STEPs

Scenarios for the Transport system and Energy supply and their Potential Effects

Deliverable No. 4.1

Modelling suite for scenarios simulations

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Executive summary

The overall objective of the STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects) project is twofold:

- to develop scenarios for the transport system and energy supply for the future which will be compared and assessed. To translate these scenarios into policy recommendations and to identify needs for future research.
- to communicate and discuss the results and findings of the project by holding Sounding Board Forums and Clustering Meetings.

Work Package 4 "Scenarios impacts" is the core of the research activities planned to fulfil the first objective of the STEPs project. According to the Description of Work, WP4 objective is "running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios". The impacts addressed include: transport demand, energy consumption, greenhouse and polluting emissions, regional development, local accessibility and others, and are considered both at European and local/regional level. Therefore, the activities within WP 4 start from the outcome of previous work packages and consist essentially in implementing the scenarios variables in the models in a coordinating way and then simulate the scenarios. The outcome of the models will constitute an input for developing indicators for scenarios assessment.

Several modelling tools are used in the STEPs project in order to simulate the scenarios on transport and energy supply and to provide quantitative responses on the effects of such scenarios on various aspects. The models can be classified into two main categories:

- models operating at the European level: the ASTRA System Dynamics Model, the SASI socio-economic model and the POLES energy model;
- models operating at the urban/regional level: Dortmund model, South Tyrol Meplan model, Helsinki Meplan model, Brussels IRIS model, Edinburgh SPM model.

All models have already been established and applied at their scales, they will work as independent models and will be loosely linked in terms of input and output exchange and comparisons.

The modelling strategy for simulating the scenarios will consist of using the models in a sort of nested structure, whereas European based models will be run first and provide overall forecasts concerning elements like the vehicles fleet, the fuel price, the car-ownership, etc. Urban/regional models will be run afterwards, assuming the exogenous inputs at the local level (e.g. land use) as well as the forecasts of the European based models. This will allow a consistent definition of scenarios across all models, even if they work as independent tools.

This is the first deliverable produced in WP4 and introduces the features of the different tools which will be used for the modelling exercise.

Chapter 1 Introduction

1.1 Background

The STEPS (Scenarios for the Transport System and Energy Supply and their Potential Effects) project has the following overall objective: "*to develop, compare and assess possible scenarios for the transport system and energy supply of the future taking into account the state of the art of relevant research within and outside the 6th RTD Framework and such criteria as the autonomy and security of energy supply, effects on the environment and economic, technical and industrial viability including the impact of potential cost internalisation and the interactions between transport and land use."*

To achieve this overall objective, STEPs has chosen a two-way approach: research, assessment, modelling and forecasting activities on the one hand and co-ordination, comparison and dissemination activities on the other. These two lines of activities are closely related and constantly influencing each other.

Work Package 4 "Scenarios impacts" is the core of the research activities of the project. In fact, these activities are organised into workpackages: WP1: assessing recent and ongoing developments in alternatives to fossil fuels and related needs in energy supply chains, analysing national policies on transport and energy; WP2: identifying relevant trends in transport and energy use and their interaction with the socio-economic, political and technological environment; WP3: defining three scenarios of the transport and energy supply system for the future; WP4: running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios; WP5: assessing and comparing the impacts forecast for the three scenarios with respect to criteria and indicators which reflect the overall goal of transport and energy sustainability; WP6: drawing conclusions and to give policy recommendations and define needs for future research.

The WP4 objective is "running a set of inter-linked models at the European and urban-regional level to produce forecasts of relevant impacts of the scenarios". The impacts addressed include: transport demand, energy consumption, greenhouse and polluting emissions, regional development, local accessibility and others, and are considered both at European and local/regional level. Therefore the activities within WP4 start from the outcome of previous work packages and consist essentially in implementing the scenarios variables in the models in a coordinating way and then simulate the scenarios. The outcome of the models will constitute an input for developing indicators in WP5.

This is the first deliverable produced in WP4 and introduces the features of the different tools which will be used for the modelling exercise.

1.2 Models and simulation strategy

Several modelling tools are used in the STEPs project in order to simulate the scenarios on transport and energy supply and to provide quantitative responses on the effects of such scenarios on various respect. The models can be classified into two main categories:

- models operating at the European level: the ASTRA System Dynamics Model, the SASI socio-economic model and the POLES energy model;
- models operating at the urban/regional level: Dortmund model, South Tyrol Meplan model, Helsinki Meplan model, Brussels IRIS model, Edinburgh SPM model.

All models are already established and applied at their scale, they will work as independent models and will be loosely linked in terms of input and output exchange and comparisons. For instance, forecasts concerning fuel price produced by the POLES energy model would be used as input for the ASTRA and SASI model, whereas the ASTRA transport demand development would be an input for POLES and so on.

The design of the STEPs models linkages is a critical task in WP4. There are a few important issues in this exercise:

- models have to be based on a coherent set of assumptions: as an example, GDP or population growth, either endogenously modelled (like in ASTRA) or exogenously assumed (like in other models) have to be reasonably similar in the different tools;
- the interconnection among the models has to be exploited as much as possible: this is easier when an output of model A can be used as input data for model B, but it is more complex (and not always feasible) when model B already incorporates some of the features of model A and thus an alignment between the two models would require the revision of the calibration parameters (or the module design) of B;
- models do have limitations and, on the other side, transport and energy supply scenarios are complex: this means that the models cannot simulate all the scenarios implications and therefore it is important to bear in mind that STEPs scenarios impact results will be at the end a collection of models output and, where needed, off-line calculations.

The modelling strategy for simulating the scenarios will consist in using the models in a sort of nested structure, where European based models will be run first and provide overall forecasts concerning elements like the vehicles fleet, the fuel price, the car-ownership, etc. Urban/regional models will be run afterwards, assuming the exogenous scenarios inputs at the local level (e.g. land use) as well as the forecasts of the European based models. This will allow a consistent definition of scenarios across models, even if they work as independent tools.

1.3 Structure of the report

This report is organised as follows. After this introduction, section 2 includes, for each modelling tool, the brief profile, the study region, the zoning system, the key exogenous inputs, the endogenous variables and outputs and the outline of the reference scenario. Section 3 addresses the use of models for simulating the scenarios and provides a sketch of how input and output will be exchanged among models.

Chapter 2 Description of the models main features

2.1 Introduction

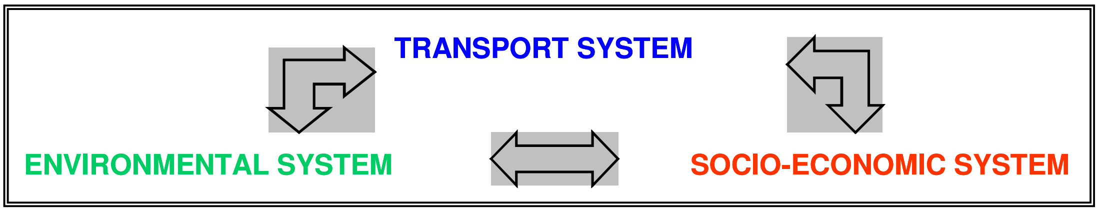
In this chapter, a description of the models is provided. As far as possible, a common framework is adopted, with some adaptation especially to take into account the different scale of European and local models.
The framework includes first a description of the spatial segmentation (for the European model) or of the region covered (for the local models). Then, a brief overview of the model is presented and the main input and output variables of the model are reported. Finally, the reference solution modelled is described.

Table 2.1 List of the models involved in STEPs project

European models	Urban/regional models
ASTRA Model	Brussels IRIS model
SASI model	Dortmund model
POLES model	Edinburgh SPM model
	Helsinki Meplan model
	South Tyrol Meplan model

Table 2.2 Overview of the ASTRA model

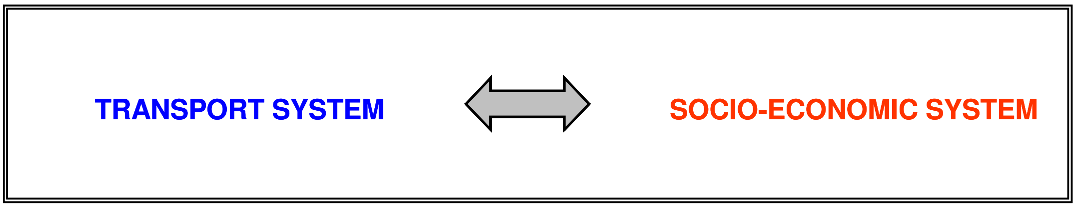
ASTRA System Dynamics Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	transport modes speed, transport cost, trip generation rates, volume-to-value ratios, load factors, vehicle occupancy factors	traffic performance, modal split, vehicle fleet size and composition
ENVIRONMENTAL SYSTEM	emission factors, unitary fuel consumptions	fuel consumption, emission levels
SOCIO-ECONOMIC SYSTEM	taxation, fertility, mortality	GDP, employment, investments, tax revenues

Table 2.3 Overview of the SASI model

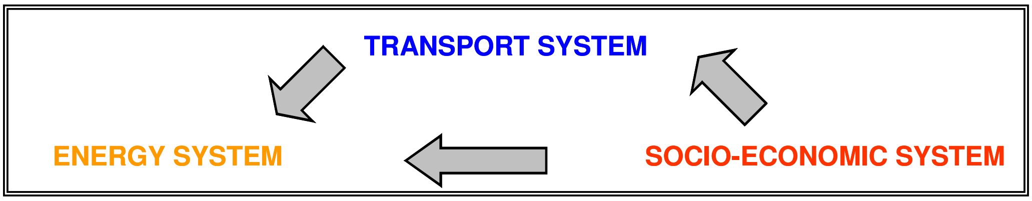
SASI Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	transport project, transport policies	regional accessibility
SOCIO-ECONOMIC SYSTEM	labour productivity, endowment, fertility, mortality, migration policies, transfer payments	accessibility, GDP, employment, population, labour force

Table 2.4 Overview of the POLES model

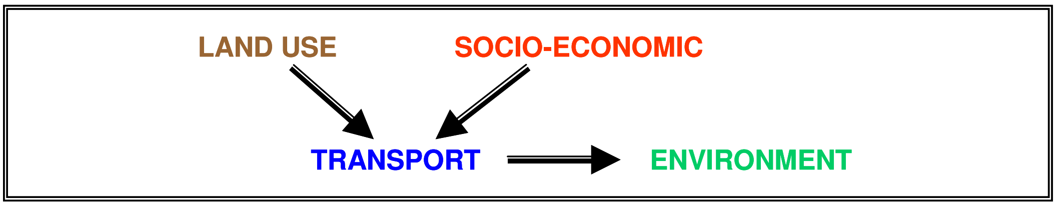
POLES Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT SYSTEM	techno-economic characterisation, fuel efficiency, emission factors, car costs	vehicle fleet size and composition, fuel consumption, emission levels
ENERGY SYSTEM	techno-economic characterisation	energy prices
SOCIO-ECONOMIC SYSTEM	GDP, population, fuel taxes, carbon taxes, subsidies for technology, emission limits	

Table 2.5 Overview of the Brussels model

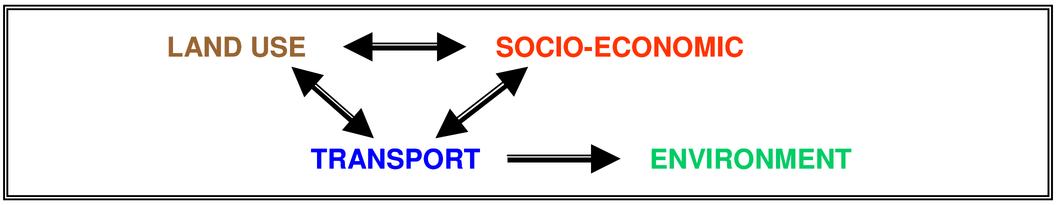
Brussels Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, car ownership	passenger-km for the public transport, vehicle-km for the private vehicles
SOCIO-ECONOMIC	employment, population	
LAND USE	location of households, jobs and commercial activities	
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, CO2 emissions

Table 2.6 Overview of the Dortmund model

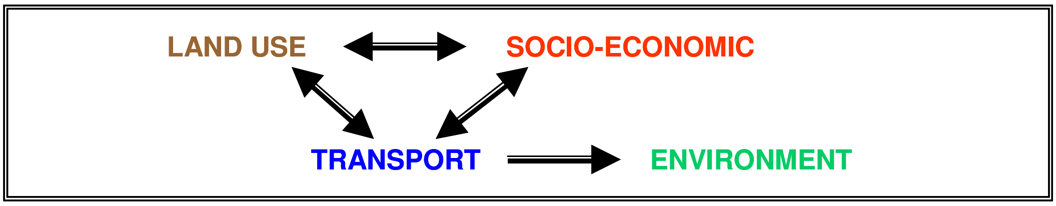
Dortmund Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport lines and services, road network projects, fuel costs and consumption, public transport fares	accessibility, trip by purpose and mode trip length, travel time car ownership
SOCIO-ECONOMIC	total regional employment by sector, total regional immigration and outmigration	zonal population, zonal employment, intraregional migration industrial relocation
LAND USE	local land use planning, local public facilities	zonal housing, zonal industrial floorspace
ENVIRONMENT	emission functions	Fuel consumption, emissions by transport, land take

Table 2.7 Overview of the Edinburgh model

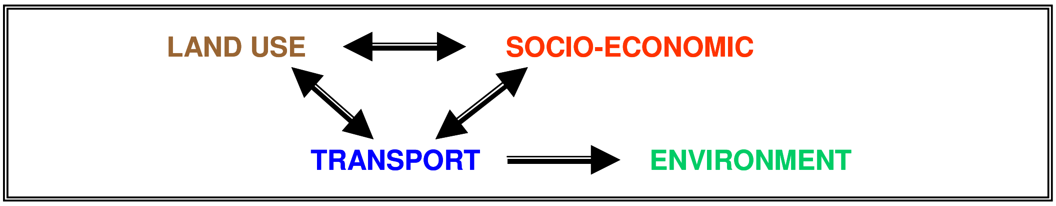
Edinburgh Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	transport costs, distances, public transport frequencies, tolls, taxes, parking costs, commute trip rate, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	average income, population, car-ownership, workplaces, employment, licence holding	
LAND USE	land use for residential, land use for commercial, land use for green space	residential location, workplace location
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption , emissions level, total accidents cost

Table 2.8 Overview of the Helsinki model

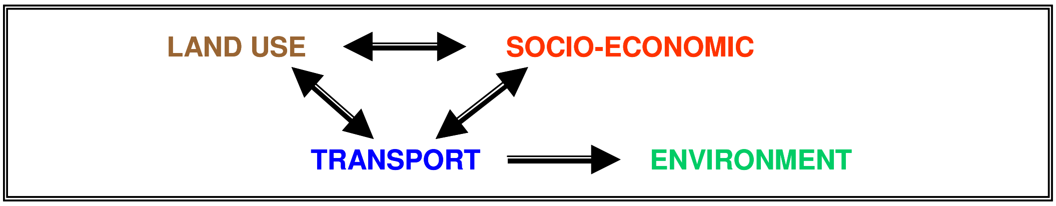
Helsinki Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	employment, population	
LAND USE	floorspace use	floorspace price, zone attractiveness
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, emissions level,

Table 2.9 Overview of the South Tyrol model

South Tyrol Model



	KEY INPUTS	MAIN OUTPUTS
TRANSPORT	public transport services, road network, transport costs, tariffs, occupancy factors	traffic performance, modal split, load on link, average speed, level of congestion
SOCIO-ECONOMIC	employment, population	
LAND USE	floorspace destination	floorspace price, zone attractiveness
ENVIRONMENT	emission functions, fuel consumption factors	Fuel consumption, emissions level,

2.2 The ASTRA model

2.2.1 The ASTRA model study region

The ASTRA model is a System Dynamics[1] model at the European scale focused on describing the linkages between transport, economy and environment. The ASTRA model covers the EU25 member states and, to complete the picture, Bulgaria, Norway, Romania and Switzerland. The model has been developed from the original version built in the ASTRA project (1997) and updated within the TIPMAC project (2002) and, recently in the LOTSE study (2004).

In ASTRA two different top-level spatial categorisations are applied in parallel in different parts of the model and if passenger or freight transport demand are considered:

- the first categorisation is based on the country level spatial differentiation and applied for all the countries covered by the model.
- the second categorisation is founded on the system of European NUTS II zones that were grouped into four functional zones according to their settlement patterns and population densities.

The 4 functional zones used at the second level are the following:

- Metropolitan Areas (MPA);
- High Density Areas (HDA);
- Medium Density Areas (MDA);
- Low Density Areas (LDA).

Furthermore functional zones are "nested" into each European country. This means that up to 4 functional zones (not every country has Metropolitan Areas) are found in every country and that those functional zones are different from country to country.

Geographical zoning and functional zoning so are integrated, as zoning system is defined by a functional zone associated with the belonging country. As the average density is very variable among countries a unique criterion could not be adopted. At the same time, a specific rule for each country would reduce the comparability of modelling results. Then it has been made a compromise. As far as possible a limited number of bounds for the different classes have been chosen. The aim was to have the four zone types in all countries and to have a well represented Medium Density Area class. However, sometimes this goal could not be achieved, for instance in new EU-member states, in Denmark, Bulgaria, Norway, Romania and Switzerland where exist only two zones or a single functional zone. The following figure shows the functional zones nested into the single countries for the 29 countries covered by the model.

[1] System Dynamics was developed during the 1960ies by J.D. Forrester. The basic concept of System Dynamics are that systems consist of a set of interacting feedback loops whose development over time can be described by means of difference equations. For more details see Forrester (1962, 1977)

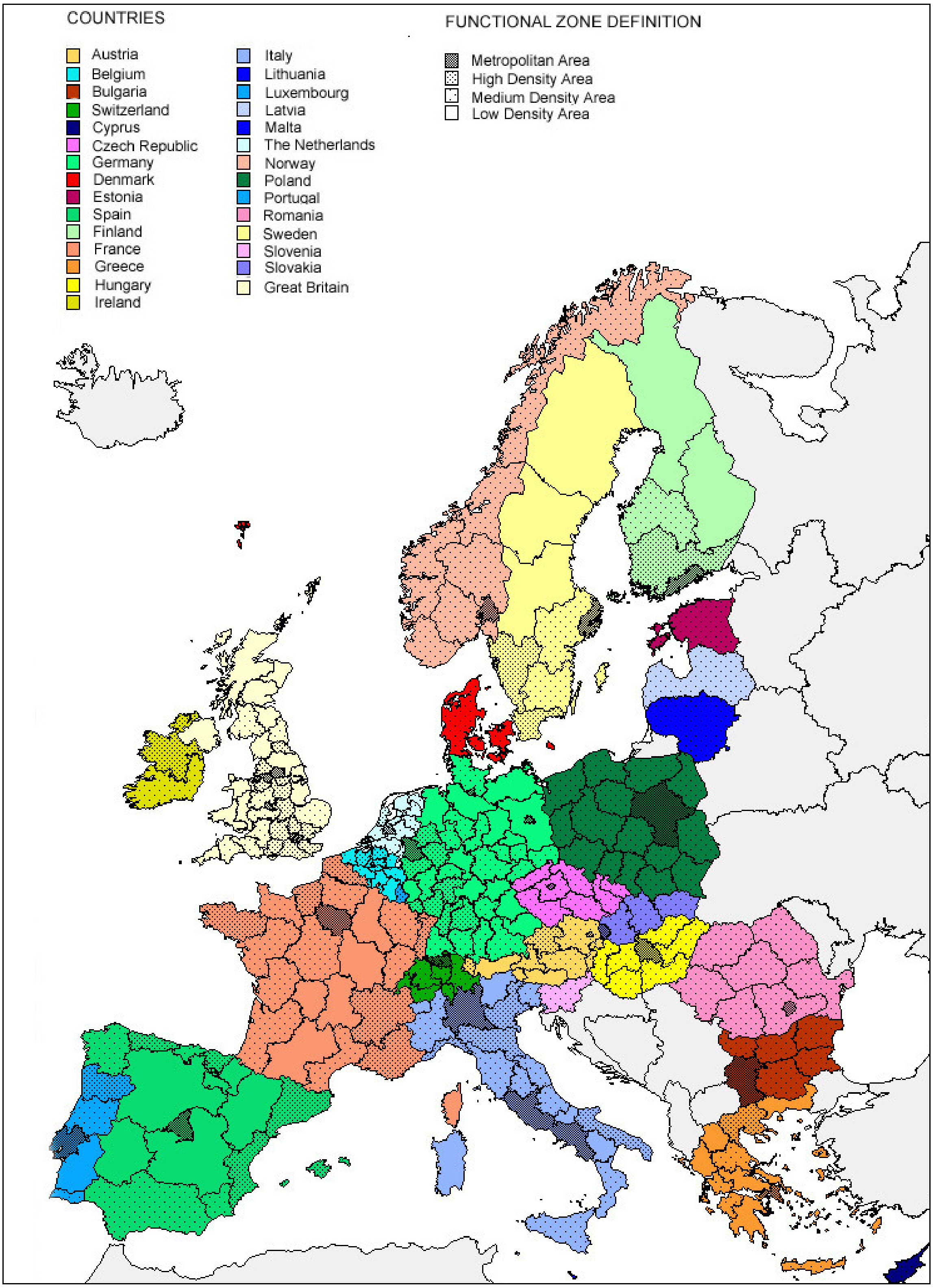


Figure 2.1 Spatial overview of ASTRA

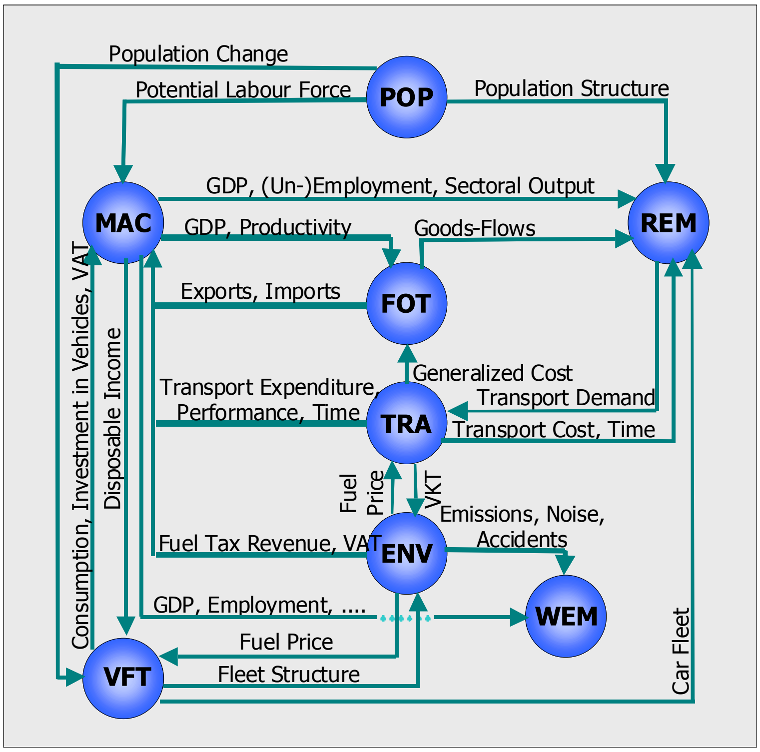
2.2.2 The ASTRA model description

The ASTRA model consists of eight main modules:

- Population Module (POP),
- Macro-economic Module (MAC),
- Regional Economic Module (REM),
- Foreign Trade Module (FOT),
- Transport Module (TRA),
- Environment Module (ENV),
- Vehicle Fleet Module (VFT) and
- Welfare Measurement Module (WEM).

