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The SASI Model: Model Software

*Deliverable D13 of the EU Project
Socio-Economic and Spatial Impacts of
Transport Infrastructure Investments
and Transport System Improvements
(SASI)*

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1. Summary

The Trans-European Transportation Networks (TETN) programme is one of the most ambitious initiatives of the European Union since its foundation. However, the impacts of this programme on the social and economic development of the European regions are uncertain. In the face of conflicting policy goals of the European Union, the consistent prediction and transparent evaluation of likely socio-economic impacts of major infrastructure investments will therefore become of great political importance for European decision makers.

The relationship between transport infrastructure and economic development has become more complex than ever. There are successful regions in the European core confirming the theoretical expectation that location matters. However, there are also centrally located regions suffering from industrial decline and high unemployment. On the other side of the spectrum the poorest regions, as theory would predict, are at the periphery, but there are also prosperous peripheral regions such as the Scandinavian countries. To make things even more difficult, some of the economically fastest growing regions are among the most peripheral ones.

The central task of the SASI project is to identify the way transport infrastructure contributes to regional economic development in different regional contexts. The main goal of the project is to design an interactive and transparent modelling system for forecasting the impacts of transport infrastructure investments and transport system improvements, in particular of the TETN, on socio-economic activities and developments in Europe. For that purpose the impacts have to be measured by means of indicators that can be related to the policy goals of the European Union.

This report, which is the eleventh deliverable of the EUNET project and the fifth of the SASI sub-project, describes the implementation of the SASI model based on the previous SASI Deliverables D4 (Bökemann et al., 1997), D5 (Schürmann et al., 1997), D7 (Masser et al., 1997) and D8 (Wegener and Bökemann, 1998).

The SASI model is a recursive simulation model of socio-economic development of 201 regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments and transport system improvements, in particular of the TETN. The model has six forecasting submodels: *European Developments*, *Regional Accessibility*, *Regional GDP*, *Regional Employment*, *Regional Population* and *Regional Labour Force*. A seventh submodel calculates *Socio-Economic Indicators* with respect to efficiency and equity. For each region the model forecasts the development of accessibility, GDP per capita and unemployment in one-year increments until the forecasting horizon 2016. 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.

The SASI model 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), which makes it possible to model regional unemployment. The impacts of transport infrastructure investments and transport system improvements on regional production is modelled by regional production func-

tions in which, besides non-transport regional endowment factors, sophisticated spatially disaggregate accessibility indicators are included.

The study area of the model are the regions of the European Union with the other European countries, including the European part of Russia, considered as external regions. This makes the model suited to model spatial redistribution effects of the TETN within the European Union. However, it is not presently intended to model the aggregate macroeconomic multiplier effects of transport investments on the European economy as a whole. As the model does not contain a full transport submodel, it does not take network congestion or intermodality of transport networks into account.

This deliverable describes the software of the SASI model i.e. tools for network scenario generation, the model input files, the model database and output files, the model software itself and finally the programmes developed for analysing and visualising the model results.

The results of the demonstration scenario simulations will be presented in the forthcoming Deliverable D15. A joint final report will summarise the work of both EUNET and SASI.

2. Introduction

2.1 Problem Statement

Article 2 of the Maastricht Treaty states as the goals of the European Union the promotion of harmonious and balanced economic development, stable, non-inflationary and sustainable growth, convergence of economic performance, high levels of employment and social security, improvement of the quality of life and economic and social coherence and solidarity between the member states. A prominent role for the achievement of these goals play the envisaged trans-European networks in the fields of transport, communications and energy (TEN). Article 129b of the Treaty links the trans-European networks to the objectives of Article 7a (free traffic of goods, persons, services and capital in the Single European Market) and Article 130a (promotion of economic and social cohesion). In particular, the trans-European transport networks (TETN) are to link landlocked and peripheral areas with the central areas of the Community.

More recently Decision No. 1692/96/CE of the European Parliament and of the Council (European Communities, 1996) states that "the establishment and development of TEN contribute to important objectives of the Community such as the good functioning of the internal market and the strengthening of the economic and social cohesion" and underlines that TETN have "to ensure a sustainable mobility for persons and goods, in the best social, environment and safety conditions, and to integrate all transport modes".

In physical and monetary terms the trans-European transport networks are one of the most ambitious initiatives of the European Community since its foundation. The masterplans for rail, road, waterways, ports and airports together require public and private investment between 400 and 500 billion ECU until the year 2010, nearly a quarter of which are needed for fourteen priority projects proposed at the 1995 EU summit in Essen.

