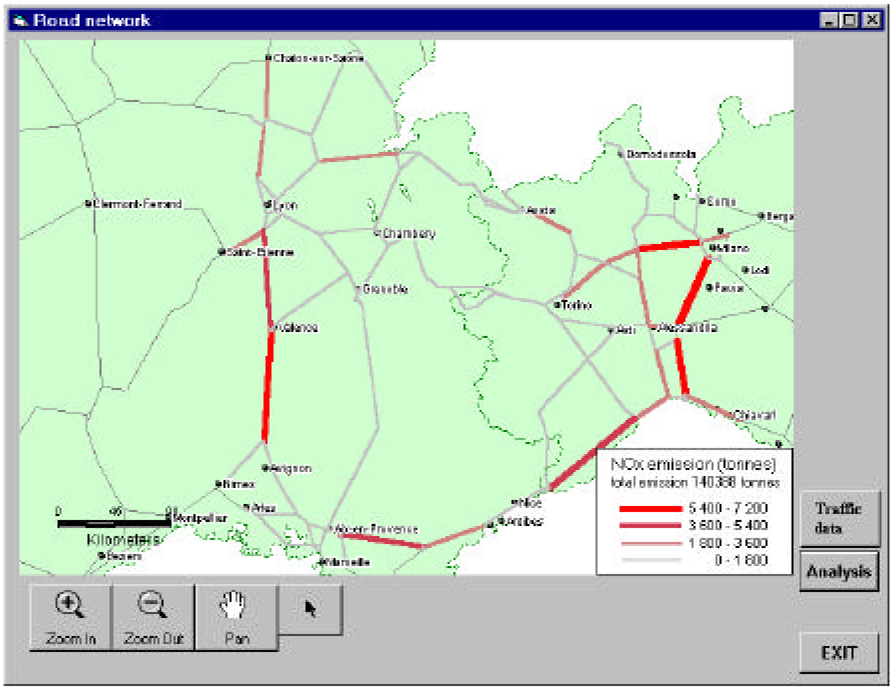


Analysis of the results after calculation

The analysis will be displayed on the selected links

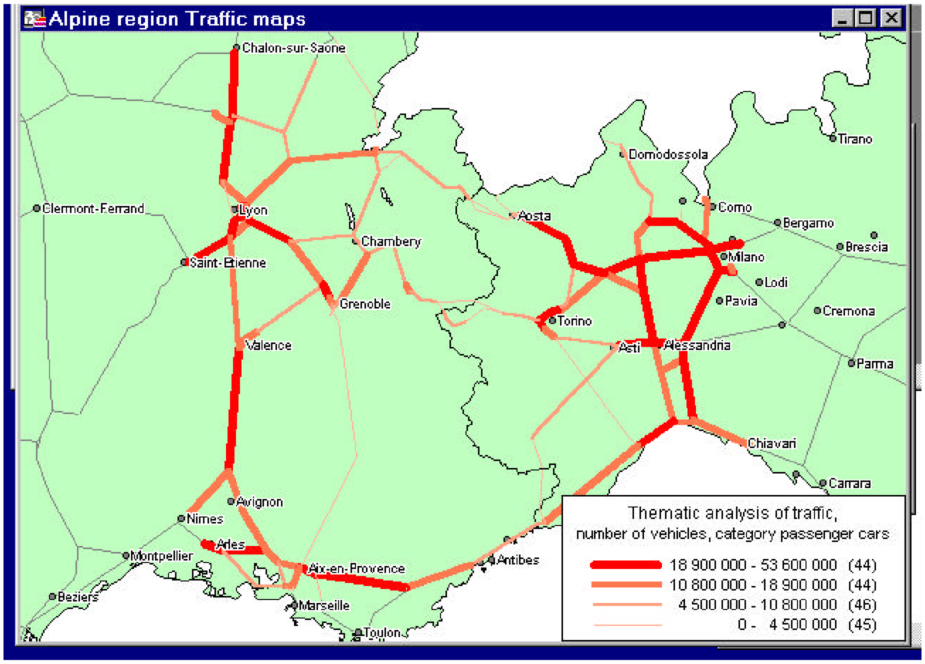


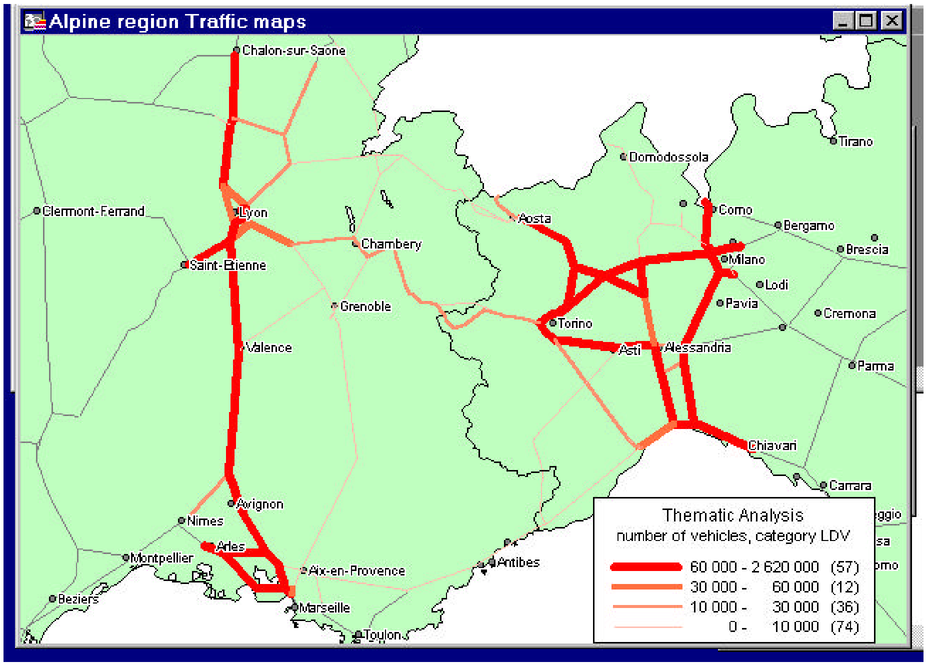
Example of thematic analysis of NOx emissions on selected links