Figure 2.2 shows the interrelationships between the eight ASTRA modules picturing the major output variables coming from and input variables going into the modules. Herewith an essential description of the modules is provided.

The *Population Module (POP)* provides the population development for each modelled country with one-year age cohorts. The model depends on exogenous factors like fertility rates, death rates, infant mortality rates and migration.
Five major elements constitute the *macro-economics module (MAC)*. First, the sectoral interchange model reflects the economic interactions between 25 economic sectors of the national economies by an Input-Output table structure. Second, the demand side model depicts the four major components of final demand: consumption, investments, exports-imports (which is modelled in detail in the foreign trade module) and the government consumption. Third, the supply side model has as basic element a production function of Cobb-Douglas type calculating potential output incorporating three major production factors: labour supply, capital stock and natural resources; technical progress is considered under the from of Total Factor Productivity (TFP) endogenised as depending on sectoral investments, freight transport time-savings and labour productivity changes. The fourth element of MAC consists in the employment model that is based on value-added as output from input-output table calculations and labour productivity. The fifth element describes government behaviour.



POP = Population Module
MAC = Macroeconomics Module
REM = Regional Economics Module
FOT = Foreign Trade Module
TRA = Transport Module
VFT = Vehicle Fleet Module
ENV = Environment Module
WEM = Welfare Measurement Module

Figure 2.2 The structure of the ASTRA model

The *Regional Economic Module (REM)* mainly provides the generation of freight transport volume and passenger trips. The number of passenger trips is driven by the employment situation, the car-ownership situation and the number of people belonging to different age classes. Domestic freight transport depends on output by sector that is translated into flows for the fifteen sectors, which produce goods by means of value-to-volume ratios.
In the foreign trade module (FOT) trades are mainly driven by relative productivity between modelled countries or between the modelled countries and the rest-of-the-world, GDP growth of importing country and world GDP growth as external factors to trade. Additionally the INTRA-EU trade flows depend on the development of average generalized cost of transport between each O/D country pair.

The major input to the *Transport Module (TRA)* is the link based transport demand for passenger and freight transport. Using transport costs and transport time matrices the transport module calculates the modal split based on a classical Logit function depending on generalised costs.

The *Environment module (ENV)* uses the vehicle-kilometres-travelled generated by the TRA module per mode and the information from the vehicle fleet model on the drives, car categories and emission standards to calculate the most important transport emissions - CO2, NOx and soot particles as well as fuel consumption and fuel tax revenues. Furthermore accident rates for each mode form the input to calculate the number of accidents in the European countries.

The *Vehicle Fleet Module (VFT)* calculates the vehicle fleet composition for all road modes for the EU15 countries. Vehicle fleets are differentiated into different age classes based on one-year-age cohorts and into different emission standard categories. Additionally, the car vehicle fleet is differentiated into gasoline and diesel powered cars with different cubic capacity categories.

Finally in the *Welfare Measurement Module (WEM)* major macro-economic, environmental and social indicators can be compared and analysed.

An additional module in ASTRA is an user-friendly interface, which can be used to define policy scenarios using a set of predefined variables and to read the output of the simulations – in a graphical or tabular fashion – choosing among several variables from different modules.

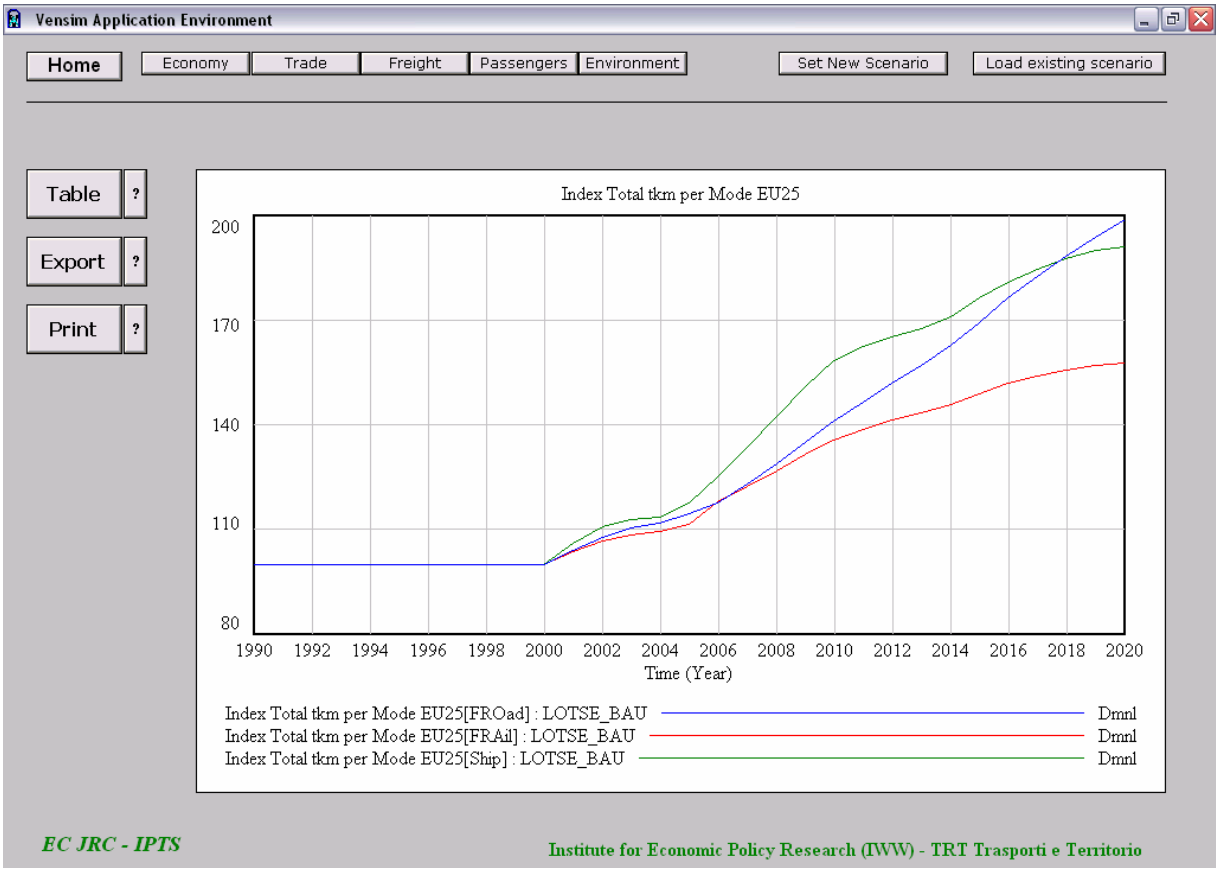


Figure 2.3 An example of results of ASTRA interface

2.2.3 Key exogenous inputs, endogenous variables and outputs

One of the main features of the ASTRA model is that all main variables describing the state and the development of various systems are endogenous. In general, main input concerns basic parameters like trip rates, transport costs, transport times, emission factors, vehicle occupancy factors, volume-to-value ratios, labour productivity, etc. Furthermore, there are additional parameters like modal constants of which value is defined during the calibration phase.

Assuming to work with a calibrated model, main variables and parameters which can be used as input are:

- Trip generation rates, volume-to-value ratios (these variables allow to change the volume of transport demand)
- transport costs under various forms – fuel price, fuel taxes, road pricing, tariffs, etc. - transport modes speed;
- emission factors, unitary fuel consumptions;
- load factors, vehicle occupancy factors.

The ASTRA model provides several outputs from the different modules. Outputs are produced per country and, where relevant, with further segmentation (e.g. mode, economic sector, etc.). Main outputs are:

- on the transport side, traffic performance (pass-km, tonnes-km), modal split, vehicle fleet size and composition;
- on the environmental side: fuel consumption, emission levels;
- on the economic side: GDP, employment, investments, tax revenues.

2.2.4 The ASTRA model reference scenario

The base scenario or Business-As-Usual (BAU) scenario for the ASTRA model is based on expected trends and consequences of already taken policies. The scenario considers the policy framework set by already taken decisions as well as European strategy documents with reference to the time horizon of year 2020. This includes:

- The accession of the ten new member states to the European Union in May 2004.
- The demographic development with a transition towards ageing societies in most European countries.
- The European White Paper on European transport policy for 2010: time to decide (CEC 2001), which defines about 60 measures to take actions to reach the four main goals expressed in the strategy:
  - Shifting the balance between modes of transport.
  - Eliminating bottlenecks.
  - Placing users at the heart of transport policy.
  - Managing the globalisation of transport.

Where appropriate the 60 measures are translated into cost and time changes for the different transport modes and are implemented in ASTRA in accordance with the TIPMAC project that developed plausible changes of these transport parameters until 2020. The implementation of the Trans-European Transport Networks according to current plans also forms part of the base scenario.[2]

GDP development is one of the most important elements of future scenarios calculated endogenously by ASTRA. In general, GDP growth of the European member states before May 2004 (EU15) is significantly lower than for the Accession Countries that acceded in May 2004 (AC). Expressed as average yearly growth rates of GDP between 2000 and 2020

[2] In detail this scenario framework is described in the TIPMAC deliverables (PONTI et al. 2002, SCHADE 2004).

the EU15 would reach a growth close to 2,2% compared with an expected growth of ACs of 3,9%.
Besides the growth of GDP the development of the population is a second relevant descriptive element of any future scenario. ASTRA includes a cohort-based population model for all the 29 countries in the model. Base data for the population structure in 1990 is taken from EUROSTAT. Birth rates, death rates and migration shape the overall development of the national populations. The age cohorts can be aggregated to different categories that influence economic and transport behaviour of the countries: children, potential labour force and retired (65 and older). Figure 2.4 shows the development of these aggregated groups for EU15 and ACs. Besides the fact that the number of retired is growing significantly in both areas the overall picture is rather different. The absolute population in ACs is declining while it is stabilising in EU15. The ageing process starts about 10 years earlier in the ACs and the number of children is reduced much more drastically in ACs than in the EU15.

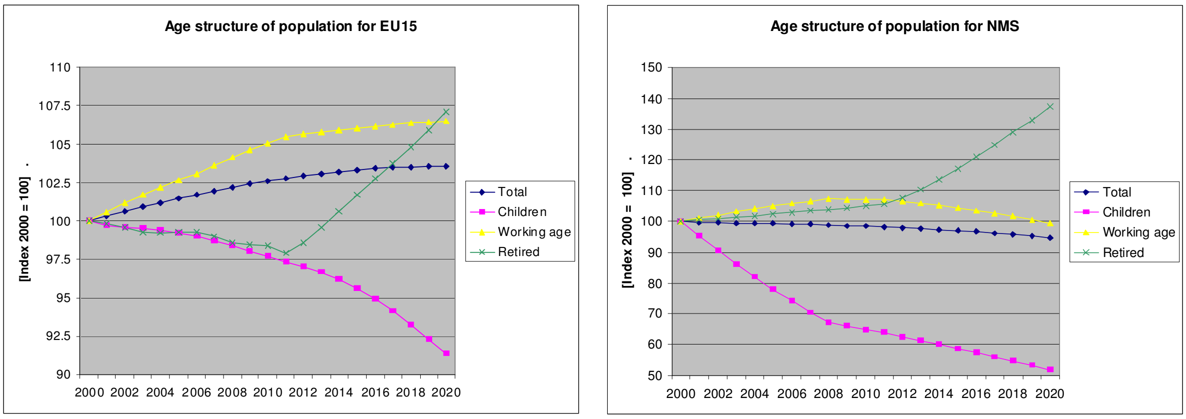
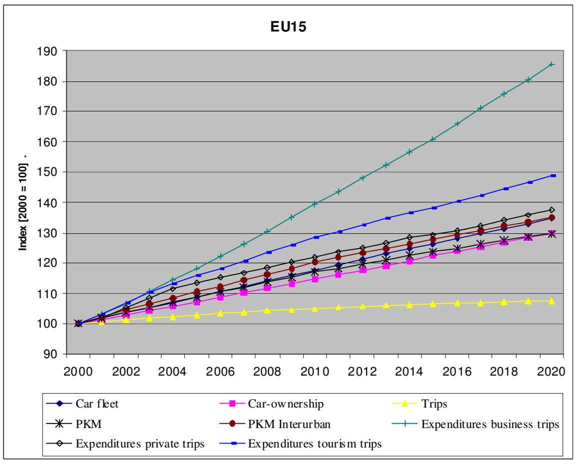


Figure 2.4 Development of population groups for EU15 and ACs in ASTRA model reference solution

Employment growth differs also significantly between EU15 and ACs. Total employment in EU15 countries increases by 9% compared with 43% for the ACs. This fits to the rule of thumb that about 1,5 to 2% of GDP growth would be needed for Western European countries to increase employment. Since, the growth of EU15 is slightly higher a very moderate growth of employment could be expected. For ACs this threshold of 2% is outranged significantly with +3,9% such that also the employment growth of 43% seems to be plausible. Nevertheless, to reach this growth from the supply side of employment it will be necessary that the activity rate of the potential labour force increases such that the number of persons belonging to the actual labour force is growing.
Looking at passenger transport the development of socio-economic variables calculated by ASTRA involves large differences between EU15 and ACs: strongest growth in EU15 can be observed for the overall expenditures for business trips (+85%), while in ACs the largest growth concerns the car-ownership (+76%) and the car fleet (+67%). The difference of population development explains the difference of the growing number of trips in EU15 associated with the still growing number of population and people in working age, while the stagnation of population in ACs leads also to a stagnation of trips. Consequently this leads to a more than 10% higher growth of pkm in the EU15 (+29%) compared to ACs (+16%) where in both cases the interurban pkm grow about 10% stronger.



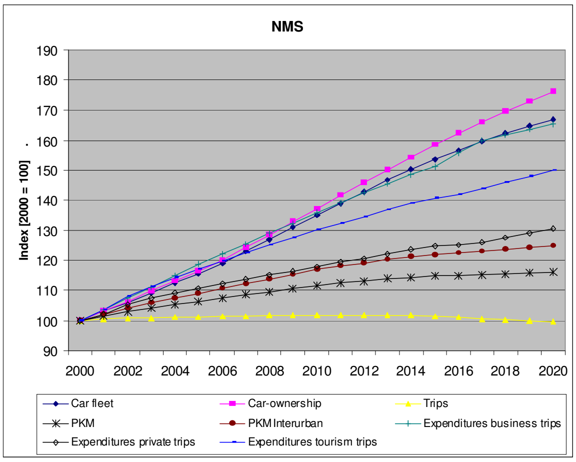


Figure 2.5 Development of passenger transport for EU15 and AC in ASTRA model reference solution

2.2.5 The ASTRA model references

ASTRA project (1997): Assessment of Transport Strategies. 4th EU RTD Framework Programme.

PONTI et al. (2002): TIPMAC project - Transport infrastructure and policy: a macroeconomic analysis for the EU, 5th EU RTD Framework Programme.

LOTSE study (2004) - Quantification of technological scenarios for long-term trends in transport. JRC – IPTS Seville

SCHADE W (2004): „ASTRA-T: Results of the TIPMAC policy scenarios". Deliverable D5 of TIPMAC (Transport infrastructure and policy: a macroeconomic analysis for the EU) project funded on behalf of the European Commission 5th RTD framework, Karlsruhe.

2.3 The SASI model

The SASI model is a recursive simulation model of socio-economic development of 1,330 regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments, in particular of the trans-European transport networks (TEN-T), and other transport policies.

2.3.1 The SASI model study region

The study area of the model are the 25 countries of the European Union plus Norway and Switzerland and the two accession countries Bulgaria and Romania and the western Balkan countries Albania, Bosnia-Herzegovina, Croatia, Macedonia and Yugoslavia. The SASI model forecasts accessibility and GDP per capita of 1,330 NUTS-3 or equivalent regions in the study area. (see Figure 2.6). These 1,330 regions are the 'internal' regions of the model. The remaining European countries, including the European part of Russia, are the 'external' regions, which are used as additional destinations when calculating accessibility indicators.

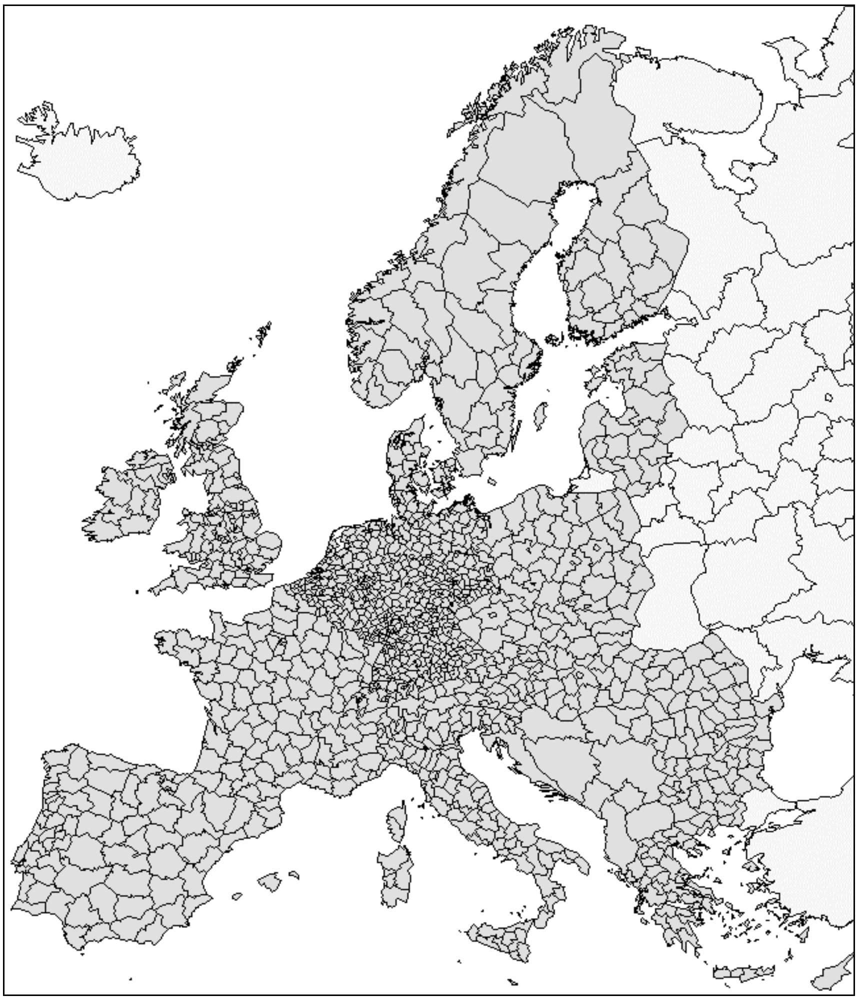


Figure 2.6 The SASI system of regions

The spatial dimension of the system of regions is established by their connection via networks. In SASI road, rail and air networks are considered. The 'strategic' road and rail networks used in SASI are subsets of the pan-European road and rail networks developed by the Institute of Spatial Planning of the University of Dortmund (IRPUD). The 'strategic' road and rail networks contain all TEN-T links according to the most recent EU planning documents (European Union, 2004) and the east European road and rail corridors by the TINA consortium (TINA Secretariat, 2002) as well as additional links selected for connectivity reasons (see Figures 2.7 and 2.8).

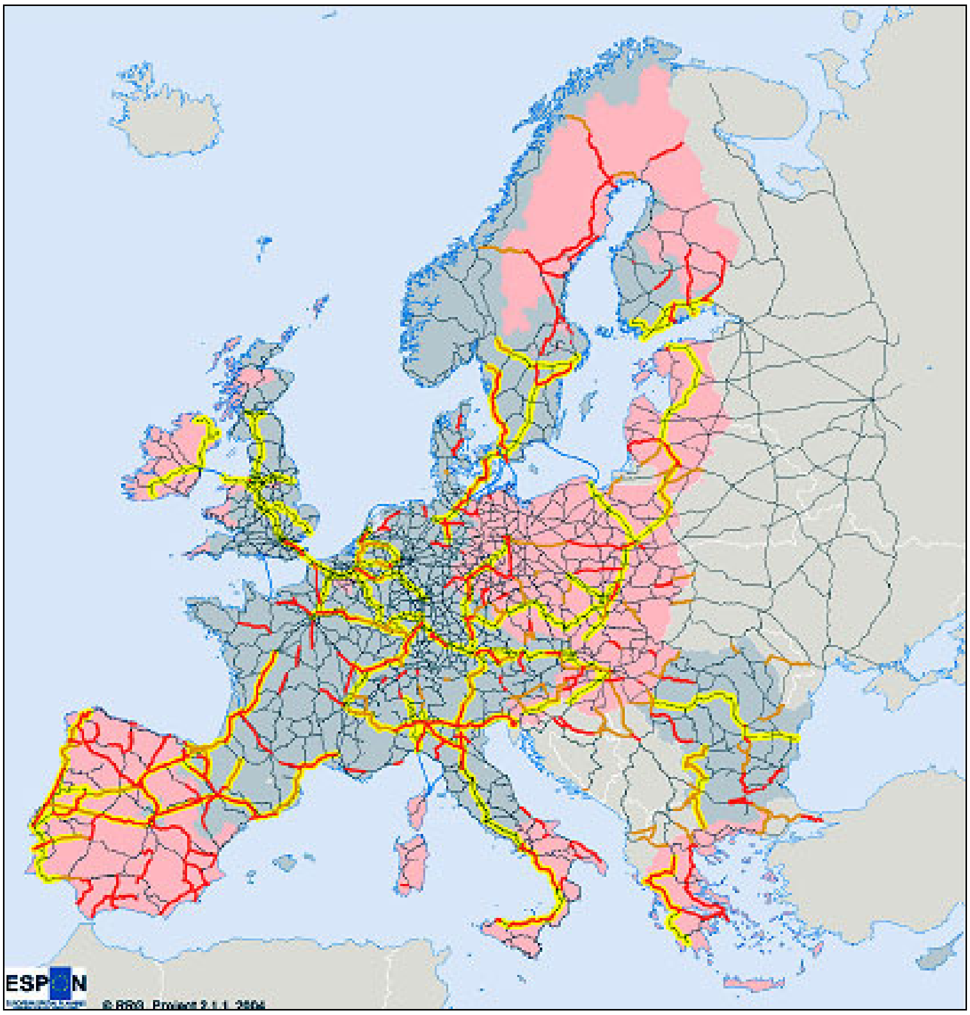


Figure 2.7 The SASI road network

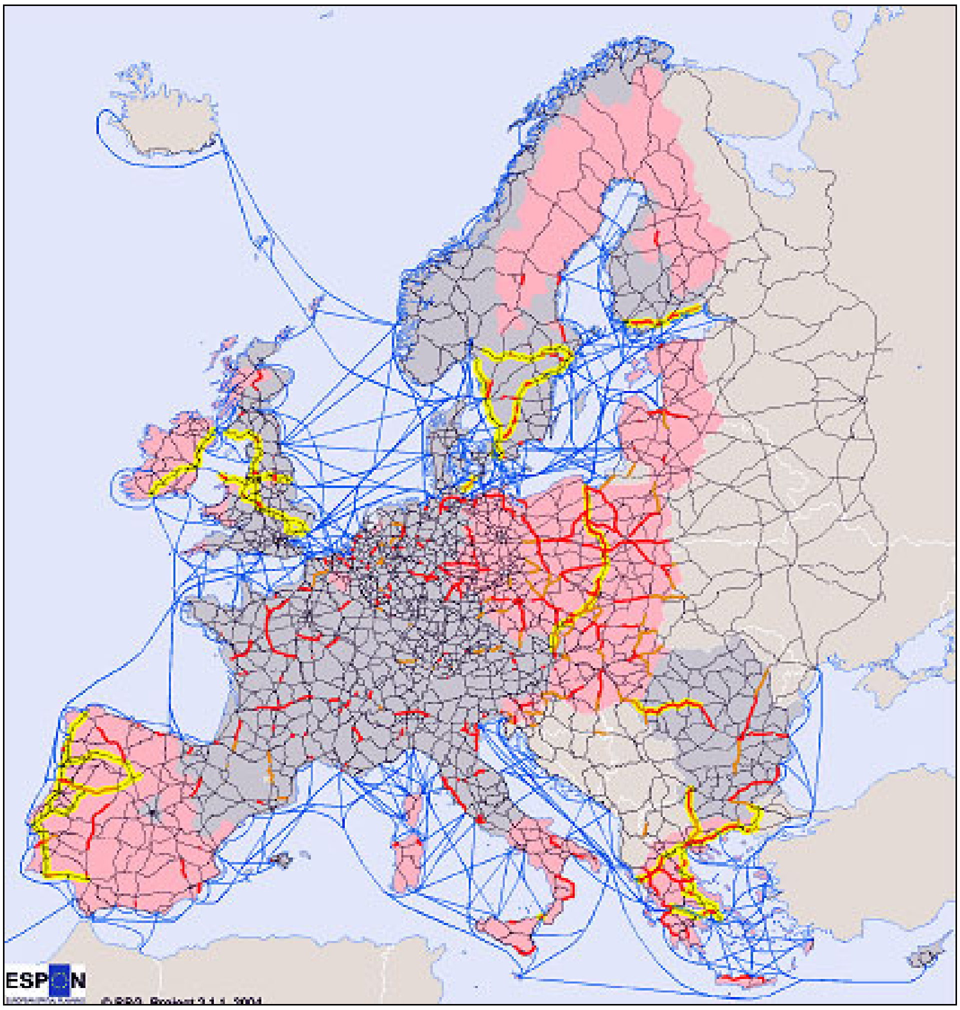


Figure 2.8 The SASI rail network

2.3.2 The SASI model description

The SASI model (Wegener and Bökemann, 1998; Bröcker et al., 2004a; 2004b) differs from other approaches to model the impacts of transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets).