However, the programme is not undisputed. Critics argue that many of the new connections do not link peripheral countries to the core but strengthen the ties between central countries and so reinforce their accessibility advantage. Only forty percent of the new motorways in the road masterplan are in peripheral countries, whereas sixty percent are in countries with an already highly developed road infrastructure. Some analysts argue that regional development policies based on the creation of infrastructure in lagging regions have not succeeded in reducing regional disparities in Europe, whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions. From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region, for instance, makes it easier for producers in the peripheral region to market their products in large cities, however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies.

In addition there are environmental concerns. High-speed rail corridors or multi-lane motorways consume environmentally valuable open space in high-density metropolitan areas and cut through ecologically sensitive habitats and natural regions outside of cities and in addition contribute to the general trend of inducing more and higher-speed travel and goods transport.

In the face of these conflicting goals the consistent prediction and the rational and transparent evaluation of likely socio-economic impacts of major transport infrastructure investments become of great political importance both for the European Union and for its member states. This is also underlined by the European Commission's *Cohesion Report* (1997) which emphasises that "regions should ensure that policy success is measurable, that results are regularly monitored, and that the public and political authorities are regularly informed of progress."

2.2 Objectives of the SASI Project

The SASI project aims at the development of a comprehensive and transferable methodology for forecasting the socio-economic and spatial impacts of large transport investments in Europe, in particular of different scenarios of the development of the trans-European transport networks (TETN) planned by the European Union. With respect to the cohesion objective of the European Union the model is to answer the question whether the TETN will lead to a reduction of regional disparities and which regions of the European Union are likely to benefit from the TETN and which regions are likely to be disadvantaged.

To achieve this objective the project focuses on

- developing a comprehensive, consistent and transferable methodology for the prediction of the impacts of transport infrastructure investments and transport system improvements (road, rail and air) on socio-economic activities and development, including spatial and temporal distribution of impacts;
- designing an interactive, transparent modelling system for forecasting of socio-economic impacts of transport investment decisions and policies;
- demonstrating the usability of the modelling system by applying it to a number of scenarios of transport infrastructure investments and transport system improvements.

The proposed methodology and modelling system is innovative in that it is based on measurable indicators derived from advanced location-theory approaches to explain and predict the locational behaviour of investment capital, manufacturing and service activities and population. It is pragmatic and feasible in that it does not require massive and repeated collection of data on socio-economic distributions or trade flows and travel patterns. It is designed to facilitate political discussion and negotiation by being transparent, understandable and open for new indicators and issues that may become relevant in the future.

2.3 The Position of D13 within SASI

The first deliverable of SASI, or D4 in the count of EUNET deliverables, (Bökemann et al., 1997) linked the policy objectives of the European Union, in particular of its Common Transport Policy, to the model to be developed in SASI. For this purpose the main political goals of the European Union were systematically structured. Then a set of socio-economic indicators was derived taking account of (i) the state of the art in social indicator research, (ii) the indicators most frequently used in other studies and their strengths and weaknesses, (iii) their relevance for the policy goals of the European Union, (iv) their ability to express socio-

economic impacts of transport policies and (v) their interpretability by decision makers, as well as technical constraints such as (vi) their computability by the model to be developed and (vii) the availability of data. Finally, empirical illustrations of selected indicators were presented. In the conclusions the limitations of the proposed methodology were discussed.

The second deliverable of SASI, or D5 of EUNET (Schürmann et al., 1997), defined, discussed and tested accessibility indicators to be generated and used in the SASI model. Accessibility is the main 'product' of a transport system. It determines the locational advantage of a region relative to all other regions and so is a major factor for the social and economic development of a region. At the same time accessibility has a value by itself as an element of quality of life. Accessibility indicators therefore are a central sub-group of the socio-economic indicators discussed in D4 (Bökemann et al., 1997). D5 identified basic types of accessibility frequently appearing in the literature. Based on their weaknesses, new disaggregate measures of accessibility were proposed and demonstrated with pan-European data. For these new accessibility indicators also 'cohesion' indicators measuring the distribution of accessibility across regions were developed. The preliminary empirical findings indicated that the trans-European networks, in particular the European high-speed rail networks, are likely to stabilise if not increase the differences in accessibility between central and peripheral regions in Europe. However, it also became apparent that accessibility is no longer the most important factor determining location choice of firms but rather one of many transport and non-transport location factors (Linneker, 1997). The conclusion was that accessibility has to be seen as an enabling condition necessary to facilitate economic development but which, if present, does not guarantee that development will occur.