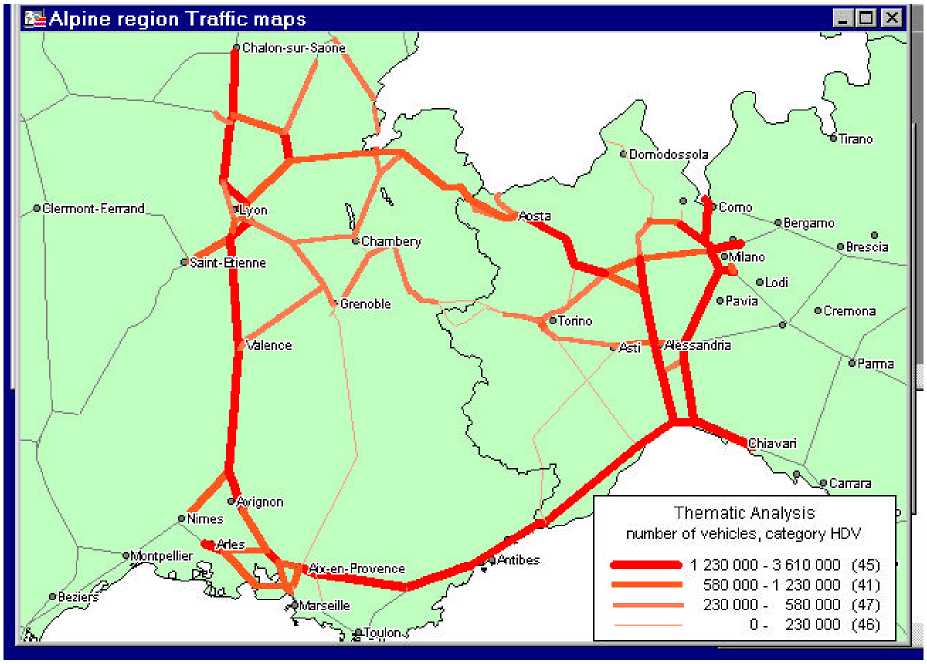


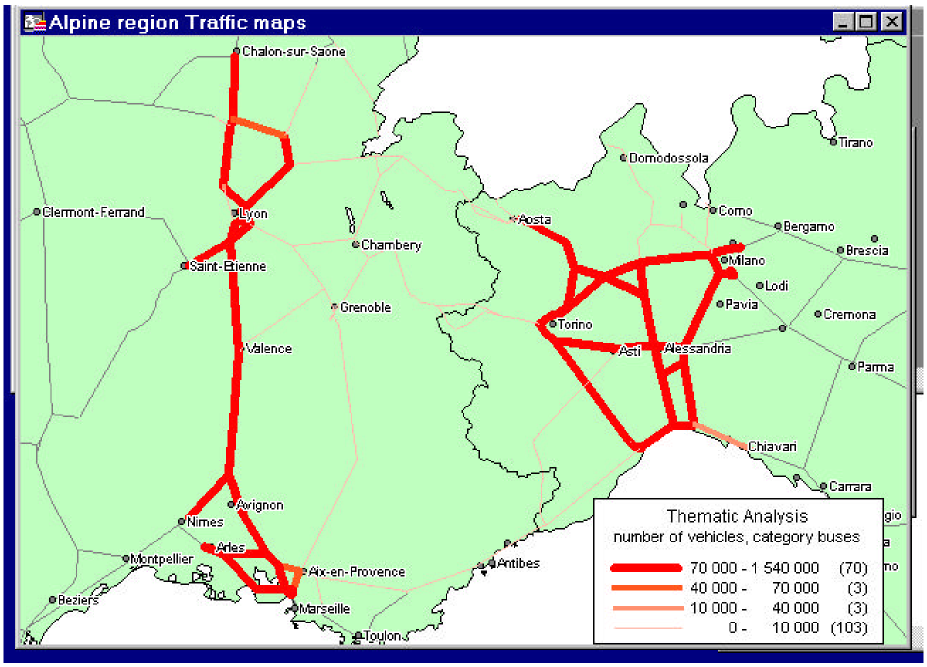
Display of traffic data on MapInfo maps (STREAMS data, non urban links, 1995)

*These maps are built with MapInfo tools, by crossing the road network map with the tables of vehicles*km stored in COMMUTE Access database. A map is done for each category of vehicles provided in STREAMS data. The analysed value is the number of vehicles, that is vkm/length.*



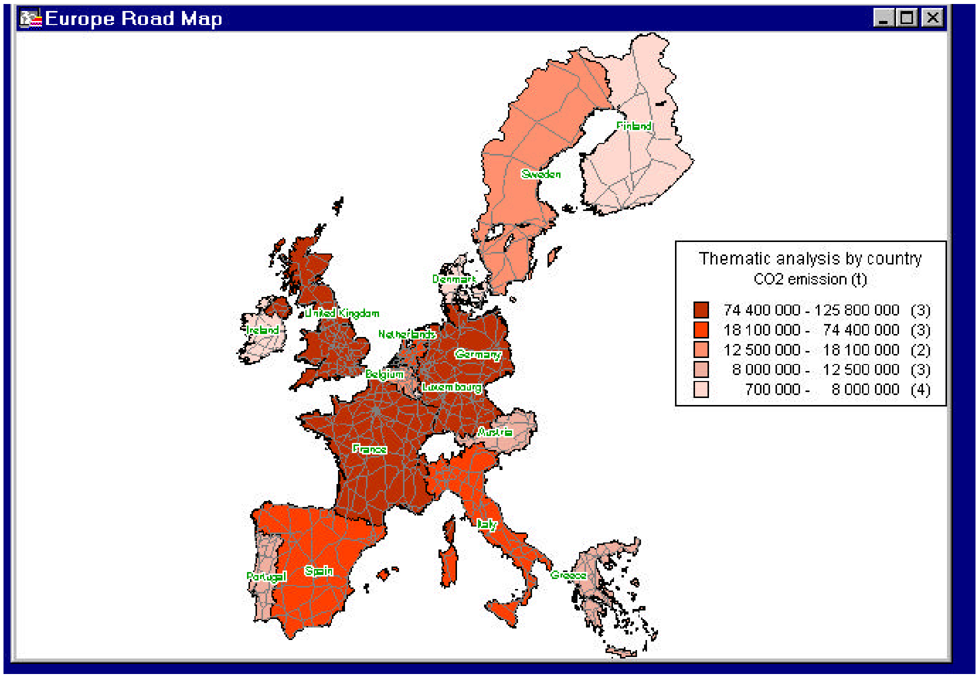



Alpine region Traffic maps
Chalon-sur-Saone
Tirano
Domodossola
Clermont-Ferrand
Lyon
Aosta
Como
Bergamo
Brescia
Chambery
Milano
Saint-Etienne
Lodi
Grenoble
Pavia
Cremona
Torino
Valence
Asti
Alessandria
Parma
Chiavari
Carrara
Avignon
Nimes
Arles
Montpellier
Aix-en-Provence
Antibes
Beziers
Marseille
Toulon
Thematic Analysis
number of vehicles, category HDV
1 230 000 - 3 610 000 (45)
580 000 - 1 230 000 (41)
230 000 - 580 000 (47)
0 - 230 000 (46)