The impacts of transport infrastructure investments and transport system improvements on regional production is modelled by regional production functions in which, besides non-transport regional endowment factors, sophisticated spatially disaggregate accessibility indicators are included.

The model is suited to represent spatial redistribution effects of the TEN-T within the European Union. However, although in principle possible, it does not presently model the aggregate macroeconomic multiplier effects of transport investments on the European economy as a whole. Although the model does not contain a full transport submodel, it does take account of network congestion in urbanised areas.

The model has six forecasting submodels (see Figure 2.9):

- European Developments,
- Regional Accessibility,
- Regional GDP,
- Regional Employment,
- Regional Population,
- Regional Labour Force.

In the *European Developments* submodel, assumptions about European developments are entered: future performance of the European economy as a whole, level of immigration and outmigration across Europe's borders and policy decisions on the trans-European networks. They serve as constraints to ensure that the regional forecasts of economic development and population are consistent with external developments not modelled.

The *Regional Accessibility* submodel calculates regional accessibility indicators expressing the locational advantage of each region with respect to relevant destinations in the region and in other regions as a function of travel time and travel cost to reach these destinations by the strategic road, rail and air networks.

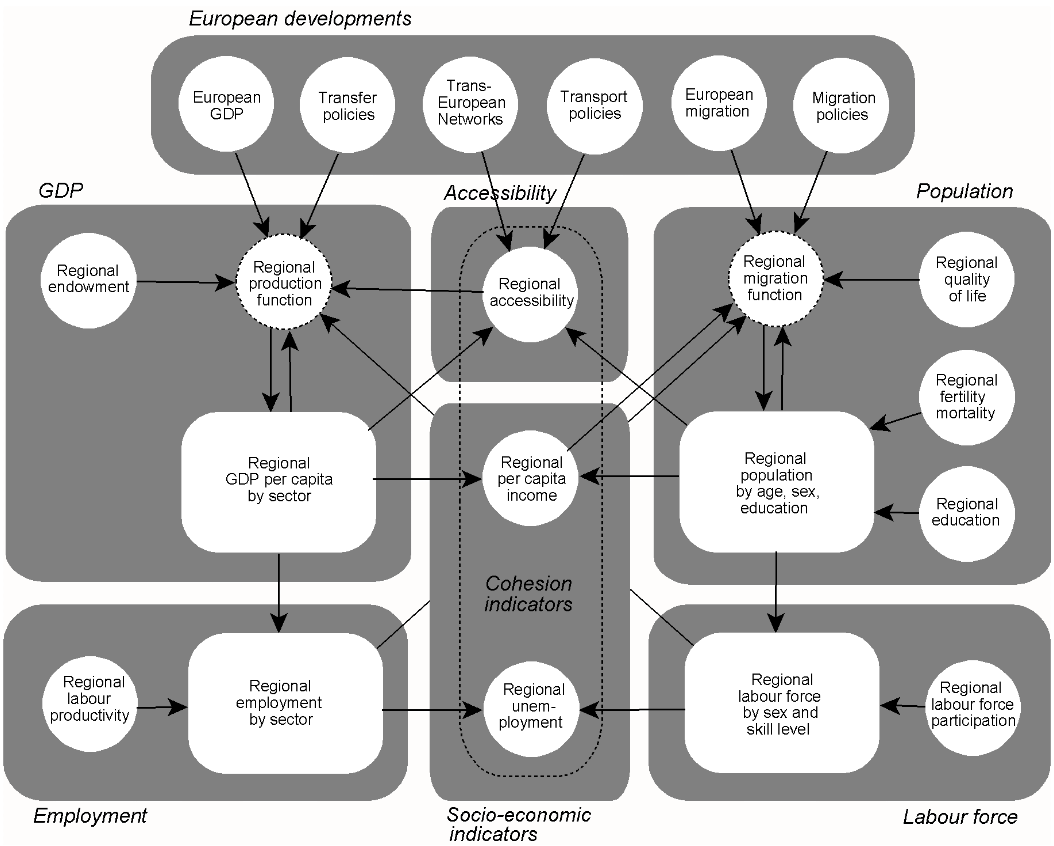


Figure 2.9 The SASI model

The *Regional GDP* submodel is the core of the SASI model. It forecasts Gross Domestic Product (GDP) per capita by six industrial sectors (agriculture, manufacturing, construction, transport and tourism, financial services and other services) generated in each region as a function of endowment indicators and accessibility. Endowment indicators measure the suitability or capacity of the region for economic activity: they include traditional location factors such as availability of skilled labour and business services, capital stock (i.e. production facilities) and intraregional transport infrastructure as well as 'soft' location factors such as indicators describing the spatial organisation of the region, i.e. its settlement structure and internal transport system, institutions of higher education and cultural facilities and quality of life.

The *Regional Employment* submodel computes regional employment from regional GDP by exogenous forecasts of regional labour productivity by industrial sector (GDP per worker).

In the *Regional Population* submodel births and deaths are modelled by a cohort-survival model subject to exogenous forecasts of regional fertility and mortality rates. Interregional migration within the European Union is also modelled in a simplified migration model

The *Regional Labour Force* submodel computes regional labour force from regional GDP and exogenous forecasts of regional labour force participation rates modified by effects of regional unemployment.
A seventh submodel calculates socio-economic Indicators. For each region the model forecasts the development of accessibility and GDP per capita in one-year increments until the forecasting horizon 2021. In addition cohesion indicators expressing the impact of transport infrastructure investments and transport system improvements on the convergence (or divergence) of socio-economic development in the regions of the European Union are calculated.

2.3.3 Key exogenous inputs, endogenous variables and outputs

The data required to perform a typical simulation run with the SASI model can be grouped into base-year data and time-series data. Base-year data describes the state of the regions and the strategic road, rail and air networks in the base year 1981. Time-series data describes exogenous developments or policies defined to control or constrain the simulation. They are either collected or estimated from actual events for the time between the base year and the present or are assumptions or policies for the future. Time-series data must be defined for each simulation period, but in practice may be entered only for specific (not necessarily equidistant) years, with the simulation model interpolating between them.

Exogenous assumptions are required concerning changes in regional labour productivity, regional educational attainment and regional labour force participation. All other regional base-year values such as GDP, employment or labour force are calculated by the model. Network data specify the road, rail and air networks used for accessibility calculations, and the evolution of the networks over the simulation period is needed as input.

2.3.4 The SASI model reference scenario

The reference scenario serves as benchmark for the comparison between policy scenarios. The reference scenario is defined as the scenario in which between 1981 and the present all transport infrastructure investments are implemented as observed and in which until the target year 2021 only policies already 'in the pipeline', i.e. the implementation of which can be assumed to be certain, are implemented. In other words the base scenario includes all new or upgraded TEN-T links on which definite decisions have been taken.

Because of the exogenous assumptions made for all scenarios (see 2.3.3) total GDP in the whole study area grows by 2.7 percent per year between 1981 and 2001 (as in reality) and by 1.9 percent per year until the target year 2021. Because total European population grows by only 0.3 percent per year between 1981 and 2001 and declines by 0.2 percent per year between 2001 and 2021, this translates to a real growth in GDP per capita of 2.3 percent and 2.1 percent per year, respectively.

During the same period of forty years the European transport system undergoes a dramatic development in density and speed. Figure 2.10 shows the growth in multimodal accessibility, i.e. combined accessibility by road, rail and air, in Europe between 1981 and 2021. The persistent pattern of high accessibility in the core and low accessibility in the European periphery can be clearly seen.

2.3.5 The SASI model references

Bröcker, J., Meyer, R., Schneekloth, N., Schürmann, C., Spiekermann, K., Wegener, M. (2004a): *Modelling the Socio-economic and Spatial Impacts of EU Transport Policy. IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies) Deliverable 6*. Funded by 5th Framework RTD Programme. Kiel/Dortmund: Christian-Albrechts-Universität Kiel.

Bröcker, J., Capello, R., Lundqvist, L., Meyer, L., Rouwendal, J., Schneekloth, N., Spairani, A., Spangenberg, M., Spiekermann, K., van Vuuren, D., Vickerman, R. Wegener, M. (2004b): *Territorial Impact of EU Transport and TEN Policies. Final Report of ESPON 2.1.1*. Kiel: Institut für Regionalforschung, Christian-Albrechts-Universität Kiel.

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TINA Secretariat (2002): *Status of the Pan-European Transport Corridors and Transport Areas. Developments and Activities in 2000 and 2001. Final Report*. Vienna: TINA Secretariat.

Wegener, M., Bökemann, D. (1998): *The SASI Model: Model Structure. SASI Deliverable D8. Berichte aus dem Institut für Raumplanung 40*. Dortmund: Institut für Raumplanung, Universität Dortmund. http://irpud.raumplanung.uni-dortmund.de/irpud/pro/sasi/ber40.pdf

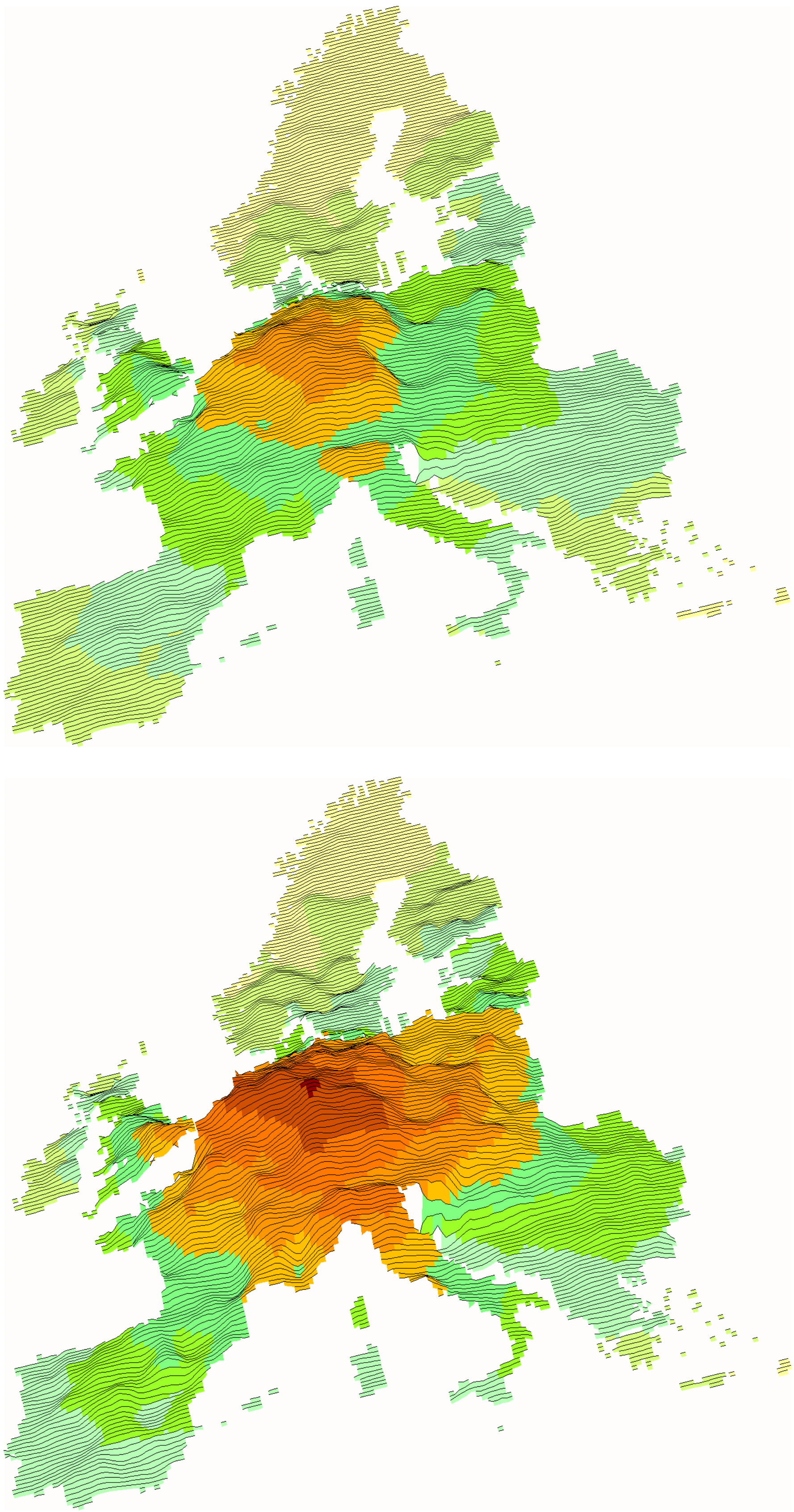


Figure 2.10 Multimodal accessibility in Europe 1981 (top) and 2021 (bottom) in the SASI reference scenario

2.4 The POLES model

2.4.1 The POLES model study region

In the current geographic disaggregation of the POLES model, the world is divided into 47 countries or regions, allowing to identify the key world regions of most energy studies (see figure 2.11 and table 2.1).

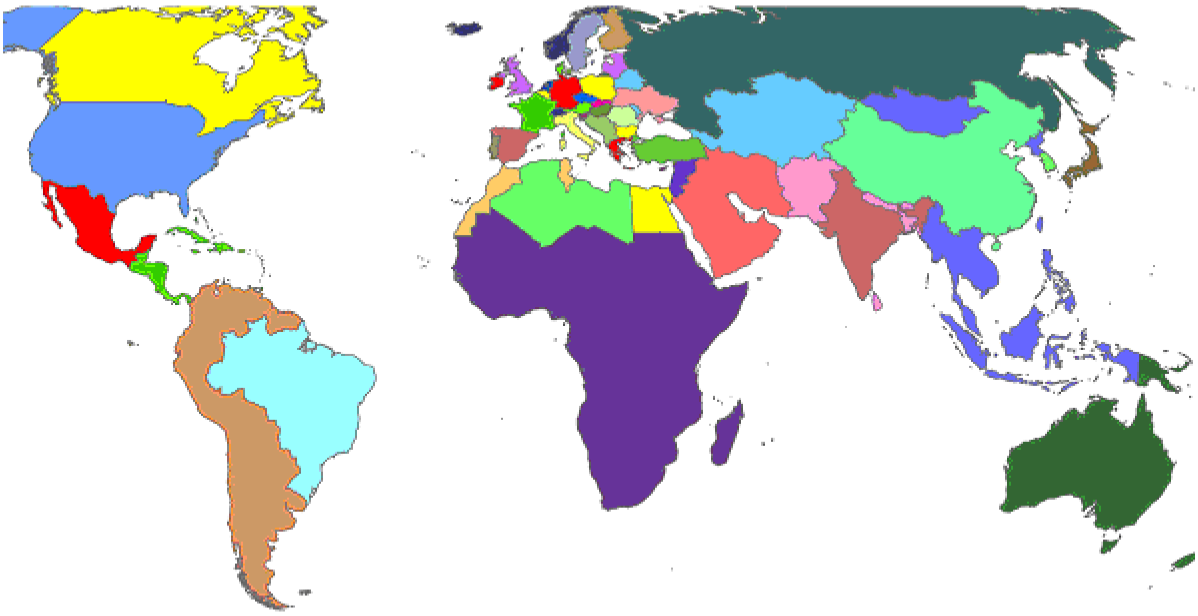


Figure 2.11 POLES world regions

In most of these regions the larger countries are identified and treated, as concerns energy demand, with a detailed model. In the current version these countries are the G7 countries plus the countries of the rest of the European Union and five key developing countries: Mexico, Brazil, India, South Korea and China.

Table 2.1 POLES world regions

Europe		Rest of the World	
Acronym	**Region**	**Acronym**	**Region**
AUT	Austria	CAN	Canada
BLX	Belgium and Luxembourg	USA	United States
DNK	Denmark	MEX	Mexico
ESP	Spain	RCAM	Rest of Central America
FIN	Finland	BRA	Brazil
FRA	France	RSAM	Rest of South America
GBR	United Kingdom	CHN	China
GRC	Greece	COR	South Korea
IRL	Ireland	JPN	Japan
ITA	Italy	NDE	India
PRT	Portugal	RSAS	Rest of South Asia
NLD	Netherlands	RSEA	Rest of South East Asia
RFA	Germany	RJAN	Rest of Pacific OECD
SWE	Sweden	RUS	Russia
SMC	Slovenia, Malta and Cyprus	UKR	Ukraine
CZE	Czech Republic	RFSU	Rest of Former Soviet Union
HUN	Hungary	SSAF	Sub-Saharan Africa
BLT	Lithuania, Estonia and Letonia	EGY	Egypt
POL	Poland	NOAN	North Africa Non-producers
SVK	Slovak Republic	NOAP	North Africa Producers
TUR	Turkey	GOLF	Gulf States
BGR	Bulgaria	MEME	Mediterranean Middle East
ROU	Rumania		
RCEU	Rest of Central Europe		
ROWE	Rest of Western Europe		

Figure 2.12 Geographic disaggragation in POLES model

2.4.2 The POLES model description

The POLES model structure follows a hierarchical system of interconnected modules at three level of analysis :

- international energy markets;
- regional energy balances;
- national energy demand, new technologies, electricity production, primary energy production systems and CO2 emissions per sector.

The dynamics of the model corresponds to a recursive simulation process, common to most applied models of the international energy markets, in which energy demand and supply in each national / regional module respond with different lag structures to international prices variations in the preceding periods. In each module, behavioural equations take into account the combination of price effects and of techno-economic constraints, time lags or trends.

For each region covered, the model articulates four main modules dealing with:

- Final Energy Demand by main sectors;
- New and Renewable Energy technologies;
- The Electricity and conventional energy and Transformation System;
- The Primary Energy Supply.

While the simulation of the different energy balances allows for the calculation of import demand / export capacities by region, the horizontal integration is ensured in the energy markets module, the main inputs of which are import demand and export capacities of the different regions. Only one world market is considered for the oil market (the "one great pool" concept), while three regional markets (America, Europe, Asia) are identified for coal, in order to take into account for different cost, market and technical structures. Natural gas production and trade flows are modelled on a bilateral trade basis, thus allowing for the identification of a large number of geographical specificities and the nature of different export routes.
The comparison of import and export capacities and the changes in the Reserves/Production ratio for each market determines of the variation of the prices for the subsequent periods.

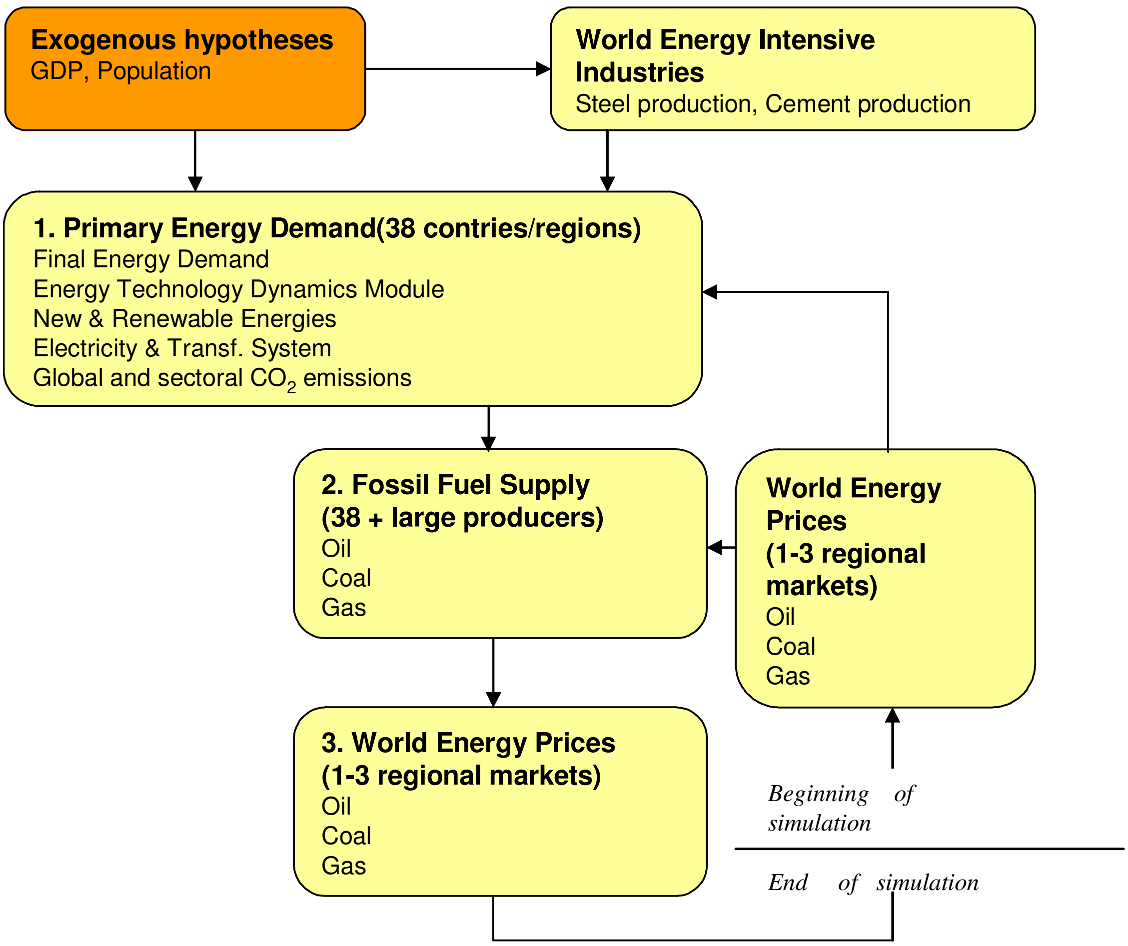


Figure 2.13 POLES five modules and simulation process

Within POLES, the transport module (the IPTS transport technologies model) is used to describe the dynamics of the passenger car market and the introduction of new technologies in the sector. The model simulates the way that consumer choices concerning passenger cars are influenced by changes in car and fuel prices, technological development and general socio-economic trends. The first step of the simulation is the estimation of the expected changes in car ownership levels for each EU member state. As in most comparable models, car ownership levels are modelled with a Gompertz function that uses the changes of GDP per capita as input. The calibration of the model on the basis of past data allows the definition of the country specific parameters that affect factors such as the saturation level of demand, the changing elasticities as income grows and the differences in the speed of the effects. The exogenous projections needed, i.e. GDP and population growth, are obtained from EUROSTAT and UN projections.