The third deliverable of SASI, or D7 of EUNET (Masser et al., 1997) examined the data available for SASI. The Eurostat database Regio was identified as the primary data input to the project as a whole, as it is the main official source of regional data that is provided on a regular basis and in a harmonised framework. Data problems identified were large differences in the size of regions, changes in region boundaries and the creation of new regions all resulting in outliers and gaps in the data. Data coverage was found to be very poor for the new member states Austria, Finland and Sweden and the new German Länder. Missing data, in particular for the base year 1981, had to be estimated or derived from other data sources such as national statistical offices. It was concluded that, although Regio covers a considerable amount of the data required, the collection of the information needed for the *European Developments* submodel (see Section 3.1) as well as the calculation of regional endowment factors for the *Regional GDP* submodel (see Section 3.1) require a variety of other data sources.

The fourth deliverable of SASI, or D8 of EUNET (Wegener and Bökemann, 1998) described the structure of the SASI model based on the results of the previous three SASI deliverables. Starting from a review of the state of the art of modelling regional economic development, it introduced and explained the major design considerations that led to the construction of the model. It presented a detailed description of each submodel including their interactions and summarised the data requirements, output and operation of the model.

The fifth deliverable of SASI, or D11 of EUNET (Fürst et al., 1999) presented the implementation and calibration of the model, i.e. the final form of the input data used and the statistical analyses performed to test hypotheses about factors to be included in the regional production and migration functions and their numerical specification. It was shown that the SASI model is capable of modelling the impacts of transport infrastructure investments and trans-

port system improvements on the socio-economic indicators proposed in the model specification in D8 (Wegener and Blökemann, 1998). All necessary data could be provided from Eurostat and various additional national and regional statistics using standard data preparation and adjustment methods, such as forecasting, backcasting and data interpolation. The model calibration and specification of the production function led to satisfying results regarding the capability of the model to re-produce base-year distributions of socio-economic indicators in the 201 SASI regions. The model proved to be resilient and robust with respect to interfering externalities yet sensitive enough to detect the impacts even of partial or medium-scale changes, such as variants of TEN scenarios in specific regions.

This report is the sixth deliverable of SASI, or D13 of EUNET. It describes the software of the SASI model i.e. tools for network scenario generation, the model input files, the model database and output files, the model software itself and finally the programmes developed for analysing and visualising the model results.

The results of the demonstration scenario simulations will be presented in the forthcoming final seventh deliverables of SASI, or Deliverables D15 of EUNET (Fürst et al., 2000). A joint final report will summarise the work of both EUNET and SASI.

3. Model Overview

This section gives a brief overview of the structure of the SASI model. It repeats and partially updates the tentative outline of the SASI model accompanying the five previous SASI deliverables, especially Deliverable D8 (Wegener and Bökemann, 1998) and Deliverable D11 (Fürst et. al., 1999). The overview is to make the reader familiar with the basic structure of the SASI model and the interactions between the seven submodels, which will be presented in more detail in Section 4.

The SASI model consists of six forecasting submodels: *European Developments*, *Regional Accessibility*, *Regional GDP*, *Regional Employment*, *Regional Population* and *Regional Labour Force*. A seventh submodel calculates *Socio-Economic Indicators* with respect to efficiency and equity.

This structure defines the minimum scope of the SASI model necessary to achieve the objectives outlined in Section 2.2. More submodels may be added later in order to improve the model and extend its area of application.

3.1 Submodels

In this section the seven submodels of the SASI model and the interrelationships between them are briefly described. Figure 3.1 visualises the interactions between the submodels.