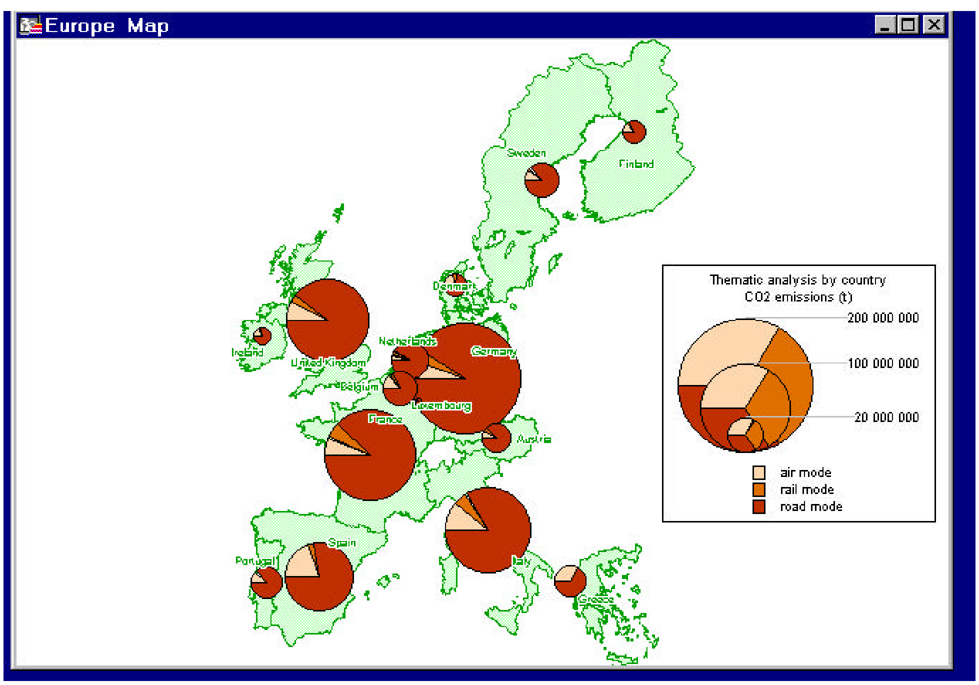

Alpine region Traffic maps
Chalon-sur-Saone
Tirano
Domodossola
Clermont-Ferrand
Lyon
Aosta
Como
Bergamo
Brescia
Chambery
Milano
Saint-Etienne
Lodi
Grenoble
Pavia
Cremona
Torino
Valence
Asti
Alessandria
Parma
Chiavari
Carrara
Avignon
Nimes
Arles
Montpellier
Aix-en-Provence
Antibes
Beziers
Marseille
Toulon
Thematic Analysis
number of vehicles, category buses
70 000 - 1 540 000 (70)
40 000 - 70 000 (3)
10 000 - 40 000 (3)
0 - 10 000 (103)

Examples of thematic maps after calculation of emission, on all fifteen countries

These examples have been built with MapInfo tools by crossing a map of Europe countries with tables of CO_2 emissions by country created in COMMUTE Access database.



Example of thematic map of CO_2 emission, for air, rail and road modes



ANNEX 2 – PUBLICATION LIST

- ?? Workshop on Technology Strategy for Transport Energy Environment, 4-5th May 1998, Brussels, jointly organised by DGXII and DGVII
- ?? 6th International Symposium Highway and Urban Pollution, 18-20th May, Baveno, Italy
- ?? TENASSESS-Seminar: Towards Coordinated Action in Research and Policy, 25th June, Vienna
- ?? European Transport Conference, 14-18th September 1998, Loughbourogh University, United Kingdom
- ?? NTF Conference, 20th - 21st August 1998, Reykjavik, Iceland
- ?? 19th ARRB International Conference, 9th December 1998, Sydney, Australia
- ?? 2nd European Road Research Conference, 7th June 1999, Brussels, Belgium