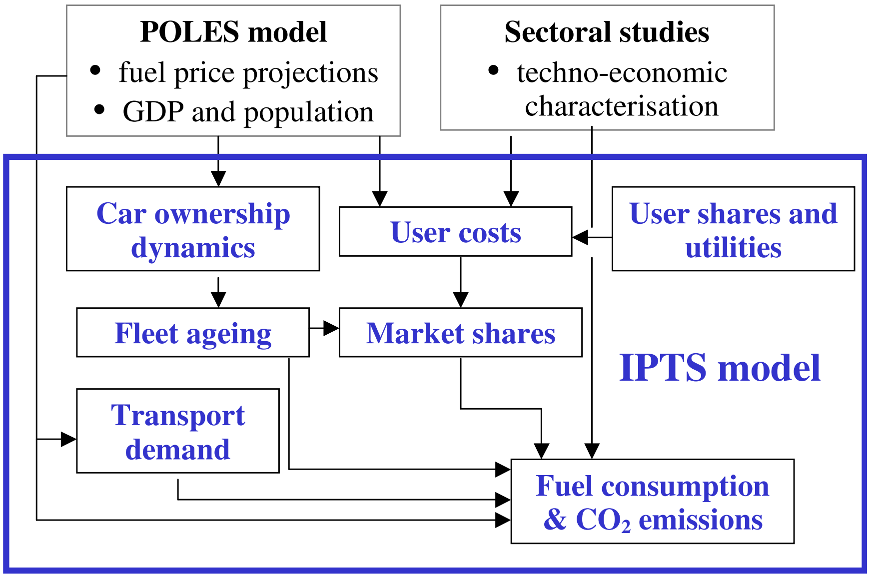


Figure 2.14 Overview of POLES model links

The number of new registrations is a result of either the change in the overall car ownership level, or of the replacement of cars that are scrapped or removed from the car park (i.e. in the case of used car exports). The number of the cars removed each year from the park is modelled through country-specific survival rate curves for each cohort of cars that has entered the market since 1965. The survival curve rate can itself change over time, either as a result of technological progress or because of higher or lower incomes that accelerate or delay car scrapping.

The model distinguishes between three types of users for each country, each corresponding to different preferences as regards car use and -as a result- different responsiveness to costs and technological characteristics. At the same time, the model currently includes seven technological options, conventional (internal combustion engines using gasoline or diesel, light or large) or emerging (electric, gasoline-electric hybrid, fuel cells). The technical and economic characteristics of each technological option have been defined through a number of sectoral techno-economic characterisation studies. These studies have provided a database of historic data for the conventional technologies and of projections by industry experts as regards the outlook for both conventional and emerging technologies. In

addition, the model uses the projected future fuel prices of the POLES model in order to estimate the future usage cost for each option.
The share of the new registrations that each option can have in the future depends therefore on the combination of the number of users of each type in each country, their responsiveness to the technical and economic characteristics of each technology, the technological progress of each option, and the development of fuel prices in the future. The model also allows the introduction of infrastructure capacity limits.
Transport demand in the model is also affected by the fluctuations of fuel prices, GDP growth, the general trends of increased transport intensity, and the changes in the costs for each market segment. Combining the projected demand, the breakdown of the car park in technologies, and the expected efficiency for each technology in each generation, the model provides an outlook for fuel consumption and CO2 emissions for each country, as well as for each of the market segments covered.

2.4.3 Key exogenous inputs, endogenous variables and outputs

The calibration of the POLES model requires several data: car prices and costs, fuel costs, fleet, GDP, population, energy consumption, emissions, new registrations and technical parameters and so on. With reference to scenario simulations, the model currently allows four general types of scenarios to be analysed:

Technological scenarios
Technological scenarios can provide the outlook for the penetration of new technologies and their impacts on the indicators measured under different assumptions than the ones currently used. Technology development is expressed in the model in terms of fuel economy and car prices through changing the exogenous variables (input) of the model: car costs, fuel efficiency, emission levels, etc.

Policy measures
Policy measures are perhaps the most interesting type of scenario analysis, and the one that provides more flexibility. The policy measures that scenarios can cover include: fuel taxes, carbon taxes, subsidising specific technology changes, imposing emission limits, accelerated scrapping schemes, imposing a zero emission limit in urban areas.

Socio-economic trends
In POLES, user choices are modelled in the context of specific socio-economic trends, covering market segments, user types, the degree of urbanisation, the environmental awareness of users, etc. that are endogenous to the model. These elements can be varied by modifying the equations describing the dynamics of the model, namely, as far as user choices are concerned, price elasticities for each specific user group.

External factors
The main external factors that the model can analyse in terms of scenarios are fuel prices and GDP growth. In its current form, the model uses as input the projections of fuel prices from the POLES model, and the same assumptions for GDP growth that the POLES model uses. Scenarios that can be carried out include the investigation of the impact that a higher

or lower price of, and/or a faster or slower economic growth would have on the dynamics of the car market, total demand, fuel consumption and CO2 emissions.

2.4.4 The POLES model reference scenario

The POLES model provides a long-term simulation of world energy scenarios and international energy markets analysis.
The energy balance data for the POLES model reference solution are extracted from an international energy database, which also includes international macro-economic data concerning GDP, the structure of economic activity, deflators and exchange rates. Techno-economic data (energy prices, equipment rates, costs of energy technologies ...) are gathered both from international and national statistics. The following tables and figures provide an overview of the main exogenous assumptions (population and GDP) and characteristics output variables (car ownership, car park, new registrations) for the European zones of the current POLES version.

Table 2.2 Exogenous assumptions used in POLES for population and GDP

	Population (in thousands of inhabitants)			GDP (in constant year 2000 €k/capita)		
	2000	**2020**	**% growth by year (2000- 2020)**	**2000**	**2020**	**% growth by year (2000- 2020)**
[AUT]	8182	8031	-0,09%	25	38	2,12%
[BGR]	8167	6904	-0,84%	6	14	4,33%
[BLT]	7436	6188	-0,91%	8	19	4,42%
[BLX]	10651	11054	0,19%	25	36	1,84%
[DNK]	5334	5477	0,13%	27	41	2,11%
[ESP]	39326	40562	0,15%	20	31	2,22%
[FIN]	5177	5290	0,11%	23	36	2,27%
[FRA]	59224	63165	0,32%	23	33	1,82%
[GBR]	58971	62307	0,28%	23	33	1,82%
[GRC]	10568	10499	-0,03%	16	27	2,65%
[HUN]	10022	9191	-0,43%	12	22	3,08%
[IRL]	3739	4519	0,95%	29	44	2,11%
[ITA]	57972	54409	-0,32%	23	34	1,97%
[NLD]	15745	16992	0,38%	26	37	1,78%
[POL]	38650	37818	-0,11%	9	16	2,92%
[PRT]	9944	9933	-0,01%	17	25	1,95%
[RCZ]	10273	9961	-0,15%	13	25	3,32%
[RFA]	81941	82222	0,02%	24	35	1,90%
[ROM]	22435	21213	-0,28%	5	12	4,47%
[RSL]	5402	5438	0,03%	11	21	3,29%
[SMC]	3135	3166	0,05%	16	33	3,69%
[SWE]	8909	9041	0,07%	23	34	1,97%
[TUR]	65293	84626	1,31%	5	11	4,02%

Table 2.3 POLES projections for car ownership and car park baseline

	Car ownership (in cars per 1000 inhabitants)			Car park (in thousand cars)		
	2000	**2020**	**% growth by year (2000- 2020)**	**2000**	**2020**	**% growth by year (2000- 2020)**
[AUT]	501	631	1,16%	4097	5064	1,07%
[BGR]	244	352	1,85%	1993	2428	0,99%
[BLT]	295	464	2,29%	2193	2874	1,36%
[BLX]	459	574	1,12%	4892	6349	1,31%
[DNK]	358	414	0,73%	1908	2265	0,86%
[ESP]	444	612	1,62%	17449	24808	1,77%
[FIN]	412	509	1,06%	2135	2693	1,17%
[FRA]	474	568	0,91%	28060	35866	1,23%
[GBR]	425	674	2,33%	25067	41992	2,61%
[GRC]	302	543	2,98%	3195	5697	2,93%
[HUN]	236	349	1,98%	2365	3204	1,53%
[IRL]	354	478	1,51%	1323	2161	2,48%
[ITA]	562	630	0,57%	32584	34260	0,25%
[NLD]	415	532	1,25%	6539	9046	1,64%
[POL]	259	426	2,52%	9991	16099	2,41%
[PRT]	529	581	0,47%	5260	5776	0,47%
[RCZ]	335	490	1,92%	3439	4881	1,77%
[RFA]	542	609	0,58%	44383	50091	0,61%
[ROM]	139	238	2,73%	3129	5051	2,42%
[RSL]	236	311	1,39%	1274	1691	1,43%
[SMC]	416	550	1,41%	1305	1740	1,45%
[SWE]	449	530	0,83%	3999	4794	0,91%
[TUR]	68	329	8,20%	4422	27875	9,64%

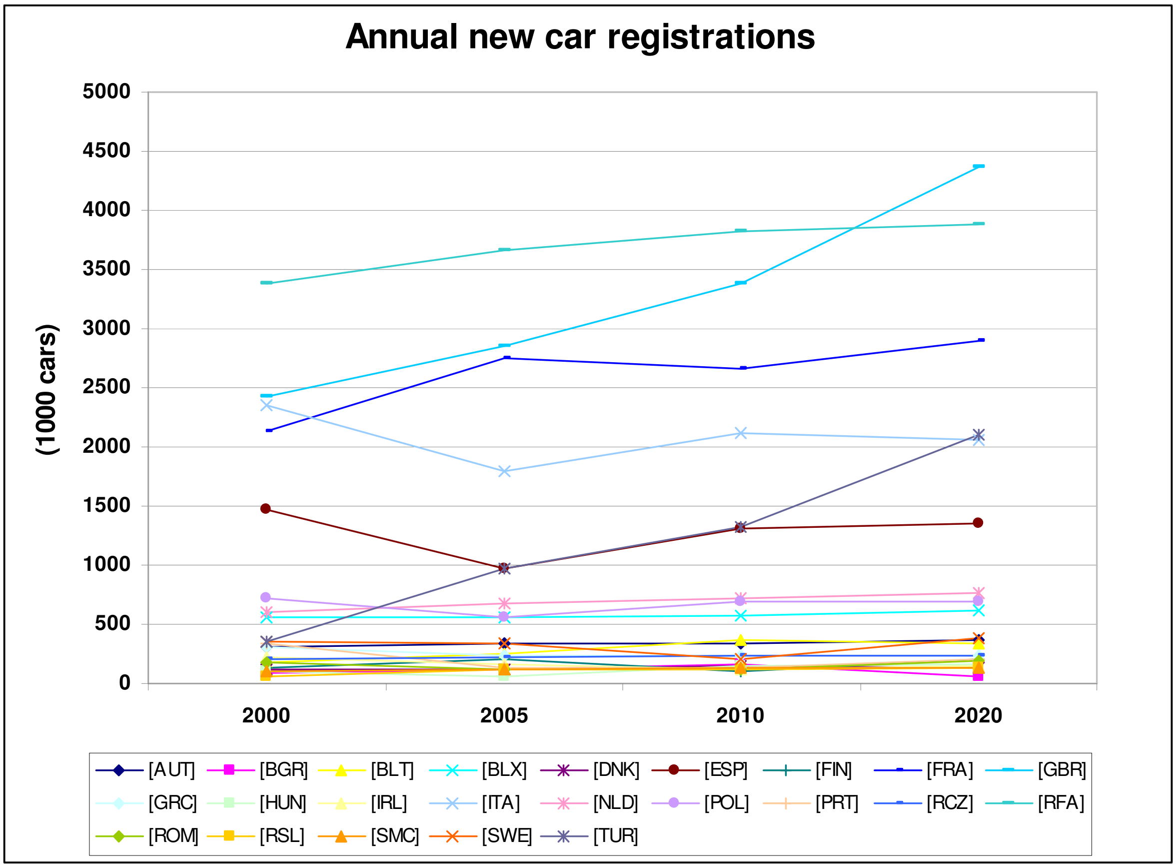


Figure 2.15 Annual new car registrations, baseline projections of POLES (in thousand cars)

2.5 The Brussels model

2.5.1 The Brussels model study region

The Brussels model is focused on the metropolitan area of the city, but the zoning systems cover the whole country with 184 zones, of which 101 zones covering the Brussels-Capital Region, 66 covering its periphery and 17 covering the rest of Belgium.
Two main regions are covered, the Brussels Capital Region whose diameter is 12 km (represented in blue on the following map) and the Regional Express Network Region whose diameter is about 60 km (represented in red on the following map).

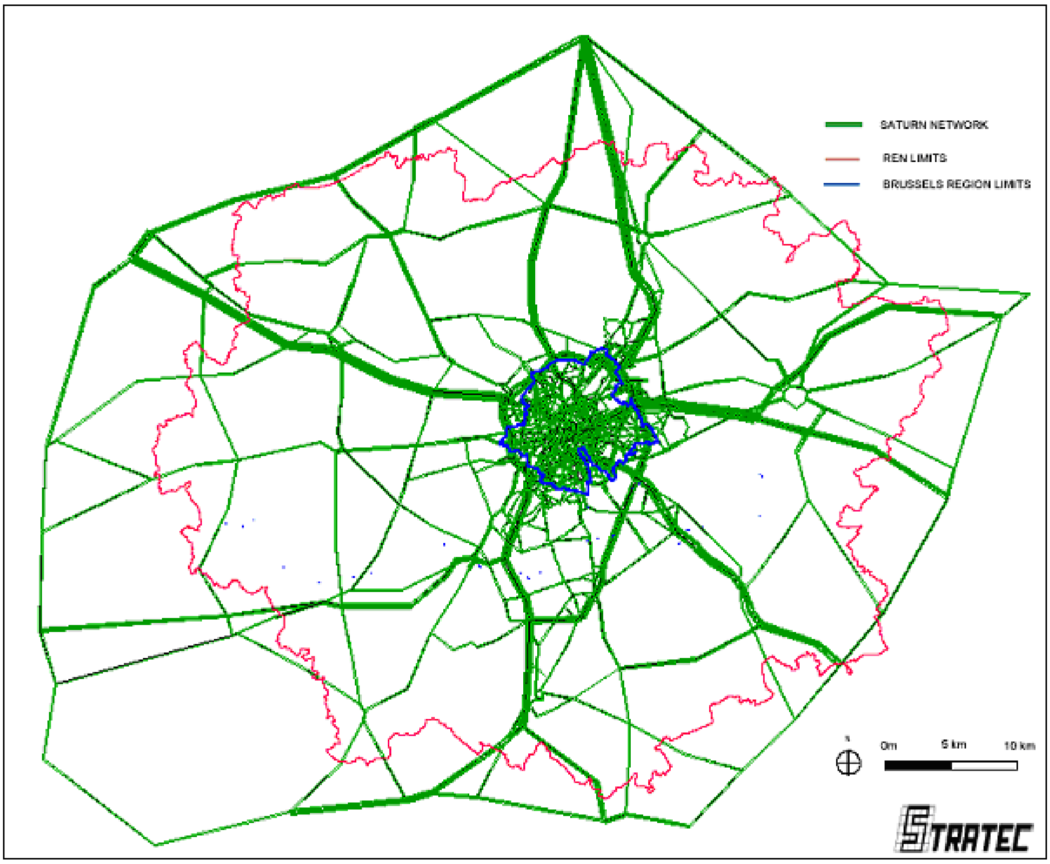


Figure 2.16 Regions covered by the Brussels model

The following map presents the urban areas of the analysed region. The two early-defined zones are also represented. In terms of population and employs, the Brussels region and the Regional Express Network region counts respectively 1 million inhabitants and 650 000 employs, and 2.9 millions inhabitants and 1.2 millions employs. The REN region is also called the Brussels metropolitan area.

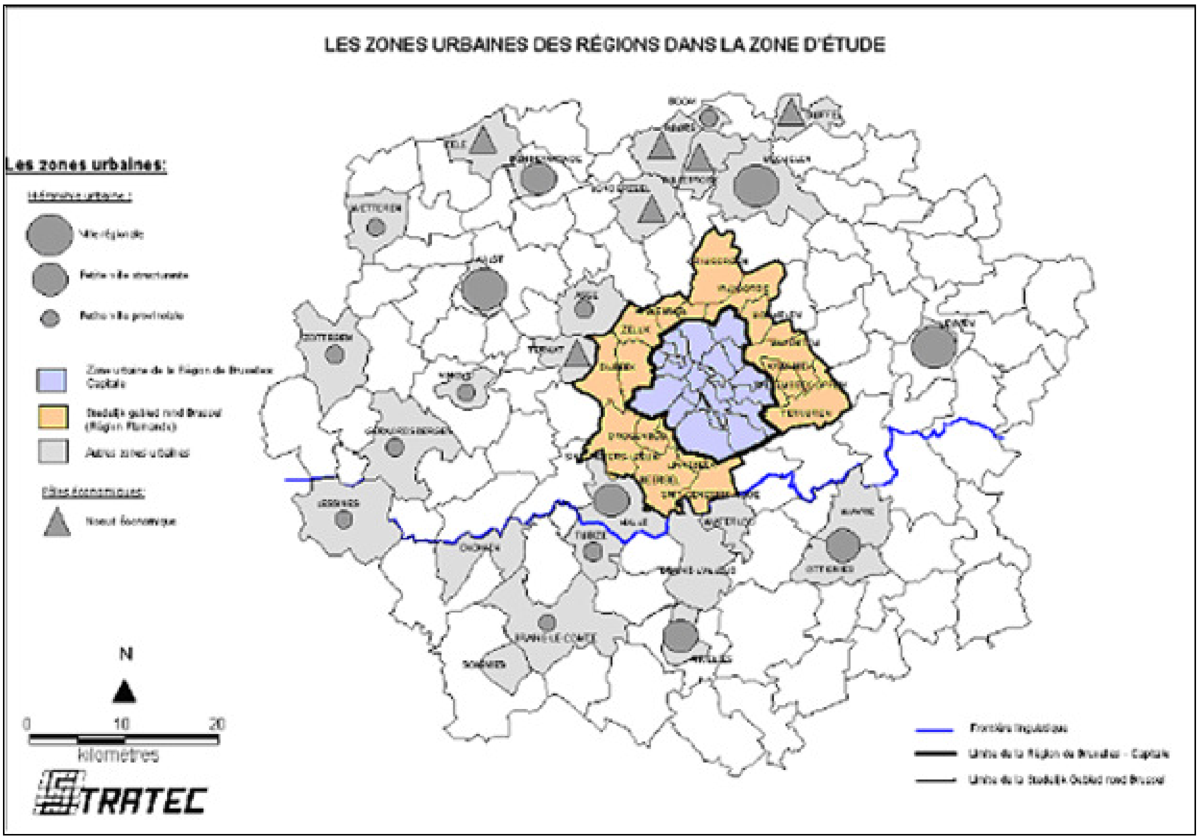


Figure 2.17 The Brussels model zoning system

The so-called "Brussels-Capital Region", is an important administrative capital, grouping a little less than 1 million inhabitants. The Region has lost population for 30 years (about 120 000 inhabitants), while economic activities – with a rather stable total number of jobs (about 650 000) - were undergoing an important mutation: strong decline of industrial and heavy tertiary activities and strong growth of administrative functions. The result of this evolution is an increase in the number of daily commuters and traffic congestion.

The spatial structure of Brussels is quite typical. An old industrial axis along a canal surrounded by poor neighbourhoods of different ethnic communities with very few green spaces makes its way through the whole city, cutting it in two parts. Neglected during decades this area slowly begins to be renovated. On the other hand, the strong increase of administrative functions introduced a speculative pressure on higher status neighbourhoods making the cost of living increase. Emigration of middle class families to the suburbs encouraged urban sprawl, commuting by car and congestion. The decline of the population of the Brussels-Capital Region and the lowering of its average income increases the scarcity of the resources, essentially based on income taxes of residents, while a lot of public works must be done to adapt the Region to its new important administrative functions. One of the major goals of the local Development Plan is to reinforce the residential attractiveness of the capital by all means. On the other hand, since the efficiency of the public transport networks is too low, especially between the periphery and the urban centre, the authorities decided to implement what could be called a “regional metro” on the existing railway tracks: this is the RER or “Regional Express Railway Network” (“Réseau Express Régional”), linking the suburbs to the central part of the metropolitan area. The total area is disaggregated into 400 traffic zones.

2.5.2 The Brussels model description

The IRIS model is used for the Brussels region as a tool used to define a global development strategy through the analysis of the relation between land use, transport, socio-economic data and environment topics. This model is used for the constitution of the travel master plan of the Brussels region.

The model was originally calibrated on household survey carried out in 1998 for the IRIS Brussels Master Plan and on the 1991 National Census data, but it has been recently re-calibrated on 2001 data. The model produces forecasts for the year 2015.

The Brussels model is a classical four steps model where each step is dealt with a specific sub-model.

The generation and attraction sub-model provides the peak hours number of trips generated and attracted by each zone using as input the locations of households, jobs and commercial activities. Trips are divided into different trip purposes plus freight trips.

The distribution procedure comes up with the trip matrix using the total generated and attracted trips from each zone as a double constraint. Matrices are computed for each trip purpose.

The modal split sub-model is based on Logit models calibrated by trip purpose on stated and revealed preferences. Attractiveness of alternative modes depend on elements like travel cost, travel time, travel distance, public transport headway, car ownership rate, etc..

The Brussels model manages the following modes: walking, cycling, motorbikes, private car (used either as drivers or as passenger), taxis, car sharing, HOV and public transports.

Private and public transport assignment are ruled by two different sub-models:

the road traffic assignment model is a SATURN assignment model of the Brussels area, its periphery and the rest of Belgium which provides the car travel times from each origin zone to each destination zone according to the volume of car determined by the modal choice model. The simulated zone (inner) covers all the Brussels Capital Region and the road ring. So, congestion is taken into account on 3500 junctions. The map 2.18 and 2.19 present a zoom of the entire SATURN network on the Brussels region.

the public transport assignment model is a VISUM assignment model of the Brussels area, its periphery and the rest of Belgium which provides the travel times by public transport from each origin zone to each destination zone related to the definition of the public transport supply. The assignment method is based on public transport schedules. The map 2.20 is a representation of the results that can be obtained from the utilisation of the VISUM part of the IRIS model. It presents for a specific place, the requested time using public transport to reach the specified place.