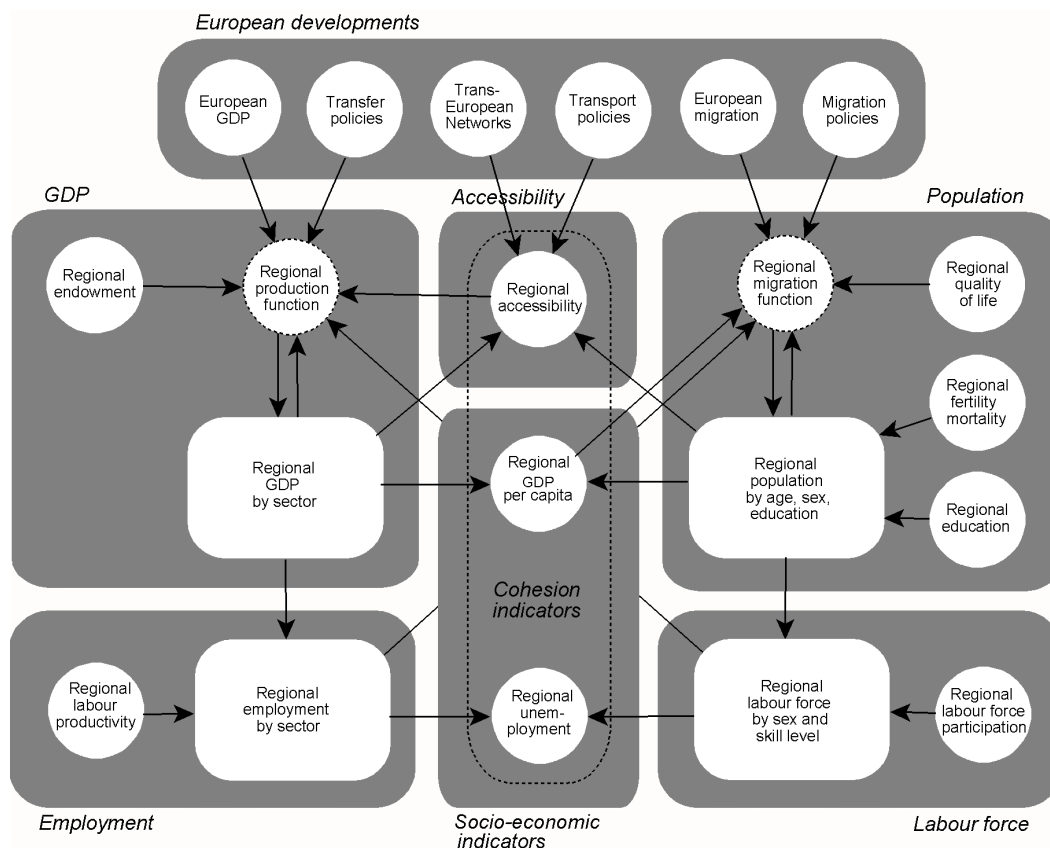


Figure 3.1. The SASI model

European Developments

The *European Developments* submodel is not a 'submodel' as it contains no forecasting equations. It simply prepares the exogenous assumptions about the wider economic and policy framework of the simulation for subsequent processing by the other submodels. European developments include assumptions about the future performance of the European economy as a whole and the level of immigration and outmigration across Europe's borders. They serve as constraints to ensure that the regional forecasts of economic development and population are consistent with external developments not modelled. Given the expected rapid population growth and lack of economic opportunity in many origin countries, total European immigration will be largely a function of immigration policies by national governments of the countries of the European Union. Another relevant European policy field are transfer payments by the European Union or by national governments, which are responsible for a sizeable part of their economic growth in some regions. The last group of assumptions concern policy decisions on the trans-European networks. As these are of focal interest in SASI, they are modelled with considerable detail. Besides a 'baseline' scenario several TETN scenarios reflecting different investment programmes for the road, rail or air networks will be specified.

Regional Accessibility

This submodel calculates regional accessibility indicators expressing the locational advantage of each region with respect to relevant destinations as a function of travel time or travel cost (or both) to reach these destinations by the strategic road, rail and air networks.

Regional GDP

This is the core submodel of the SASI model. It calculates a forecast of gross domestic product (GDP) by industrial sector (agriculture, manufacturing, services) generated in each region as a function of economic structure, labour force, endowment indicators and accessibility. Endowment indicators measure the suitability or capacity of a region for economic activity. They may include traditional location factors such as availability of business services, capital stock (i.e. production facilities) and intraregional transport infrastructure as well as 'soft' location factors, such as cultural facilities, housing and a pleasant climate and environment. Accessibility indicators are derived from the *Regional Accessibility* submodel. In addition, monetary transfers by the European Union or by national governments are considered, as these account for a sizeable portion of the economic development of peripheral regions. The results of the regional GDP per capita forecasts are adjusted in a way that the total of all regional forecasts multiplied by regional population meets the exogenous forecast of economic development (GDP) of Europe as a whole as defined by the *European Developments* submodel.

Regional Employment

Regional employment is calculated by combining the results of the GDP submodel with exogenous forecasts of regional labour productivity by industrial sector (GDP per worker), which in addition may be changed by effects of changes in regional accessibility.

Regional Population

Population forecasts are needed to represent the demand side of regional labour markets. The *Regional Population* submodel therefore predicts regional population change due to natural change and migration. Births and deaths are modelled by a cohort-survival model subject to

exogenous forecasts of regional fertility and mortality rates. Migration is modelled in a simplified migration model as annual net migration as a function of regional unemployment and other indicators expressing the attractiveness of the region as a place of employment and a place to live. The migration forecasts are adjusted to comply with total European immigration and outmigration forecast by the *European Developments* submodel and the limits on immigration set by individual countries. In addition, educational attainment, i.e. the proportion of residents with higher education, is forecast as a function of national education policy.