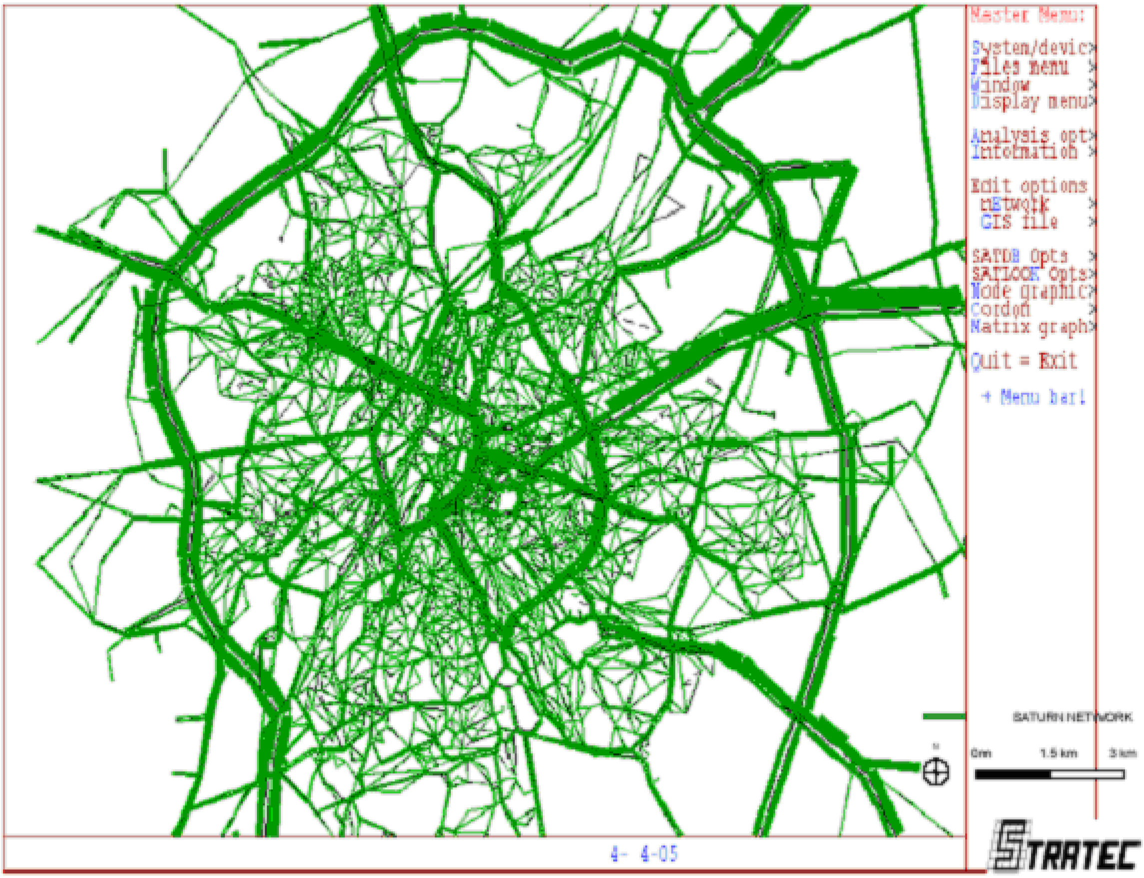


Figure 2.18 Representation of the SATURN network for the Brussels region

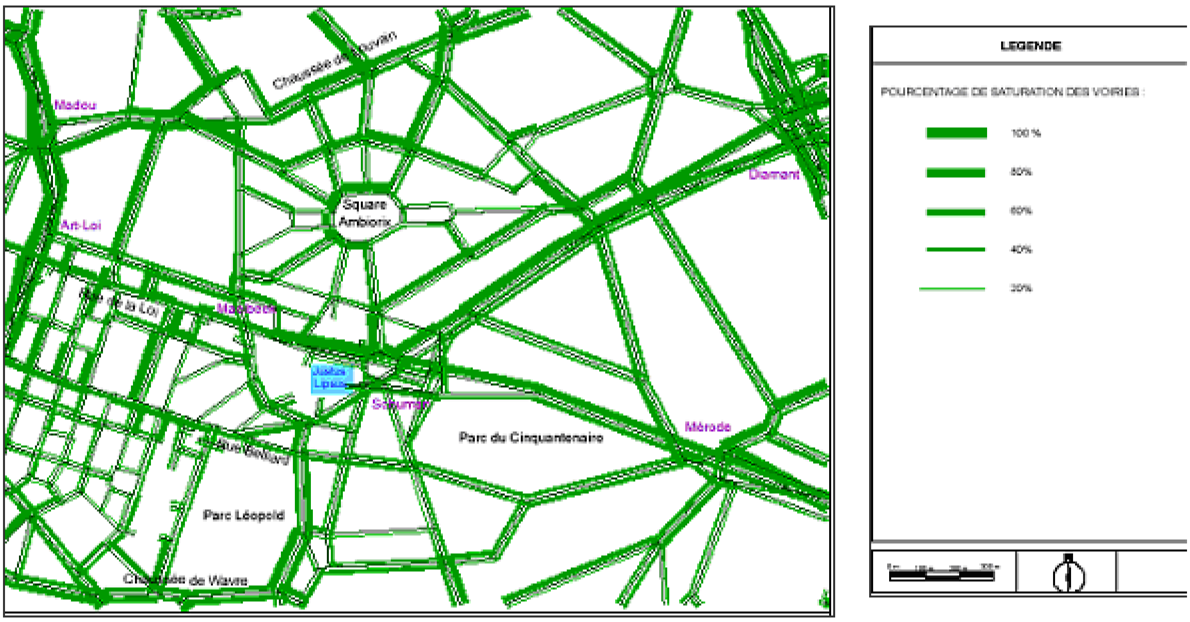


Figure 2.19 Representation of congestion trough SATURN part of the IRIS model – Simulated zone: The Brussels European quarter.

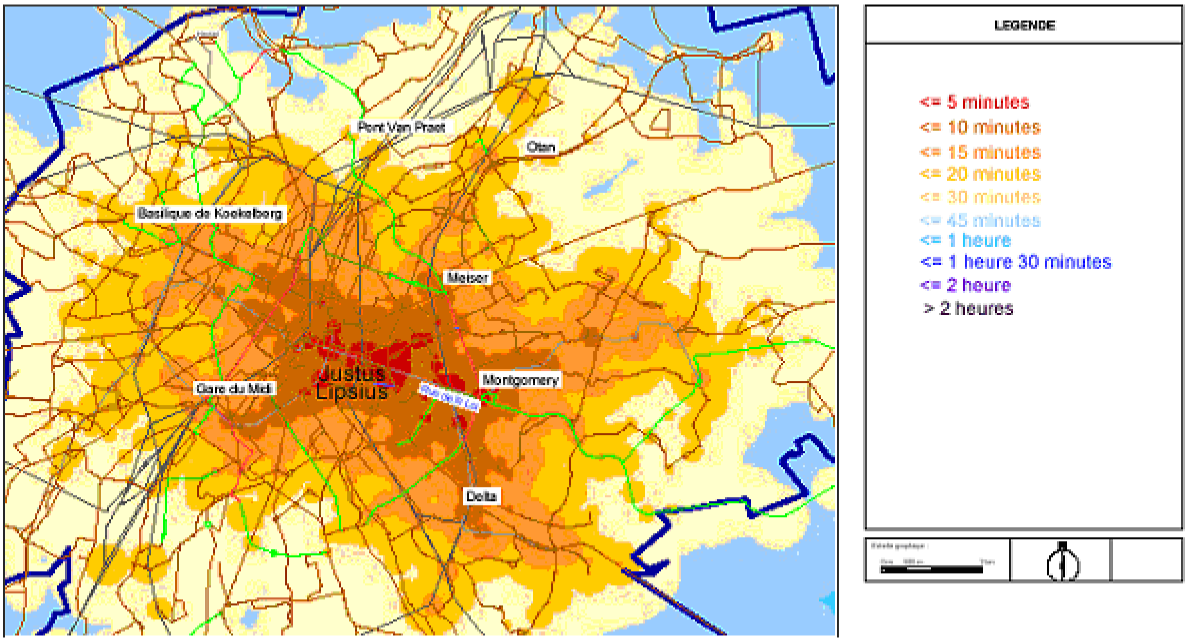


Figure 2.20 A representation of VISUM results – Simulated zone: The Brussels European quarter.

The modal split sub-model and the road traffic assignment modal are linked into an iterative way: for a given total demand scenario, the modal split model provides the road traffic demand matrix and the public transport demand matrix, notably depending on the travel time by car and public transport. The private traffic demand is assigned in the dedicated modules, which provides the resulting origin-destination time matrix by car. This origin-destination time matrix is introduced in the modal split model, which generates new demand matrix, etc. The iterative procedure is stopped at the convergence level.

Even if the Brussels model is mainly a transport model, its outputs can be used to compute environmental indicators. Results of the SATURN model can be used as inputs for the emissions simulation. Through a specific emission modelling spreadsheet, mainly based on MEET project results, the air emissions generated along each axis modelled by SATURN are computed.
The following pollutants are analysed: CO2, CO, NOx, VOC, PM10 as well as the fuel consumption which can be presented in kg or in litres.
The spreadsheet details the fleet composition: trucks, vans and cars are segmented in the module according various elements like: fuel type and EURO categories. The definition of the fleet can also be done precisely. The model allows varying the fleet composition according to the age fleet as well as the main vehicle type. For instance, it is possible to add new innovative vehicles categories (for instance biofuel, electric or hybrid vehicles). The only requested informations in order to add new vehicle types are the emission curve linked to the speed of the vehicles. Indeed, the MEET emission-consumption spreadsheet computes the emission for every axis trough an emission function that is based on the vehicles speed.
This emission model allows to test traffic policies as for instance banishment of certain vehicles types. It is then possible to analyse environmental impacts of traffic banishment measures as well as new vehicle type introduction.

The following map presents environmental emission results that can be obtained. The map presents the PM10 emission level generated by each axis present in each defined zone.

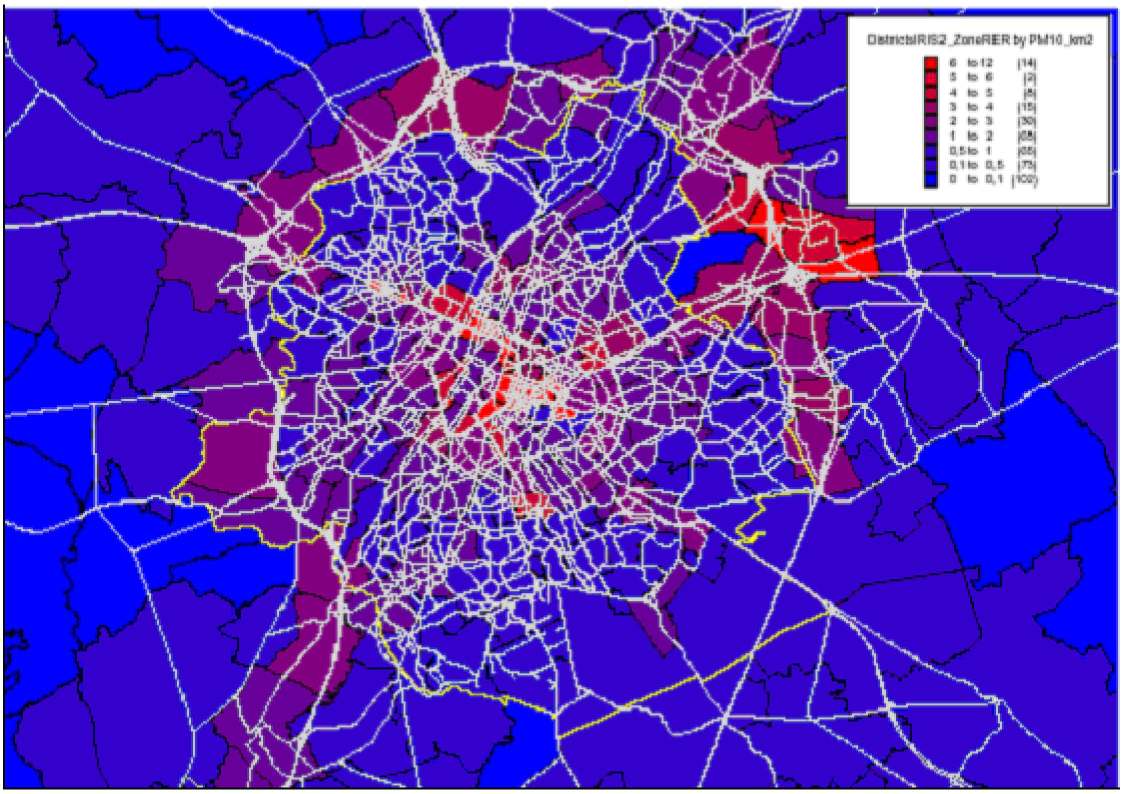


Figure 2.21 Emissions results (PM10) computed for the Brussels region trough the Brussels IRIS model (SATURN and emissions components)

2.5.3 Key exogenous inputs, endogenous variables and outputs

The Brussels model computes matrices endogenously on the basis of households and jobs locations. Modal split and assignment phases use network features, transport costs and also general variables like car ownership. Therefore, main elements that can be used as input to simulate scenarios are:

- factors development: population growth, employment growth, new floorspace, etc.;
- transport supply: new/upgraded links, new/upgraded public transport services, etc;
- transport demand: car ownership;
- mode attractiveness: perceived transport costs, tarifs, etc.;
- environmental performance: emission functions, fuel consumption factors.

The Brussels model provides several variables as output; variables are zone-based, i.e. their value is available for each traffic zone. Where relevant, output is also segmented by trip purpose or mode, etc. Main output elements are:

- modal split
- passenger-km, passenger-time and speed for the public transport
- vehicle-km, vehicle time and speed for the private vehicles.
- Fuel consumption
- CO_2, NO_x, CO, VOC, PM10 emissions.

2.5.4 The Brussels model reference scenario

The main assumptions of the IRIS model are the following:

- The original reference scenario is the one of 2001;
- Based on this 2001 reference scenario, a Business As Usual reference scenario is constructed for the year 2005;
- The population characteristics and its evolution are based on the national population register;
- Forecasts have been done on population segmented by age groups as well as by socio-economic characteristics. Scholars are divided according school degrees, and employees are divided into three classes according the qualification level of their job.
- Forecast are done on employment and are related to the GDP growth (which is spatially allocated)
- Forecasts on household car ownership are based on trends;
- Fleet composition forecasts are done by extrapolation of the present figures.
- Planned infrastructures and policies are taken into account, as well for private road transport as for public transport.

The following maps present the evolution of the employment and scholarship for the Brussels region (mentioned as RBC[3] on the maps) as well as for the REN region (Regional Express Network, mentioned as RER[4] on the maps).

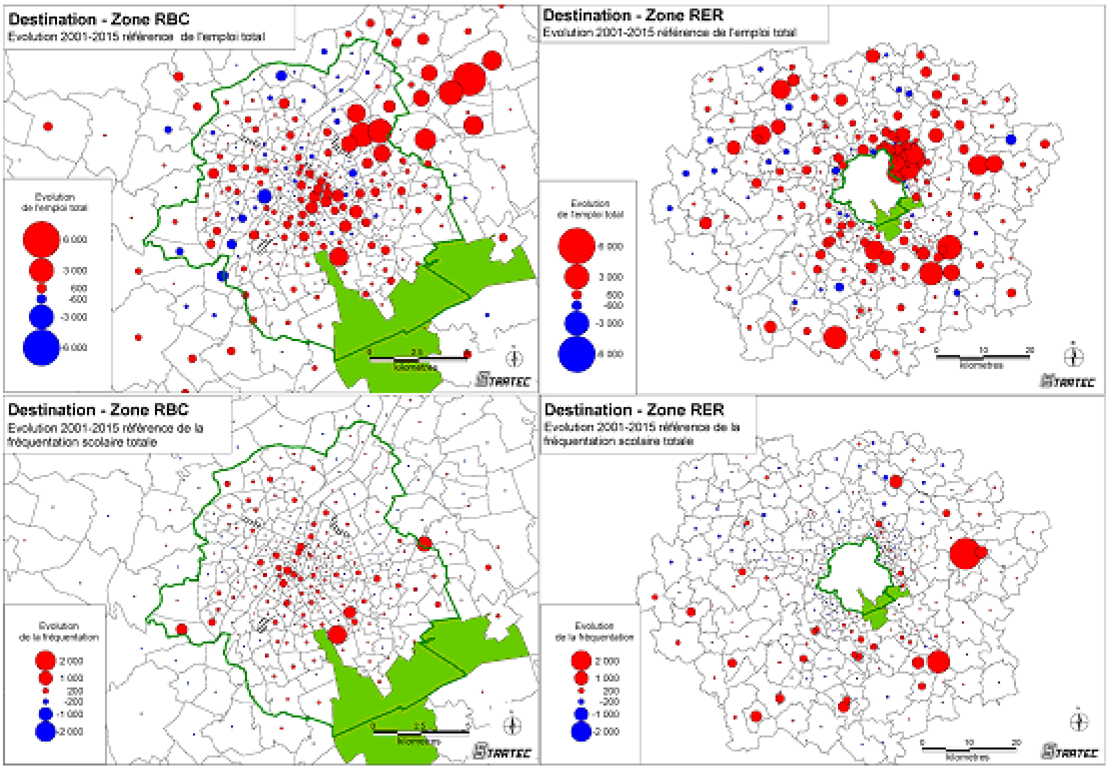


Figure 2.22 Evolution of the employment and scholarship for Brussels region and REN region

[3] RBC – Région de Bruxelles Capitale
[4] RER - Réseau Express Régional.

2.6 The Dortmund model

The Dortmund model was developed at the Institute of Spatial Planning of the University of Dortmund (IRPUD) for the simulation of intraregional location and mobility decisions in metropolitan areas.

2.6.1 The Dortmund model study region

Dortmund is the most eastern of the cities in the Ruhr area, the largest industrial conurbation in Germany. It developed rapidly from a small rural town in the early 19th century to a major industrial centre. Coal mining, steel making and breweries were the major industries of the city. The population development of Dortmund reflects its economic difficulties. From its maximum population of 660 000 in the 1960s, it declined to 570 000 in 1985 and has after a short recovery to 605 000 in 1990 because of massive immigration before and after the German unification continued to decline to 580 000 today. Part of the decline has been due to employment-related long-distance out-migration, the remaining half to natural decline and suburbanisation.

The model study area is the metropolitan area of Dortmund with a population of 2.6 million, which is sub-divided into 246 zones (Figure 2.23). In addition the model has 54 external zones representing its rural hinterland and most of the Rhein-Ruhr conurbation.(Figure 2.24).

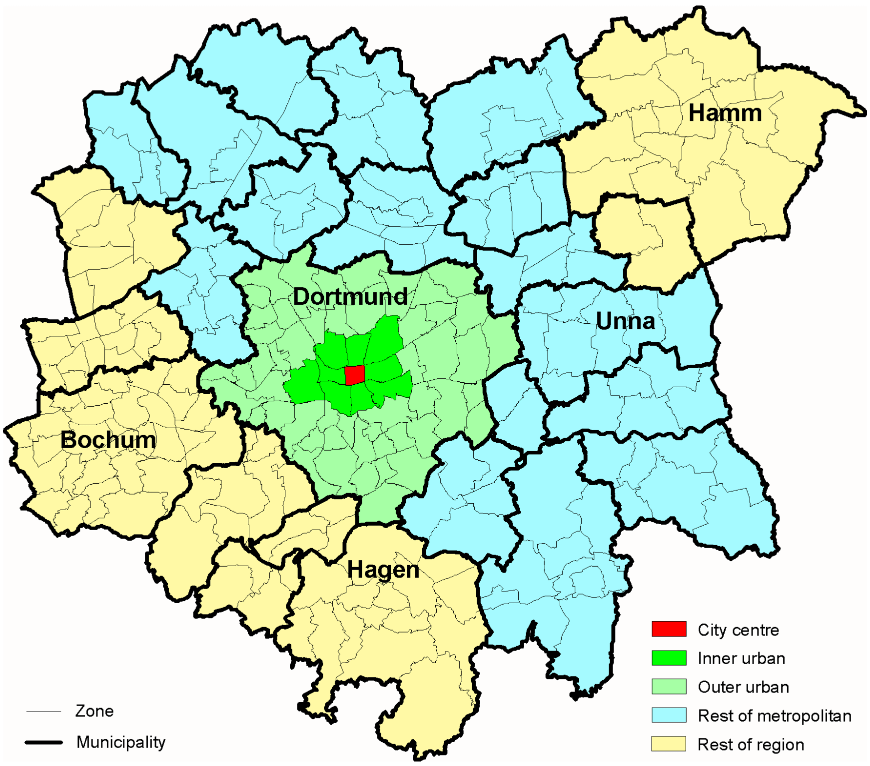


Figure 2.23 The Dortmund model internal zones

Figure 2.24 Internal and external zones of the Dortmund model

The zones are connected by transport networks containing the most important links of the road and public transport networks (Figure 2.25).

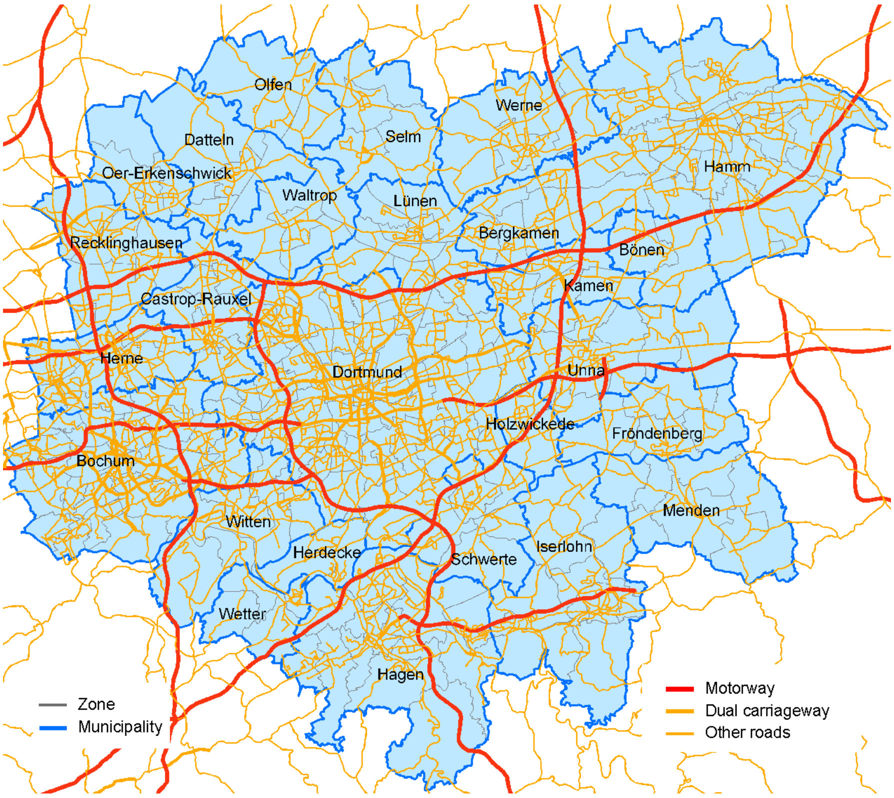
2.6.2 The Dortmund model description

The Dortmund model (Wegener, 1998; Lautso et al., 2004) has a modular structure and consists of six interlinked submodels operating in a recursive fashion on a common spatio-temporal database:

The Transport submodel calculates work, shopping, service, and education trips for four socio-economic groups, and three modes: walking/cycling, public transport and car. The model determines a user-optimum set of flows where car ownership, trip rates, modal split and route choice are in equilibrium subject to congestion in the network.