Regional Labour Force

Regional labour force is derived from regional population and exogenous forecasts of regional labour force participation rates modified by effects of regional unemployment.

Socio-economic Indicators

Total GDP and employment are related to population and labour force by calculating total regional GDP per capita and regional unemployment. Accessibility, besides being a factor determining regional production, is also considered a policy-relevant output of the model. In addition, equity or cohesion indicators describing the distribution of accessibility, GDP per capita and unemployment across regions are calculated.

3.2 Space and Time

The SASI model forecasts socio-economic development in the 201 regions at the NUTS-2 level defined for SASI for the fifteen EU countries (see Figure 3.2 and Annex Table A1). These are the 'internal' regions of the model. The 27 regions defined for the rest of Europe are the 'external' regions which are used as additional destinations when calculating accessibility indicators. The four regions representing the rest of the world are not used.

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 IRPUD and recently adopted for the GISCO spatial reference database of Eurostat. The 'strategic' road and rail networks contain all TETN links laid down in Decision No. 1692/96/CE of the European Parliament and the Council (European Communities, 1996) and the east European road and rail corridors identified by the Second Pan-European Transport Conference in Crete in 1994 as well as additional links selected for connectivity reasons. The SASI system of regions and the strategic networks used in SASI have also been used in the DGVII projects STREAMS, EUNET and STEMM.

The temporal dimension of the model is established by dividing time into discrete time intervals or periods of one year duration. By modelling relatively short time periods both short- and long-term lagged impacts can be taken into account. The base year of the simulations is 1981 in order to demonstrate that the model is able to reproduce the main trends of spatial development in Europe over a significant time period of the past with satisfactory accuracy. The forecasting horizon of the model is 2016.