The Ageing submodel computes all changes of the stock variables of the model (employment, population and households/housing) which are assumed to result from biological, technological or long-term socio-economic trends originating outside the model (i.e. which are not treated as decision-based)..

The Public Programmes submodel processes a large variety of public programmes specified by the model user in the fields of employment, housing, health, welfare, education, recreation and transport.



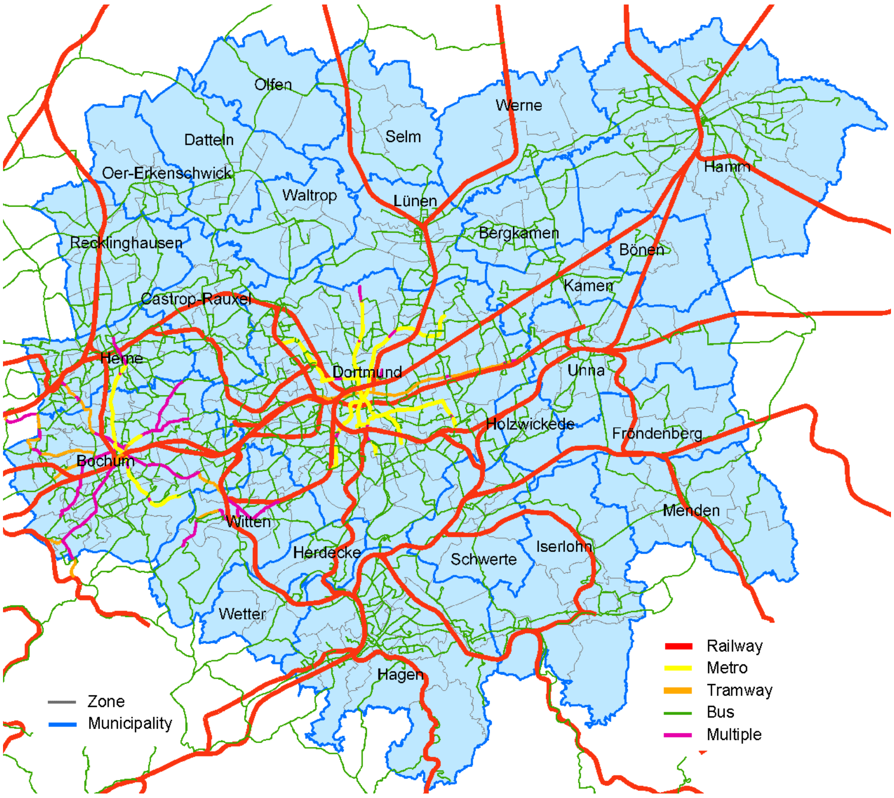


Figure 2.25 Road network (top) and public transport network (bottom) in the Dortmund model

The Private Construction submodel considers investment and location decisions of private developers, i.e. of enterprises erecting new industrial or commercial buildings, and of residential developers who build flats or houses for sale or rent or for their own use.

The Labour Market submodel models intraregional labour mobility as decisions of workers to change their job location in the regional labour market.

The Housing Market submodel simulates intraregional migration decisions of households as search processes in the regional housing market. Housing search is modelled in a stochastic microsimulation framework. The results of the Housing Market Submodel are intraregional migration flows by household category between housing by category in the zones. Figure 2.26 shows how the six submodels work together.

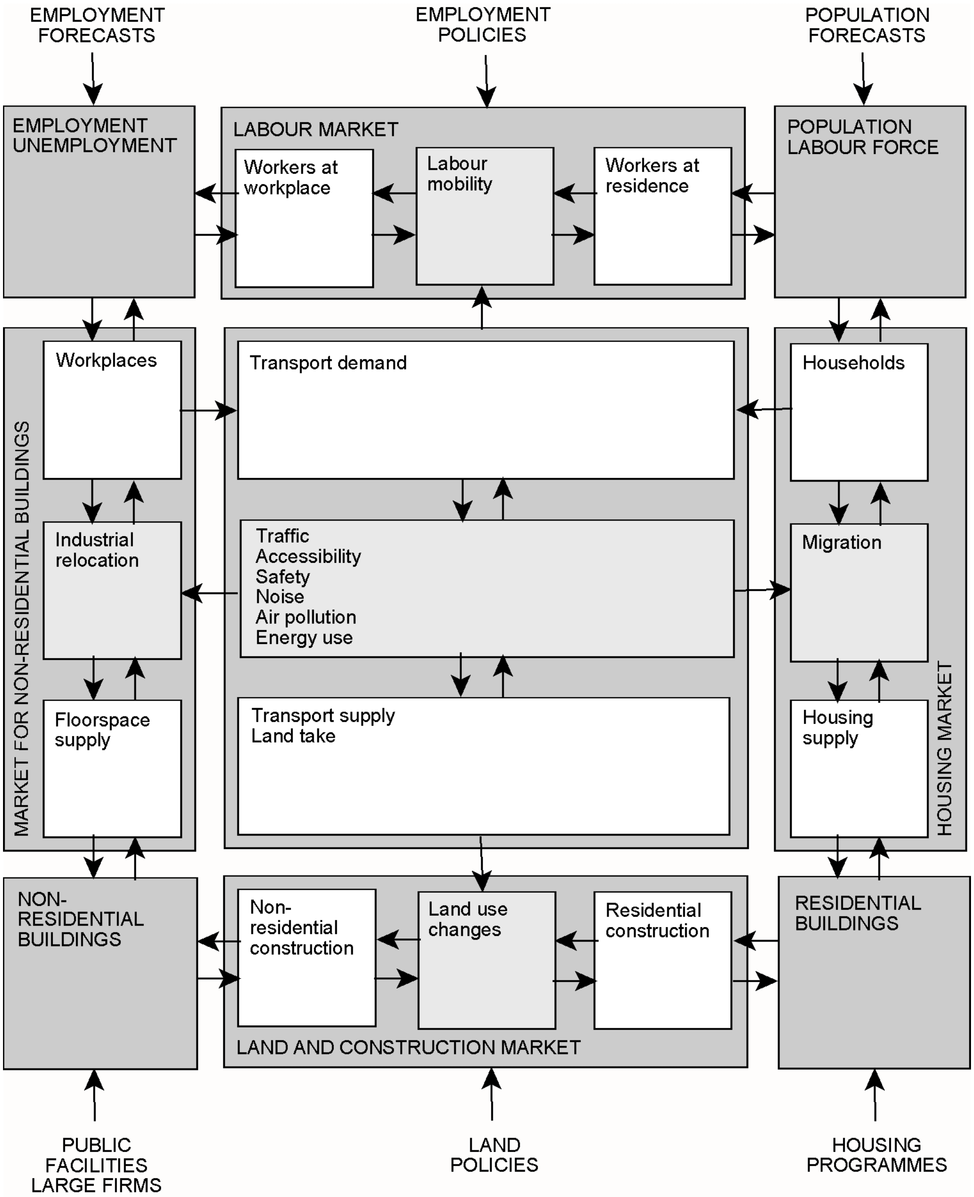


Figure 2.26 The Dortmund model structure

The Transport submodel is an equilibrium model referring to a point in time. All other submodels are incremental and refer to a period of time. The incremental submodels are executed once in each simulation period, while the Transport submodel is processed at the beginning and the end of each simulation period. Each submodel passes information to the next submodel in the same period and to its own next iteration in the following period.

Choice in each submarkets (e.g. labour market, housing market) is constrained by supply (e.g. jobs, vacant housing, vacant land, vacant industrial or commercial floorspace) and guided by attractiveness, which in general terms is an actor-specific aggregate of neighbourhood quality, accessibility and price.

2.6.3 Key exogenous inputs, endogenous variables and outputs

The Dortmund model was designed to study the impacts of policies from the fields of industrial development, housing, public facilities, land use and transport. There are two kinds of policies in the model: global and local.

Exogenous inputs are forecasts of total regional employment and total immigration into and outmigration out of the region subject to long-term economic trends or policies in the fields of industrial development, housing, public facilities and transport. There are two types of policies:

Global policies affect the economic or institutional environment of urban development in the whole region: e.g. changes in tax laws or subsidies; taxation and subsidies in the housing sector or new or regulations governing land use or construction activity; taxes or subsidies resulting in changes to petrol prices, parking fees or public transport fares; general speed limits or road pricing schemes.

Local policies may be either regulatory or direct zone-specific investment projects: e.g. local land-use planning; new industrial locations or plant closures; renewal projects in specific zones; local public facilities: schools, hospitals, recreation facilities etc.; local transport policies: additions, deletions or modifications of network links or public transport lines. The model predicts for each simulation period intraregional location decisions of industry, residential developers and households, the resulting migration and travel patterns, construction activity and land-use development and the impacts of public policies in the fields of industrial development, housing, public facilities and transport.

Examples of indicators that can be selected for output are population and employment of each zone, residential and non-residential construction, trips by trip purpose and mode (work, shopping, education, other), mean trip length and travel time, car ownership and fuel consumption, emissions by transport and land take.

2.6.4 The Dortmund model reference scenario

The Dortmund base scenario represents the most likely development of the region until the target year 2030. Due to low birth rates and outmigration, the population of the region has declined by two percent between 1970 and today and is likely to decline by another five percent until 2030. Despite the population decline, the number of households has increased by one quarter between 1970 and today and will start to decline only after 2010. By the combined effect of declining household sizes and rising real incomes, the number of dwellings in the region has grown even faster and is expected to be forty percent larger in 2030 than in the base year 1970.

It is assumed in the reference scenario that land use and transport policies will continue as they have in the last thirty years. For land use planning this means that cities and suburban communities will continue to compete for tax paying residents and firms and that thereofer urban sprawl will continue. In transport planning, it is assumed that only those new infrastructure projects that have a high chance of implementation are implemented. These are projects which are already under construction or for which the formal planning procedures have been started or which have high priorities in the transport infrastructure development plans for road and public transport of the state of North-Rhine Westphalia (MWMTV, 1998). It is further assumed for the reference scenario that consumer and fuel prices will develop as they have in the past, i.e. no major energy crises are envisaged.

These assumptions are reflected in the major travel indicators produced by the model. Car ownership grows from about 200 cars per 1,000 population in 1970 to about 530 cars today and is forecast to continue to grow to 590 cars per 1,000 population in 2030. Related to this, the share of public transport of all trips, which was about 17 percent in 1970 and about 13 percent today, is predicted to decline to about 11 percent in 2030. At the same time average trip length of all trips (including walking) grows from 7.6 km in 1970 to 10.6 km today and is expected to continue to grow to 12.5 km in 2030.

2.6.5 The Dortmund model references

Lautso, K., Spiekermann, K., Wegener, M., Sheppard, I., Steadman, P., Martino, A., Domingo, R., Gayda, S. (2004): *PROPOLIS – Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability*. LT Consultants, Helsinki.

Wegener, M. (1998): *The IRPUD Model: Overview*. http://irpud.raumplanung.uni-dortmund.de/irpud/pro/mod/mod_e.htm.

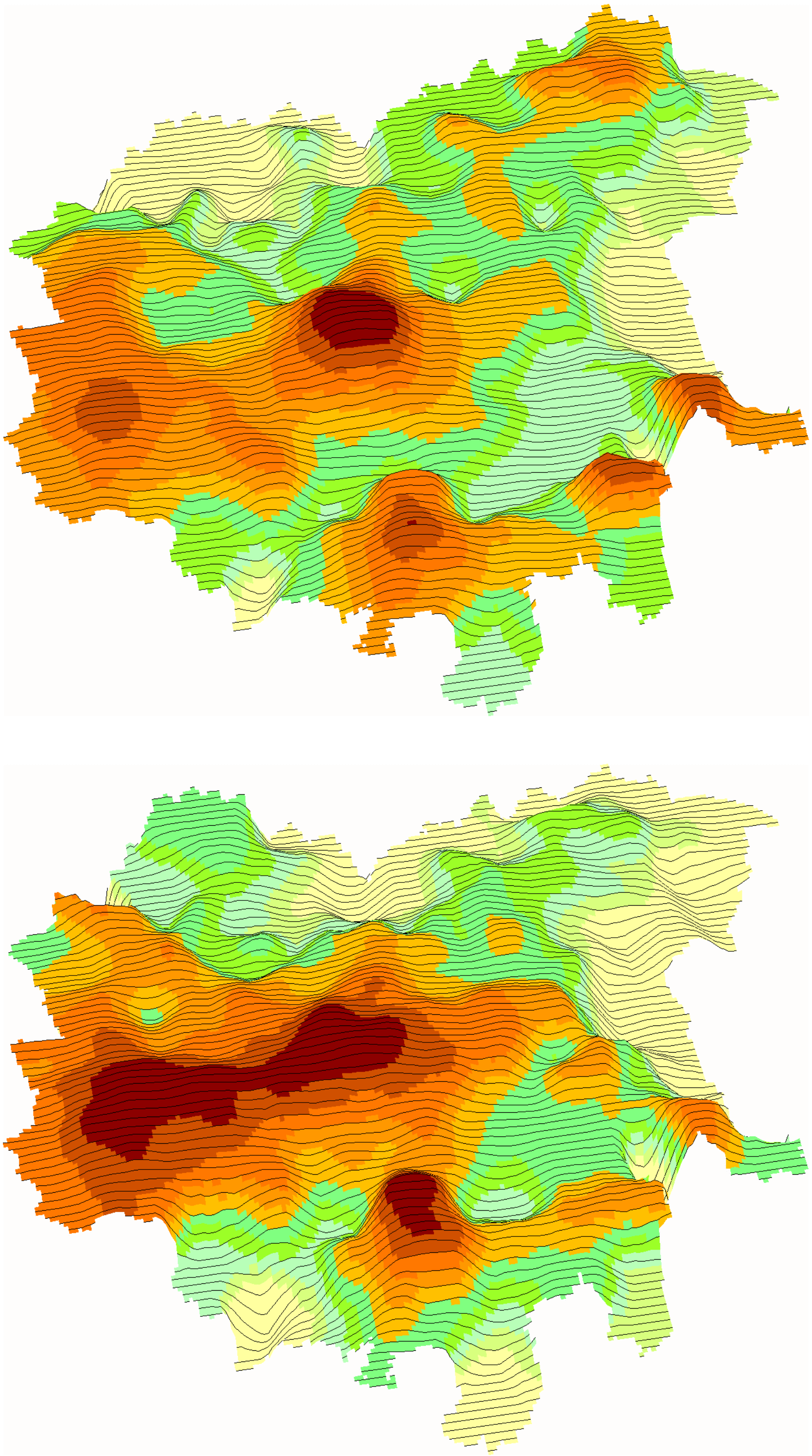


Figure 2.27 Accessibility of workplaces 1970 (top) and 2030 (bottom) in the Dortmund reference scenario

2.7 The Edinburgh model

2.7.1 The Edinburgh model study region

The Edinburgh modelled region consists of the City of Edinburgh and the surrounding regions called the Lothians and consists of 25 zones populated as shown in figure 15. The total population in the study area in year 2001 is 1.07 million.

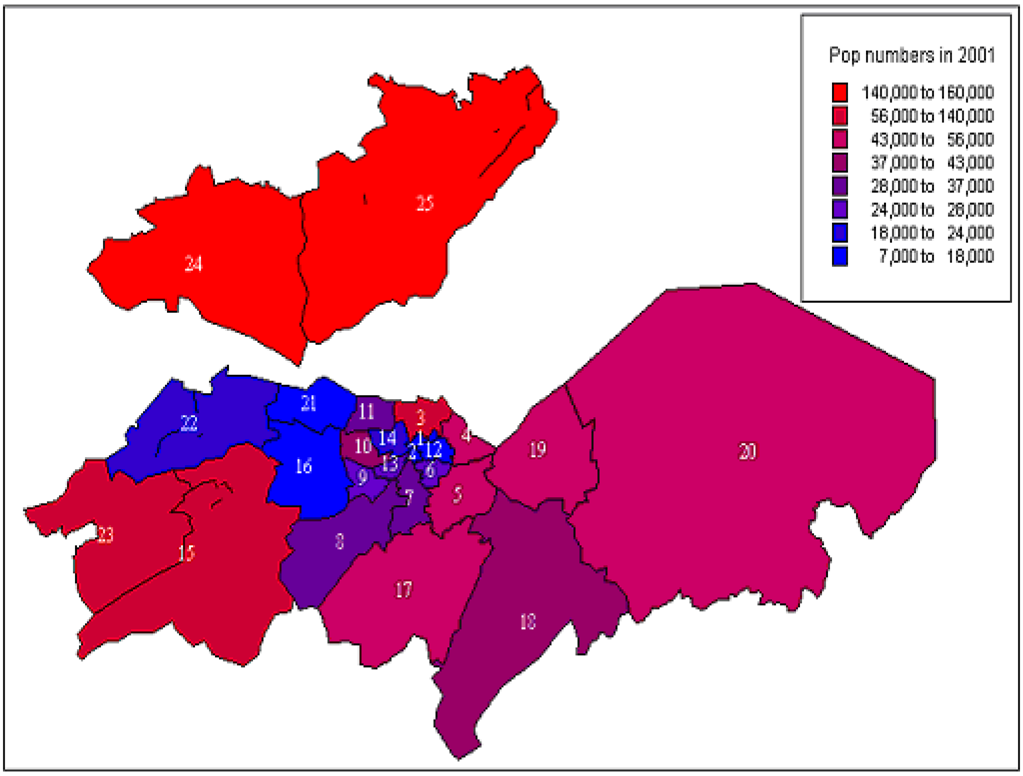


Figure 2.28 Population distribution by zone in year 2001

The "Edinburgh and Lothians Structure Plan", developed in August 2000, has provided a description of the region's features and its evolution by different profiles.

On the population side, the Lothians are forecasted to have the biggest population growth in Scotland with a potential increase of 50,000 people between the period 2001-2015. During this period, the number of households could increase by 52,000, of which 37% of totality is expected to be single person by 2015. The Plan has showed there would be a significant increase of old-aged people: 43% of population will be aged over 45 in 2015, compared to 37% in 2000, and people aged over 85 are expected to increase by 25% during this period.

On the economy side, the Plan has remarked a rapid growth: in particular the Lothians' economy has expanded rapidly and the current unemployment rate of 3.5% is the lowest on record. By the year 2015, a growth of 30,000 jobs is predicted in Lothian, expecting a 7% growth in manufacturing in West Lothian and most new jobs which will be created in the retail, finance and other service sectors.

On the transport side, the Plan has observed that car ownership has risen by 50% in Edinburgh since 1991, when 46% of Lothian households did not own a car. For 2015 the Plan has forecasted in-commuters to Edinburgh could rise to 100,000 from 88,000 in 2000 and 42,000 cars could enter the city daily on work trips.

In response to these trends and predictions Edinburgh have worked with the surrounding authorities to produce local transport plans which include most notably the inclusion of Light rail lines and a road user charging scheme based on a double cordon. Figure 2.29 shows the proposed routes for lines 1-3 of the light rail scheme.

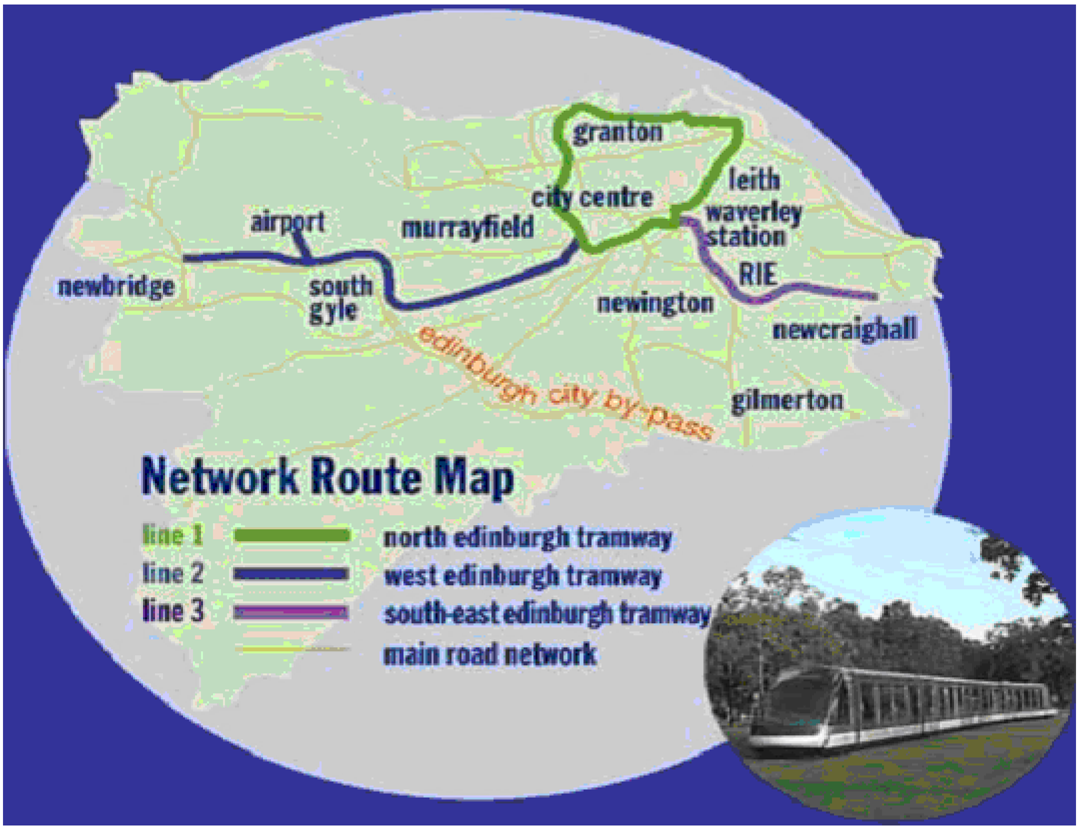


Figure 2.29 Proposed Tramway network (Source TIE-Edinburgh – Tram time)

2.7.2 The Edinburgh model description

The Edinburgh model is one application of the MARS (Metropolitan Activity Relocation Simulator) model, a strategic, interactive land-use and transport interaction (LUTI) model. MARS can be divided into two main sub-models: the land-use and the transport model. These two model parts are linked together with time lags (see figure 2.30).

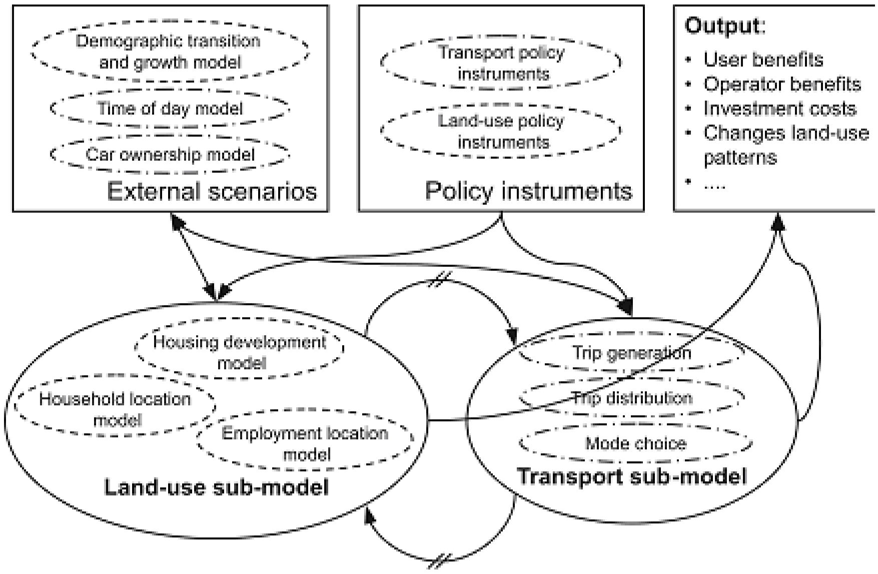


Figure 2.30 Development of the qualitative structure of MARS using causal loop diagramming

The model can deal with the transport and behavioural responses to several demand and supply-side instruments. These impacts can then be measured against targets of sustainability. MARS assumes that land-use is not a constant but is rather part of a dynamic system that is influenced by transport infrastructure. The interaction process is modelled using time-lagged feedback loops between the transport and land-use sub-models over a period of 30 years.

The links between the sub-models are shown in Figure 2.31. Accessibility is one of the outputs of the transport sub-model. Accessibility in the year n is used as an input into the location models in the year n+1. Workplace and residential location is an output of the land use model. The number of workplaces and residents in each zone in the year n is used as attraction and potential in the transport model in the year n+1. MARS iterates in a time lagged manner between the transport and the land use sub-model over a period of 30 years, i.e. a single MARS run consists of 30 iterations. At present the MARS model is being moved to a systems dynamic based platform.

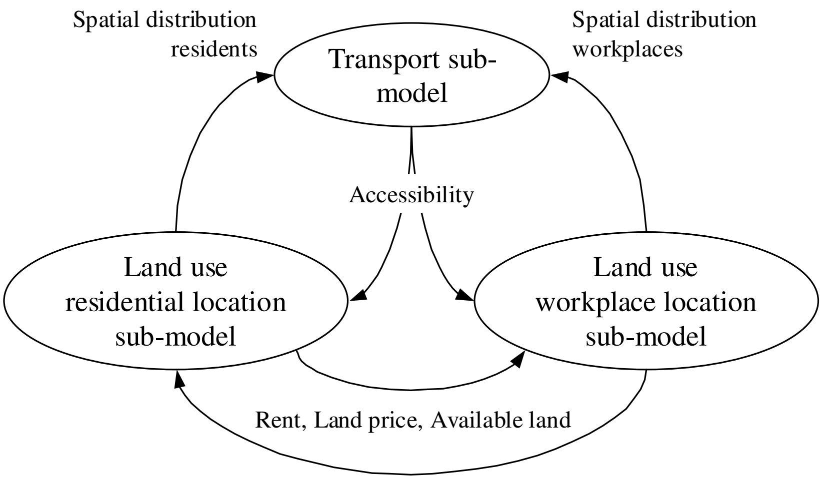


Figure 2.31 Link between the transport and the land use sub-model of the MARS

In the Edinburgh model, base year is 2001. Two person groups, with and without access to a car, are considered in the transport model. The transport model is broken down by commuting and non-commuting trips, including travel by non-motorised modes, and uses the concept of a constant travel time budget to model trip generation. The inter-peak is assumed to be un-congested.

The land-use model considers residential and workplace location preferences based on accessibility, available land, average rents and amount of green space available in 25 zones.

The total population growth in the study area as well as the change of workplace is assumed exogenously and the model computes location and following mobility patterns.

2.7.3 Key exogenous inputs, endogenous variables and outputs

The model requires input for the transport and land use model in the base year. The transport side includes transport costs, average speeds, distances, public transport frequencies, access/egress and interchange times, fares, tolls, taxes and parking costs. Where appropriate these are input as matrices for each OD pair. Exogenous inputs include commute trip rates and occupancy factors.

The land use model requires current population, average household size, average income, land uses for residential, commercial and green space per zone. Key exogenous factors which drive the model include growth in population, workplaces, car-ownership levels and licence holding.

Therefore, main elements which can be used as input to simulate scenarios are:

- factors development: population growth, employment growth, new floorspace, development controls etc.;
- transport supply: new/upgraded public transport services, changes to road capacity;
- transport demand: vehicle occupancy factors; commute trip rates
- mode attractiveness: perceived transport costs, tariffs, etc. Typical transport policies such as road user charging, fuel taxes, fare changes, parking charges etc.
- environmental performance: emission functions, fuel consumption models for the average car.

The Edinburgh MARS model provides typical transport outputs at either the study area level or by OD pair. Where relevant, output is also segmented by trip purpose or mode, etc. Main output elements are:

- on the transport side, traffic performance (pass-km), modal split (including slow modes), average speed and level of congestion;
- on the environmental side: fuel consumption, emission levels; total accident costs
- on the land use side: movements in population and business in response to transport strategies, floorspace, rents, etc..

All elements can be presented over time or can be combined to form a typical social welfare (CBA) analysis.

2.7.4 The Edinburgh model reference scenario

In the Edinburgh model reference solution the population is assumed to grow at 0.606% p.a. for the next 25 years followed by 0.2% p.a. until year 30 giving an increase of 17.5% over the 30 year period or an extra 187k residents. These assumptions are based on the Edinburgh and Lothians Structure plan (2000) and extrapolated over the evaluation period. During the same period workplaces are expected to grow by 24%.

The average level of car-ownership is 370 per 1000 population and this is assumed to grow by 1.2% p.a. based on UK TEMPRO data for the evaluation period. In the current model reference scenario the vehicle fleet is made up of "average cars" and their fuel consumption is based on UK DfT advice (Webtag Unit 3.5.6) i.e. the fuel consumption is dependent on a quadratic in average speed with assumptions about the proportion of diesel cars in the overall fleet.

In the base year the mode split is as shown in table 2.4.

Table 2.4 Base year mode splits (Source : 2001 Journey to work census and Scottish Household survey)

	Slow Mode	**Public Transport**	**Private Car**
Commute	26%	22%	52%
Other trips	29%	14%	57%

Figures 2.32-2.33 show the projection for mode splits over the 30 years period in the reference scenario. Note the decline in public transport and slow mode shares as car ownership increases. This effect is less strong in the peak due to growth in congestion over time.

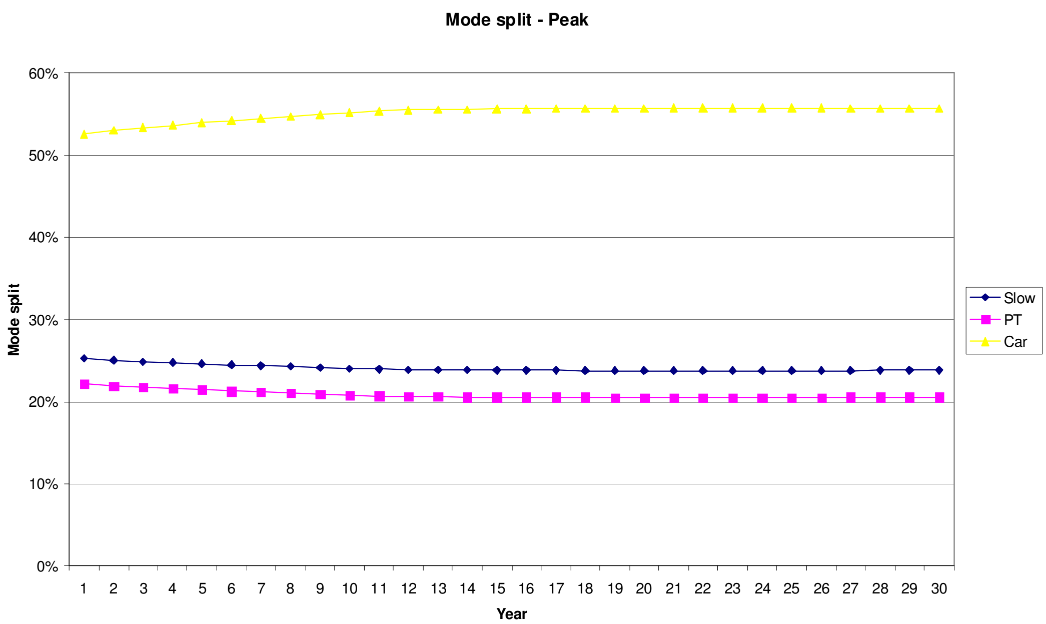


Figure 2.32 Mode split projection for the peak period – Reference Scenario

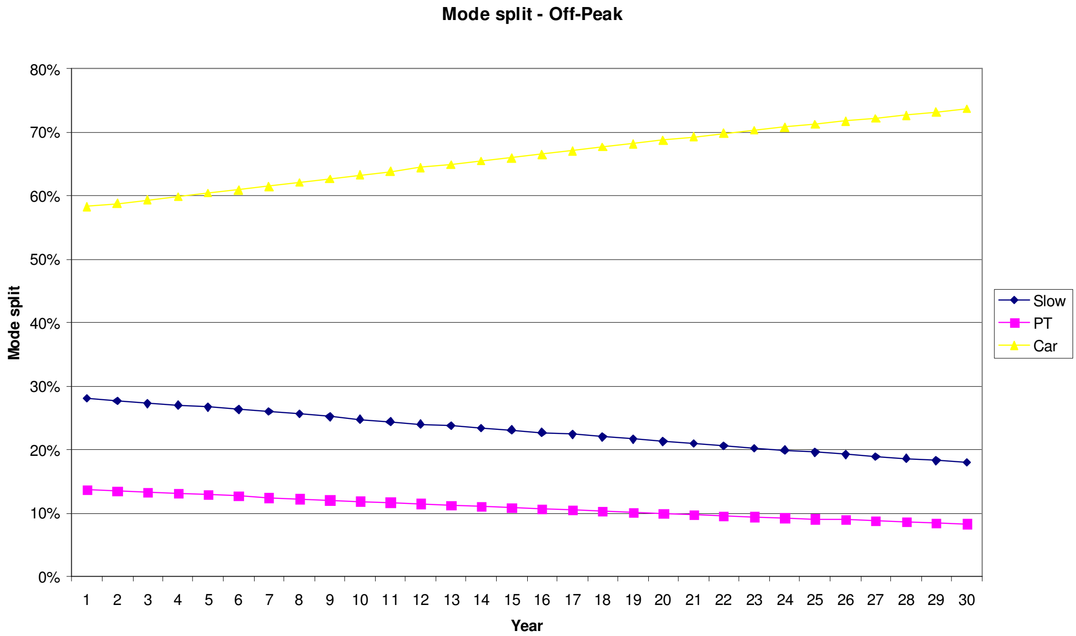


Figure 2.33 Mode split projection for the Off-peak period – Reference Scenario

2.7.5 The Edinburgh model references

(2000), Edinburgh and Lothians Structure Plan

2.8 The Helsinki model

2.8.1 The Helsinki model study region

The geographical scope of the model is the Region around Helsinki within about 100 km radius (pendel region, 1 657 000 inhabitants). The study area covers the Helsinki Metropolitan Region (946 000 inhabitants) and is divided into 53 +35 = 88 land use zones and transport zones. Seven external zones are also considered.

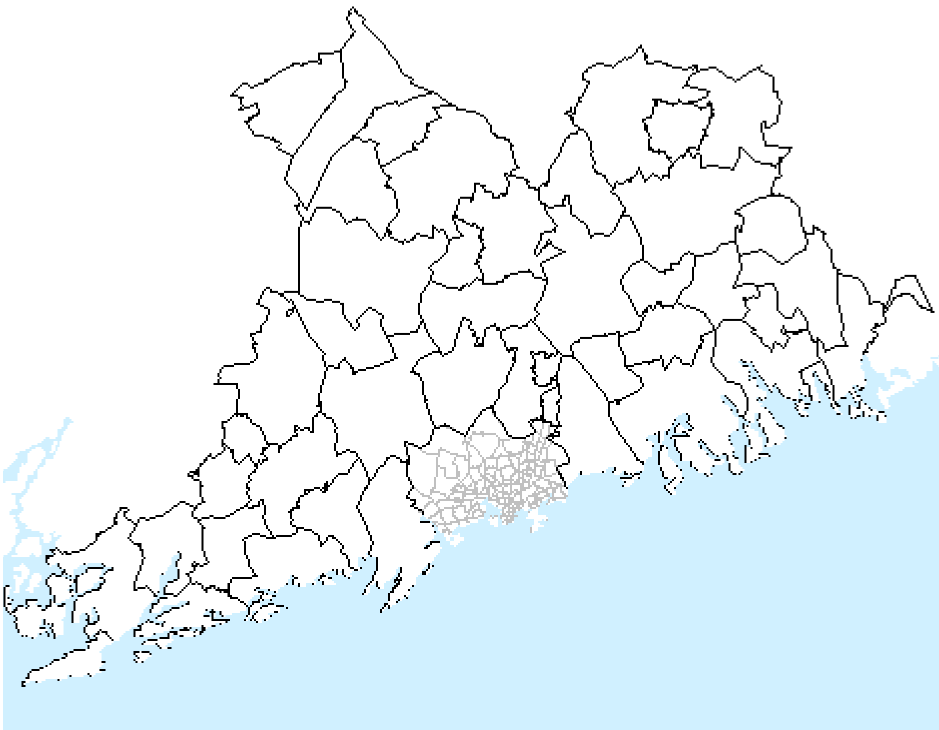


Figure 2.34 The Helsinki model zoning system

The Helsinki model area is actually a large region that includes both urban and rural areas. At the heart of the region lies Helsinki, the capital of Finland, surrounded by three smaller cities. Together they form the Helsinki Metropolitan Area. Additionally, included in the model area is a relatively large surrounding region with smaller cities and towns lying within the Metropolitan Area's commutershed. The total land area is 13 827 km2 of which the metropolitan region is 743 km2.
Helsinki region accounts for about one third of Finland's GDP. In addition to its administrative status as the capital city and home for industry headquarters, the economy of the region is based on retail, wholesale and private services. The region, therefore, has a trade surplus with the rest of the country. While the traditional manufacturing industries have been declining, the share of high-technology industries and services has been

growing. The large and concentrated traditional industries such as metal and paper are not typically located in the region. Consequently, foreign exports are not so dominant as for the rest of the country. Consistent with its high population density, the level of imports is high.
A sign of the structural change in the 1990s is the stratification of population and regions. The spread in income levels has increased along with the demand for the less educated labour force diminishing. The Helsinki Metropolitan area and its surroundings form a region that has been the most successful one in the country, but also within the region itself certain areas are prosperous while others are impoverished.
The Metropolitan Area faces a rapid population growth from the present 920 000 to 1.1 million inhabitants by the year 2020. This increases the pressures of urban sprawl as well as the use of natural and other green areas. It is expected that Helsinki can only accommodate less than one-fourth of the forecast growth, the rest being directed to the other cities of the Metropolitan Area.
It is predicted that mobility will increase faster than the population. One reason for this is the decentralising land use, but also the number of trips is expected to grow. The share of public transport has been dropping significantly during the past few decades, but this decline is now anticipated to have reached its low. If policies favouring public transport will be pursued, it is forecast that the share of collective transport will start slightly rising again.
Traffic speed in the Metropolitan Area will continue its gradual downward trend unless the increase in the use of the private car can be curbed. The growing traffic will increase the noise nuisance experienced by the in-habitants. It has been estimated that the population living in areas where the daily average noise level exceeds 55 dB(A) will increase by about 15% to more than 200 000 people by 2020.
Currently, the concentrations of nitrogen dioxide and particulate matter exceed the guidelines annually. The levels of nitrogen dioxide are expected to fall because of the technical development of the vehicle fleet, but high particulate concentrations are still expected in the busiest traffic environments. The air quality in general is improved due to the sea environs. Acidic fallout exceeds the critical load because of trans-boundary emissions.

2.8.2 The Helsinki model description

The Helsinki model was originally built in early 90s and has since then been regularly updated and expanded. It currently corresponds with the Helsinki Metropolitan Area Transport Master Plan. The model was last updated in 2003 - 2004 for the assessment of the Transport Master Plan.
The base year of the model is 2001; the model produces forecasts for years 2006, 2011, 2016 and 2021.
The Helsinki model was built using the MEPLAN software and it belongs to the group of the integrated land-use/transport models. For that reasons, two main modules can be recognised: a land use model and a transport model. An interface module provides the required connections between the two main modules in both directions.
In the land model, the local economy is represented by an input-output matrix where the interacting factors are segmented into four groups. The first group includes eight economics sectors. The second group concerns population groups (8 household types, 3 car ownership types). As third sector, floorspace is modelled according to its use (housing, employment).

The mobility of individuals is determined by the interaction between economic sectors and the population groups. Passenger trips are divided into four main trip purposes: Working, Education, Shopping and Other Purposes.
The transport model deals with the modal split and assignment of trips. Transport infrastructure is represented by a network of links and nodes for all modes, each one with detailed capacity and technical standards. Description of train and bus services and walking/cycling include routes. Four passenger modes are allowed on the network: car, bus/tram, train and walking/cycling. One mode is allocated for freight.
The integration of land-use and transport in the model framework allows not only to compute endogenously the trips matrices but also to simulate feedbacks from the transport system to land use. More specifically, changes of locations may be induced by variations of transport costs and accessibility which are the effect of increasing congestion, new infrastructures, additional services and so on. Effects on land-use are lagged (i.e. changes on the transport side at the year t are reflected on land use only at time t+n) to take into account that re-location choices need some time to be put in practice.
The Helsinki model also computes impacts on environment, that is consumption of fuels and emissions (of road modes only). The simulation uses consumption and emission functions linked to vehicle kilometres travelled. In turn, functions depend on the average composition of the vehicles fleet.

2.8.3 Key exogenous inputs, endogenous variables and outputs

The Helsinki model computes matrices endogenously on the basis of input/output parameters and the location of the various factors. Modal split and assignment phases use network features, transport costs and calibrated modal constants as input.

Therefore, main elements which can be used as input to simulate scenarios are:
- factors development: population growth, employment growth, new floorspace, etc.;
- transport supply: new/upgraded links, new/upgraded public transport services, etc., distribution centres, etc.;
- transport demand: share of trips in the peak hour, vehicle occupancy factors;
- mode attractiveness: perceived transport costs, tariffs, etc. either on a link basis or per length unit or time unit, etc.;
- environmental performance: emission functions, fuel consumption factors.

The Helsinki model provides several variables as output; variables are zone-based, i.e. their value is available for each model zone. Where relevant, output is also segmented by trip purpose or mode, etc. Main output elements are:
- on the transport side, traffic performance (pass-km, tonnes-km), modal split, load on links, average speed and level of congestion;
- on the environmental side: fuel consumption, emission levels;
- on the regional side: zone attractiveness, floorspace price, etc..

2.8.4 The Helsinki model reference scenario

The Helsinki Metropolitan Area Council has prepared a long-term transport plan for the year 2020. This plan and the projects included in the plan, their phasing and cost estimates are illustrated in the figure below. This plan forms the basis for local policies, which are variations of the basic plan.

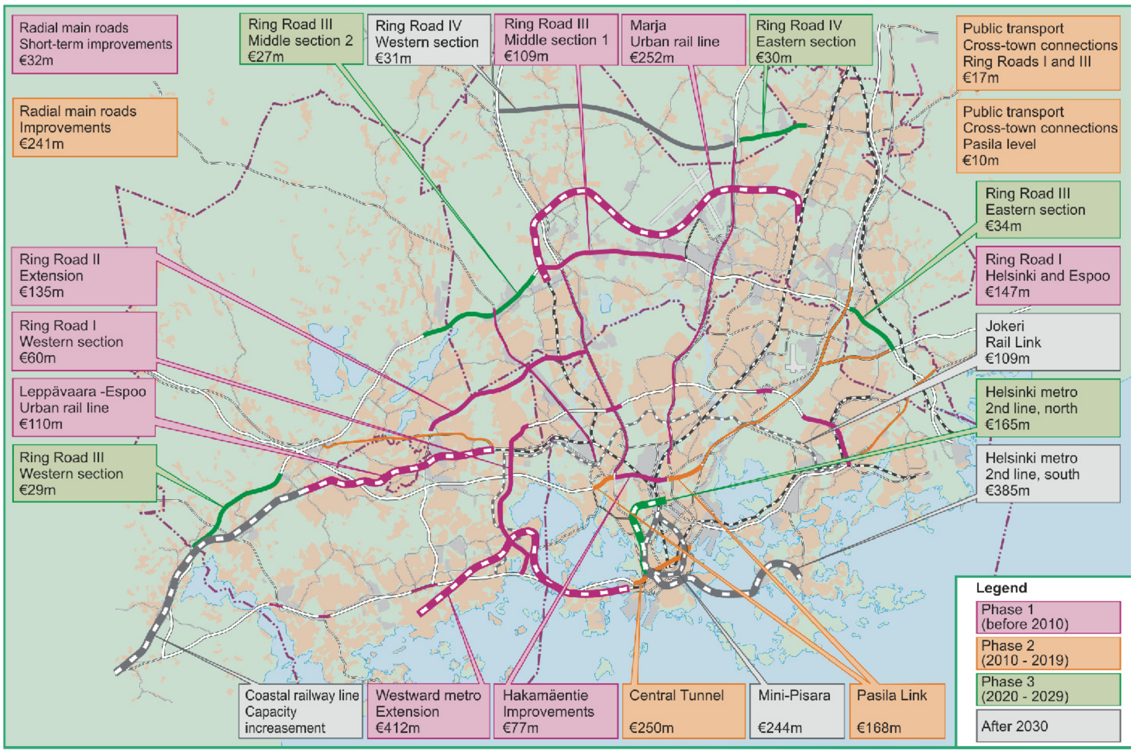


Figure 2.35 Map of the projects included in the Helsinki reference solution including cost estimates

For several years there has been a wide consensus in the Helsinki Metropolitan Area that transport investment resources have been allocated approximately evenly between the private transport (road) sector and public transport sector (mainly commuter rails and metro). This plan follows this principle. At the same time the local authorities try to locate people and places of employment near the public transport corridors. Through the parking pricing policy and limiting the number of the parking places in the CBD area the share of the PT has been quite satisfied in the radial corridors.

In the reference scenario some common assumptions in the model have an influence on the transport demand development: GDP real growth about 2 % annually and the assumption that there are differences in the development of the transport unit prices (in real prices) for different modes (see figure 2.36).