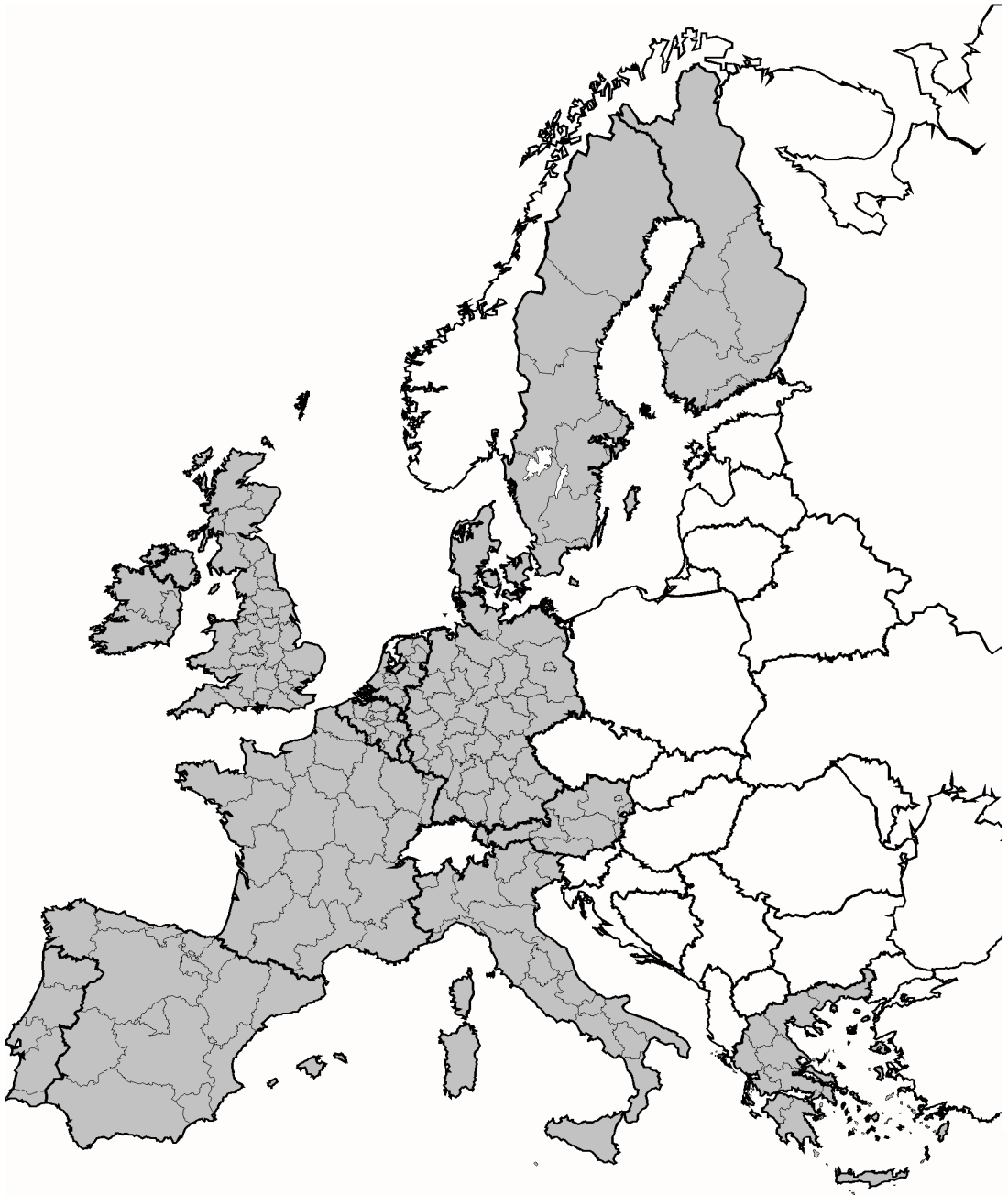


Figure 3.2. The SASI system of regions

In each simulation year the seven submodels of the SASI model are processed in a recursive way, i.e. sequentially one after another. This implies that within one simulation period no equilibrium between model variables is established; in other words, all endogenous effects in the model are lagged by one or more years. Figure 3.3 illustrates the recursive organisation of the model:

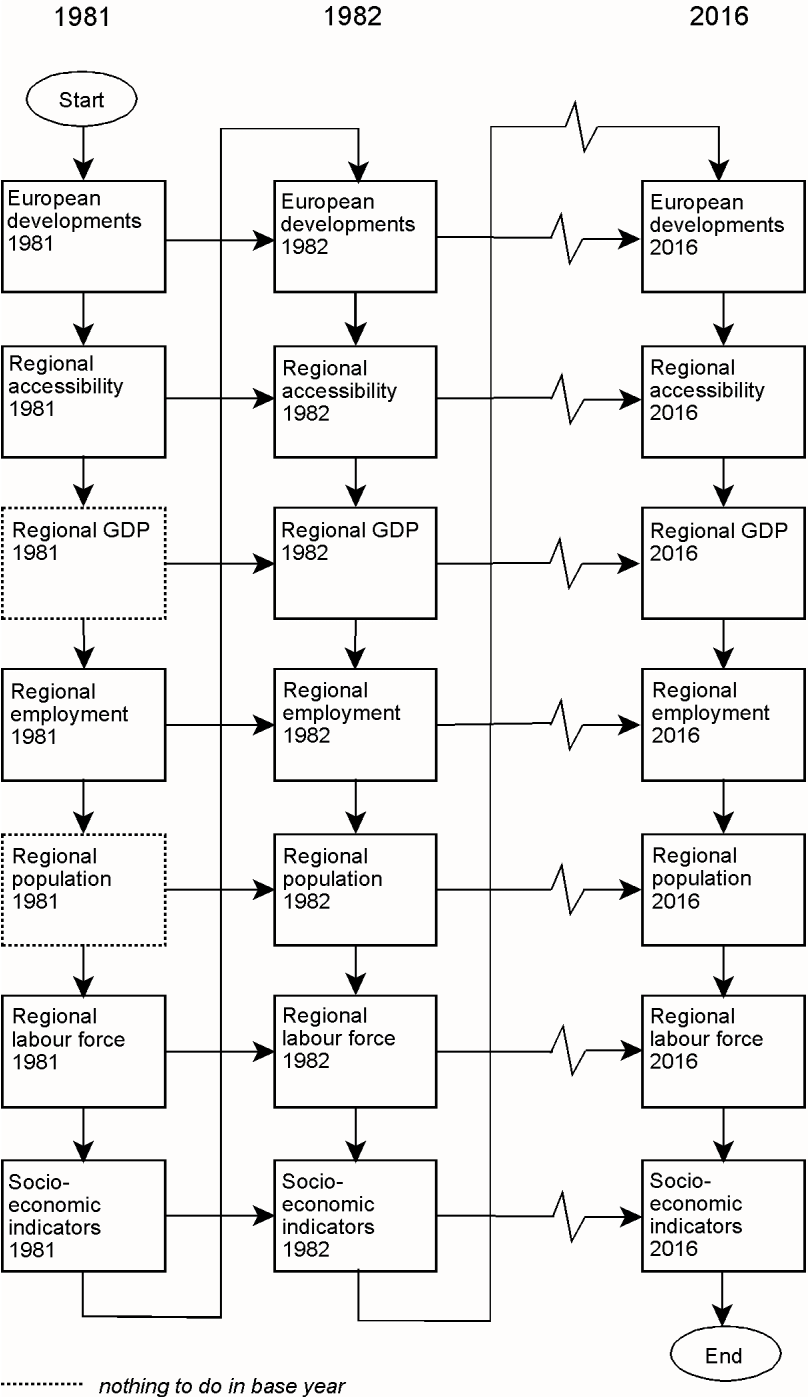


Figure 3.3. The recursive organisation of the SASI model

4. Model Software

In this section the components of the model software are presented. The SASI model is a self-contained software running under Windows 95 or Windows NT. It requires a Pentium PC with 32 MB memory and a processor speed of 200 MHz or more.

The *model software* is modularly organised and consists of a main control module and several dependent programme modules. Each submodel described in Section 3 is a separate programme module calling further sub-modules. Figure 4.1 shows then the interaction of the modelling software with the network scenario generation, the model database and the input and output files.

A typical simulation run starts outside of the SASI model with pre-processing of the scenario networks by applying the network scenario generation software tool on top of the geographical information system ArcInfo. This tool written in the ArcInfo macro language AML (ESRI, 1997) offers a number of scenario options to be selected for modelling (see Section 4.1).

Once the scenario networks are defined, the actual SASI model is run. Typically, first a *do-nothing scenario* is simulated. A do-nothing scenario is defined as the scenario in which between the base year and the present all transport infrastructure investments are implemented as observed and in which until the target year 2016 no further network development is assumed. The do-nothing scenario serves as reference scenario for all other scenarios.

Other scenarios differ from the do-nothing scenario by different assumptions about European developments, such as the development of the European economy, immigration and outmigration and transfer payments, and by different policy decisions on transport infrastructure investments and transport system improvements. In the present SASI project, only transport policy scenarios are tested, whereas the socio-economic framework is kept fixed. In the present SASI project a *policy scenario* is therefore a time-sequenced investment programme for addition, upgrading or closure of links of the road, rail or air networks (see Section 4.1). After assessing the do-nothing scenario, a number of different policy scenarios, for which the impacts of transport infrastructure investments are to be assessed, are simulated. The number of policy scenarios is not limited.

After simulating different network scenarios with the SASI model, the results of the model runs are analysed and visualised using additional programme tools. The results are interpreted with respect to cohesion indicators such as the coefficient of variation and the GINI coefficient (Lorenz curves). In addition, results for all or subsets of regions can be displayed in trajectory diagrams (showing the development of certain indicators for certain regions or scenarios over time) and in maps showing absolute values of regional indicators or differences of indicators values between different points in time or between different scenarios.

As in the present SASI project only transport policy scenarios are examined, all other assumptions made in the model, including the assumptions about the future performance of the European economy as a whole, about immigration and outmigration across Europe's borders and about transfer payments received by the regions, are the same for all scenarios. As the policy scenarios differ only by policies becoming effective in the future, it is only necessary to simulate the years between 1996 and the target year. The organisation of the model database allows to start a new simulation or resume processing at each year previously simulated.