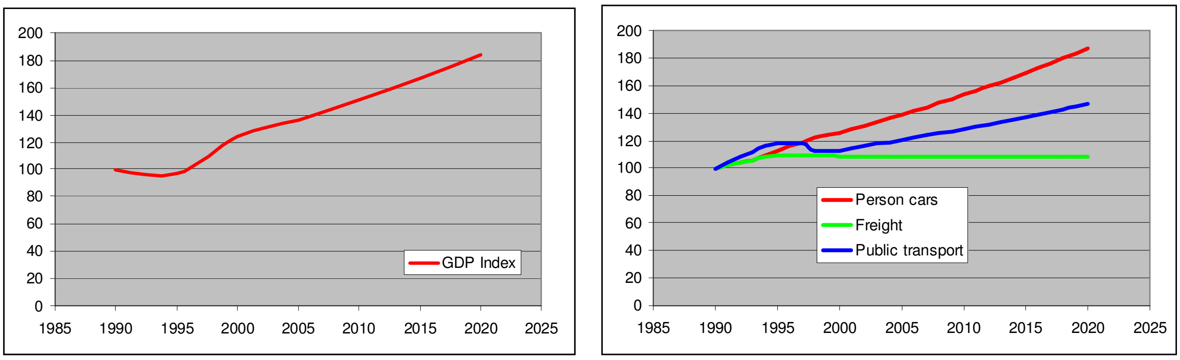


Figure 2.36 Forecast of GDP index and transport real prices in the Helsinki model

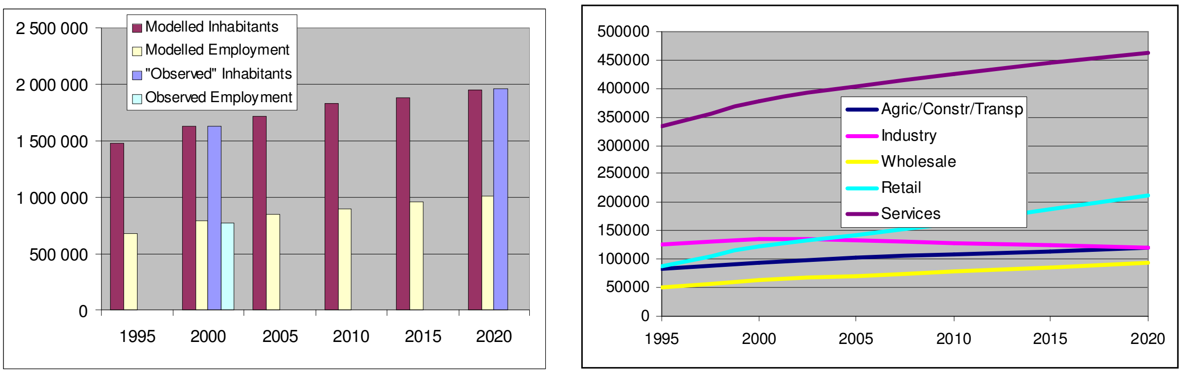


Figure 2.37 Forecast of the inhabitant and employment totals and employment by sectors in the Helsinki model area (including pendel region)

In the Helsinki Metropolitan Area car ownership grows from 345 in 2000 to about 450 in 2020, which is about 10 % lower than the average in Finland. One reason for it, beside the good public transport system, is the average household size, about 2.1 person per household. The number of single, often elderly single person households, is still increasing.

2.9 The South Tyrol model

2.9.1 The South Tyrol model study region

The geographical scope of the model is the South Tyrol region, corresponding to the Italian province "Alto Adige". The study area is divided into 98 zones for land use and transport. Six external zones are also considered.

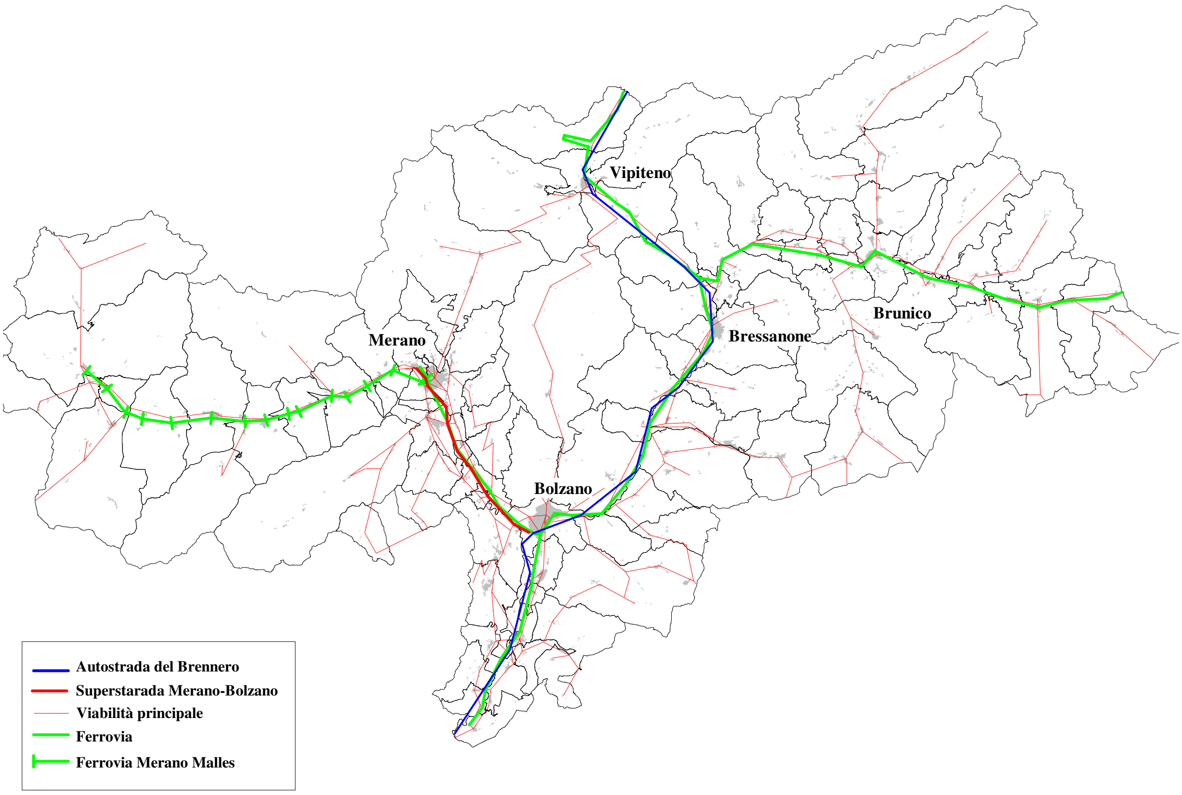


Figure 2.38 The South Tyrol model zoning system, road and rail network

The South-Tyrol area is a sparsely populated region (64 inhabitants per km2); covered by forest and rural area for 75 percent of its surface. The biggest municipality in terms of population is the city of Bolzano, with 97 232 inhabitants, surrounded by few smaller cities (Merano, Bressanone). The population development in South Tyrol has brought a moderate growth of 0.5% p.a.in last ten years.

Because of its land use features, South Tyrol has a centuries old farming tradition. Even if today agriculture no longer has the same socio-political importance as other economic sectors that it had decades ago, in 2000 about 24 500 persons (11.5 per cent of the working population in South Tyrol) were employed in the sector of agriculture. Nevertheless the employment rate in this sector decreased over the last years.

At present the industrial sector has a significant role in the economic life of the region, with 27 000 employees in 2000, what corresponds to 13 per cent of all those in work. Furthermore the South Tyrol geographical position as a transit land between important economic areas makes trade and commerce some of the most important elements in the economic structure. Particularly, South Tyrol has a remarkable role, nationally and internationally, as a goods transhipment centre.
Finally South Tyrol is a land in the heart of the Alps, with seven Nature Parks covering the 17 percent of the area of the Province. So in the last decades tourism has become one of the most important pillars of the South Tyrol economy: in 2000 South Tyrol registered a total of four million holiday-makers, coming from many different countries (Germany, Austria, Switzerland,…) and from the rest of Italy.
On the transport side the area is criss-crossed by important traffic routes and rail networks; particularly important is the Brenner pass, one of the main gates connecting North and South Europe.

2.9.2 The South Tyrol model description

The South Tyrol model was originally built in 1993 as a supporting tool for the Transport Master Plan. The model was updated in 2001 for the assessment of the Regional Transport Plan. The base year of the model was updated to 1998; the model produces forecasts for years 2007, 2014 and 2020.
The South Tyrol model was built using the MEPLAN software and it belongs to the group of the integrated land-use/transport models. For that reasons, two main modules can be recognised: a land use model and a transport model. An interface module provides the required connections between the two main modules in both directions.
In the land model, the local economy structure is represented by an input-output matrix, where the interacting factors are segmented into four groups. The first group includes twelve economics sectors ranging from agriculture to foodstuff production to tourism. A specific sector is used to compute value added. The second group concerns population groups which include both residents and tourists. As third sector, floorspace is modelled according to its destination (e.g. residential floorspace, agricultural land, etc.). The last group of factors are used as attractors for trips generated in the area.
The mobility of individuals is determined by the interaction between economic sectors and the population groups. Passenger trips are divided into four main trip purposes: Working, Education, Tourism, and Other Purposes.
The interaction between the economic sectors gives rise to a matrix of economic trades which is converted into freight traffic flows by means of volume-to-value ratios. Three freight transport flows are modelled: bulk, general cargo and container.
The transport model deals with the modal split and assignment of trips. Transport infrastructure is represented by a network of links and nodes for all modes, each one with detailed capacity and technical standards. Description of train and bus services includes routes and frequency of services as well as interchange functions. Particular attention was paid to simulating the demand of tourist travel, both in terms of distribution to different holiday resorts and daily excursions. Four passenger modes are allowed on the network: car, bus, coaches and train. Three modes are available for freight: heavy truck, light truck and rail.

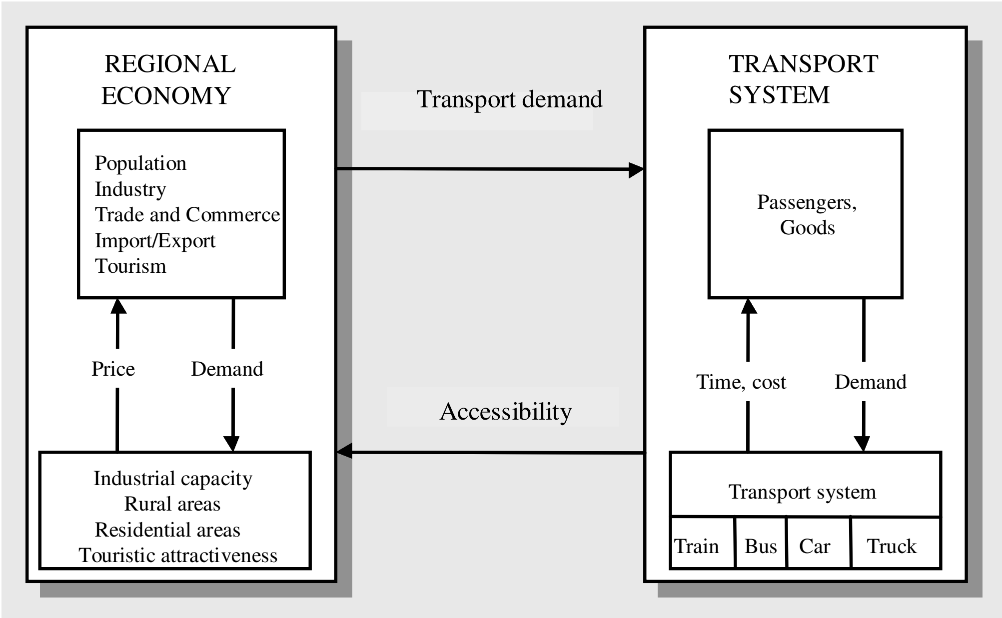


Figure 2.39 The South Tyrol model structure

The integration of land-use and transport in the model framework allows not only to compute endogenously the trips matrices but also to simulate feedbacks from the transport system to land use (see Figure 2.37). More specifically, changes of locations may be induced by variations of transport costs and accessibility which are the effect of increasing congestion, new infrastructures, additional services and so on. Effects on land-use are lagged (i.e. changes on the transport side at the year t are reflected on land use only at time t+n) to take into account that re-location choices need some time to be put in practice.
The South Tyrol model also computes impacts on the environment, that is consumption of fuels and emissions (of road modes only). The simulation uses consumption and emission functions linked to speed (on a link by link basis). In turn, functions depend on the average composition of the vehicles fleet.

2.9.3 Key exogenous inputs, endogenous variables and outputs

The South Tyrol model computes matrices endogenously on the basis of input/output parameters and the location of the various factors. Modal split and assignment phases use network features, transport costs and calibrated modal constants as input. Therefore, main elements which can be used as input to simulate scenarios are:

- factors development: population growth, employment growth, new floorspace, etc.;
- transport supply: new/upgraded links, new/upgraded public transport services, etc., distribution centres, etc.;
- transport demand: volume-to-value ratios, share of trips in the peak hour, vehicle occupancy factors;
- mode attractiveness: perceived transport costs, tariffs, etc. either on a link basis or per length unit or time unit, etc.;
- environmental performance: emission functions, fuel consumption factors.

The South Tyrol model provides several variables as output; variables are zone-based, i.e. their value is available for each model zone. Where relevant, output is also segmented by trip purpose or mode, etc. Main output elements are:

- on the transport side, traffic performance (pass-km, tonnes-km), modal split, load on links, average speed and level of congestion;
- on the environmental side: fuel consumption, emission levels;
- on the regional side: zone attractiveness, floorspace price, etc..

2.9.4 The South Tyrol model reference scenario

The reference scenario of the South Tyrol model is based on the expected trends concerning the main socio-economic and environmental variables (derived by a regional study on demographic and economic forecasts[5]) implemented in the land use module.

Population development is assumed to increase moderately (with reference to 1999) by 3.5% in 2007, 5.3% in 2014 and 6.4% in 2020 in South Tyrol as a whole. Nevertheless the growth is different in the main urban centres: the city of Bolzano decrease its population by 0.3% per year, while the other cities expect a positive growth by 0.4-0.6% per year.

On the economic side, forecasts describe an increase of employment by 1% in 2007, 1.2% in 2014 and 0.8% in 2020. Development is different for each economic sector, so some transformations in land use allocation are involved in the model, considering also the Regional Plan forecasts. In particular industrial, rural and tertiary areas have a significant increase with reference to 1999 (84%, 60% and 48% in 2020) while residential surfaces have a moderate growth (6% in 2020).

On the transport supply side, the reference solution of the South Tyrol model includes the infrastructural projects and transport policy measures planned at local, national and European level, with reference to the time thresholds of years 2007, 2014 and 2020.
The main interventions planned by regional authorities are:

- the completion of transport investment on the local road network;
- the improvement of the rail supply at the regional level: new “Val Venosta” railway line, intermodality centre in Brunico.

The improvement of the rail supply along the Brenner route is also included in the reference scenario and is part of the national and European projects.
Still on the supply side, it is assumed a renewal of the road vehicle fleet (cars and trucks) according to the MEET[6] projections for Italy, adjusted in order to take into account the base year fleet in South Tyrol.

On the demand side, the development of the socio-economic variables introduced in the land use model produced a growth of the passenger demand (with reference to 1999) by 5.7% in 2007, 9.4% in 2014 and 11.6% in 2020. The largest increment concerns mobility among the internal zones of the region, whereas the trips to and from the external zones

[5] IRE, 1999, "L'Alto Adige proiettato nel futuro"
[6] TRL, 1999, *MEET - Methodology for calculating transport emissions and energy consumption*, European Commission

show a moderate growth, even if the long-distance traffic crossing South Tyrol is assumed growing at a faster pace (with reference to 1999: 7.7% in 2007, 15% in 2014 and 22% in 2020). Modal split is not changed in a significant way.

2.9.5 The South Tyrol model references

IRE, 1999, "L'Alto Adige proiettato nel futuro"

TRL, 1999, MEET - Methodology for calculating transport emissions and energy consumption, European Commission

2.10 Summary and comparison of models features

In this section we provide a comparison of main features of the models described in this section.

Table 2.5 European models features

Features		ASTRA	SASI	POLES
Base year		1990	1981	2000
Time threshold		2020	2021	2020
Time interval		1 year	1 year	1 year
Geographic coverage		EU 25 + Bulgaria, Norway, Romania and Switzerland	EU 25 + Norway, Switzerland, Bulgaria, Romania, Albania, Bosnia-Herzegovina, Croatia, Macedonia and Yugoslavia	World regions
Zoning system		Nuts 2	Nuts 3	Country (EU25) or aggregation of countries
Passenger mode	Car	Yes	Yes	Yes
	Train	Yes	Yes	Yes
	Bus	Yes	Yes	Yes
	Ship	No	No	No
	Plane	Yes	Yes	Yes
	Slow modes	Yes	No	No
Freight mode	Truck	Yes	Yes	Yes
	Train	Yes	Yes	Yes
	Ship	Yes	Yes	No
	Plane	No	Yes	No

Table 2.6 Local models features

Features		Brussels	Dortmund	Edinburgh	Helsinki	South Tyrol
Base year		2001	1970	2001	2001	1999
Time threshold		2015	2030	2030	2021	2020
Geographic coverage		Metropolitan area	Metropolitan area	Metropolitan area	Metropolitan and rural area	Rural and urban area
Area extension (km^2)		4 332	2 014	2305	13 827	7 400
Population base year		2 900 000	2 600 000	1 070 000	1 657 000	457 000
Passenger mode	Car	Yes	Yes	Yes	Yes	Yes
	Train	Yes	Yes	No	Yes	Yes
	Bus	Yes	Yes	Yes	Yes	Yes
	Walking / cycling	Yes	Yes	Yes	Yes	No
Freight	Freight	Yes	No	No	Yes	Yes

Chapter 3 The models linkages for scenarios simulation

3.1 Introduction

The objective of linking the models is not intended in the STEPs project as building of a “supermodel” where the single tools are tightly integrated. Instead, the different models will continue working as independent tools and the integration will consist in input and output exchange and comparisons. From this point of view, the issue of linking models should deal with three main aspects:

a) defining what input should be exchanged from one model to another and identifying a procedure to make sure that the exchange is carried out in an effective way;
b) ensuring that results regarding relevant variables simulated are consistent, when more than one tool is used;
c) defining how to use the whole model framework to simulate policies.

Preliminary ideas are being discussed at this stage of the project. Such ideas will be reviewed as soon as the scenarios are defined (completion of WP3) and throughout the modelling process. A complete description of the models linkages will be provided, together with the simulation results, in D4.2, which is the final deliverable of WP4.

3.2 Scenarios simulation

The modelling of the STEPs scenarios is needed to derive conclusions about the likely impacts of policies in the fields of technology, infrastructure, pricing and regulation under different assumptions about the evolution of energy supply.

6 different scenarios have been defined in STEPs, analysing three policy strategies in two different contexts of energy supply: *A:* with a general accepted energy supply forecast; *B*: with a worst case energy supply forecast (scarcity of energy). Policy strategies are:

- *0: Business as usual* (unchanged policies towards transport and energy sectors),
- *1: Technology investments* (like infrastructure),
- *2: Demand regulation* (taxes, toll, etc.).

A0 will be the reference scenario to which the results of the other scenarios will be compared later on in the project.

Table 3.1 STEPs scenarios

	Business as usual	Technology investments	Demand regulation
Generally accepted energy supply forecast	A0	A1	A2
Worst case energy supply forecast	B0	B1	B2

In the modelling exercise, comparability is of prime importance and there are three types of comparability involved in this case:

(a) Comparability between the reference scenario A0 and the policy scenarios A1 and A2. This implies that the reference scenario and the policy scenarios must be identical in every respect except in the policies of interest. This comparability is necessary for making statements about the impact of the policies.
(b) Comparability between the A scenarios and the B scenarios. This implies that the A scenarios and the corresponding B scenarios must be identical in every respect except in the different assumptions about energy prices. This comparability is necessary for making statements about the impact of different energy supply environments.
(c) Comparability between models. This comparability implies that the assumptions made in each model are harmonised as much as practically possible. This comparability will be limited by the inevitable differences between the models and between the cities and regions modelled.

In order to guarantee these three levels of comparability, models reference scenarios will be harmonised. The reference scenario will be specified in terms of the same parameters as the policy scenarios: i.e. in terms of the temporal evolution of energy efficiency, emission factors, vehicle fleet composition, pricing and taxation, and perhaps infrastructure. The evolution of the parameters will be specified relative to the base year for all scenarios.

The differences in the results between the policy scenarios and the reference scenario can be unambiguously attributed to the differences in these parameters (comparability "a"). The A-scenarios differ from the corresponding B-scenarios only by the different assumptions about the evolution of energy prices; therefore the differences between them can be clearly attributed to the differences in energy prices (comparability "b"). Comparisons between the results of different models and different cities or regions (comparability "c") are possible within the constraints of the inevitable differences between models and cities or regions.

3.3 A preliminary scheme for models linkages

In STEPs project, each tool covers specific pieces of analysis and (when possible) inputs are exchanged to ensure consistency. In coherence with this approach, the simulation of the scenarios, once they are quantified into changes of a set of variables, would consist in implementing such exogenous changes into the relevant models and, in case, to feed other models with the results of the simulation. Finally, all models produce results at different level (global results or local results) and each model produces results according to its specialisation. In particular, regional/local models would not be requested to come up with the same (comparable) results, instead, the specific potential of each model should be considered to provide different indicators.

For instance, the Edinburgh and the Dortmund models have a very detailed description of residential location and can provide results on the effect of policies on re-location of households and workplaces; the Helsinki model is focused on the metropolitan area of the city but covers a larger area and therefore can give information of how effects of policies changes outside of a metropolitan area, The South-Tyrol model concerns a sparsely populated region rather than a metropolitan area and can therefore be focused on results in rural areas, etc.

As an example of the intended approach, which will be tested in the next stage of the project, figure 3.1 illustrates the way in which a given scenario could be modelled. Please note that links between European models and local models do not affect all pairs of models (e.g. employment and migration data are indicatively provided by SASI to Dortmund model only). All the models produce results and data for the calculation of the indicators.

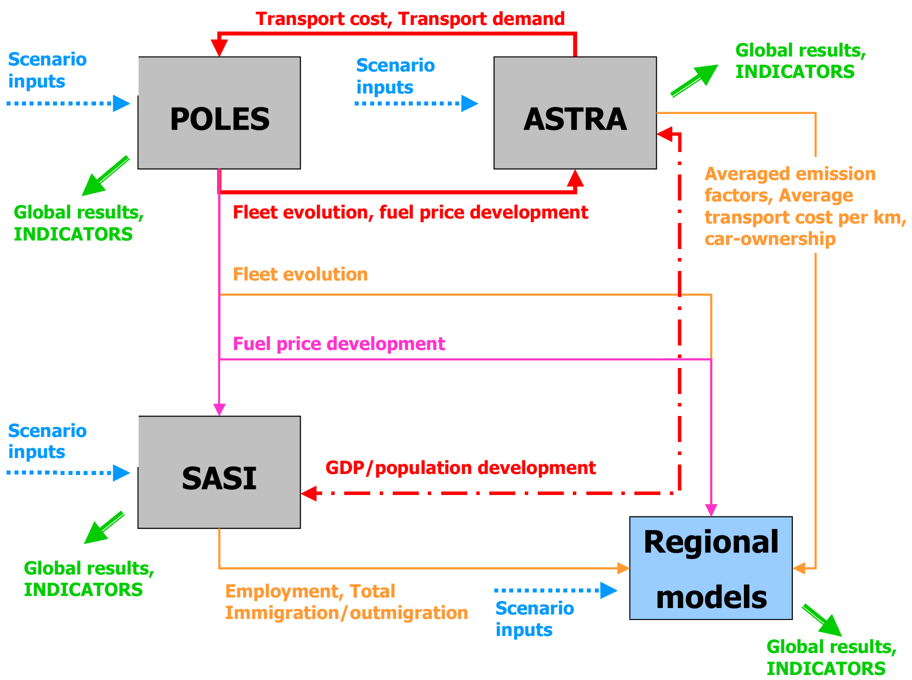


Figure 3.1 A preliminary scheme for linking models in scenarios simulation