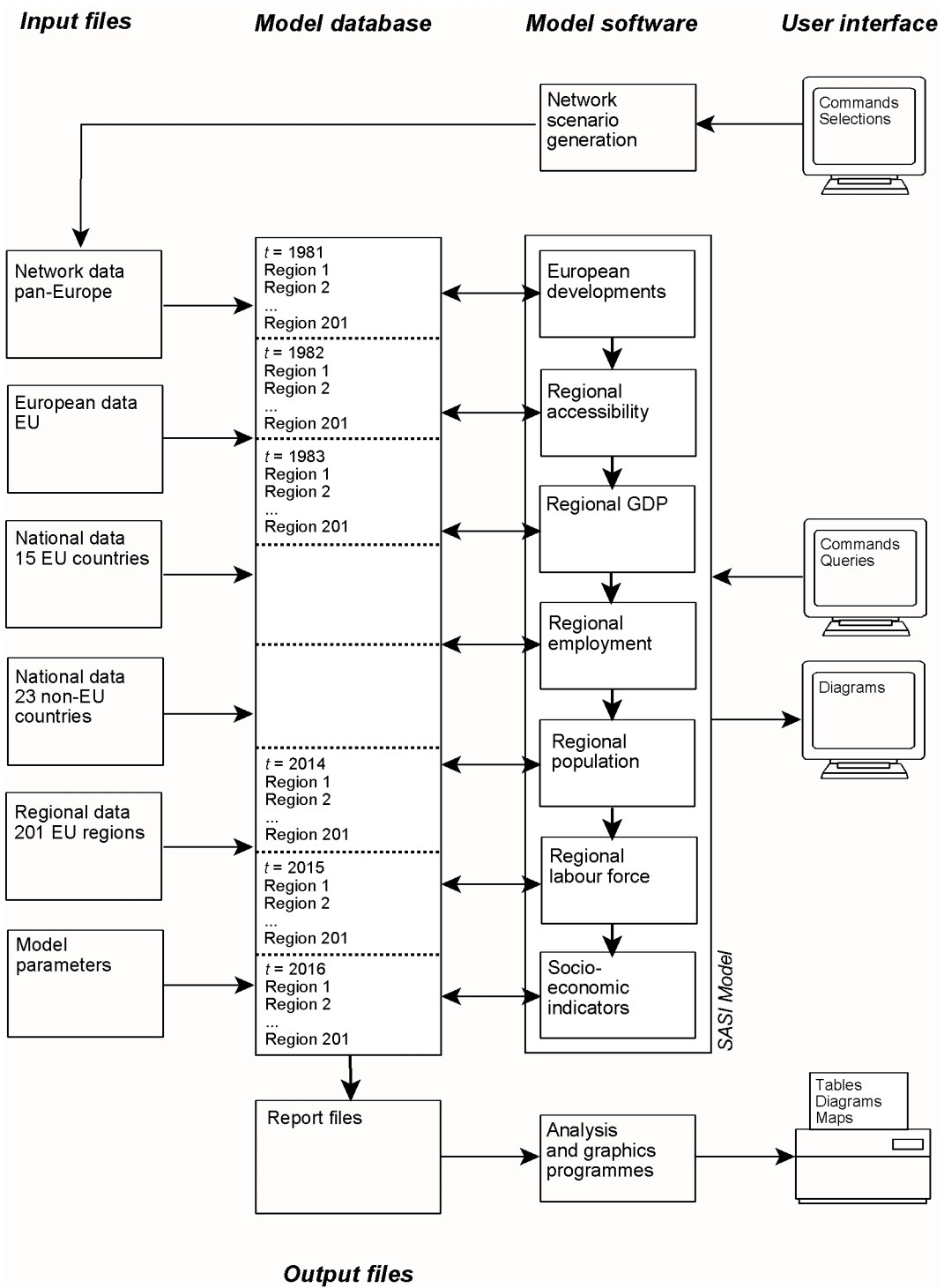


Figure 4.1 Software and data organisation of the SASI model

4.1 Network Scenario Generation

Network scenarios for the SASI model are generated in the geographical information system ArcInfo. The road, rail and aviation networks are stored and maintained in ArcInfo as separate coverages with some 40,000 links (for road and rail) and about 4,000 flight connections (IRPUD, 1999). These networks form the pan-European transportation base networks. Because their size is too large and their information is too detailed for the SASI model, so-called 'strategic' networks have been defined for use in the model. The 'strategic' road and rail networks contain all TETN links laid down in Decision No. 1692/96/CE of the European Parliament and the Council (European Communities, 1996) and the east European road and rail corridors identified by the Second Pan-European Transport Conference in Crete 1994 (European Communities, 1995) as well as additional links selected for connectivity reasons. The 'strategic' air network is based on the TEN airports and other important airports in non-EU countries and contains all flights between these airports.

The transport network links are described by a variety of different attributes (see Deliverable D11, Fürst et al., 1999). For each link of the strategic road network information on length, link category (motorway, dual carriageway, other road, car ferry and Eurotunnel) and national speed limits for that link category are stored. For each link of the strategic rail network information on length, link category (number of tracks, electrification, suitability for high-speed) and travel time are stored. Each link of the strategic air network contains information on average travel time on that link and a frequency index indicating four categories of daily or weekly frequency.

Because the networks will be used to calculate changing regional accessibility over time, the historical and future development of the networks are required as input information. This development of the strategic networks over time is reflected in intervals of five years in the database, i.e. the established network database contains the information for the years 1981, 1986, 1991, 1996, 2001, 2006, 2011 and 2016 (see Deliverable D11, Fürst et al., 1999).

The Network Scenario Generation Tool

Since the SASI model software handles input files in ASCII format, an interface was developed which extracts the strategic networks from the base networks and transforms ArcInfo binary data into the ASCII input format required by the model (see Figure 4.1). This is the main task of the network scenario generation tool .

For the road and air networks, network input files are generated by exporting the ArcInfo *Node Attribute Table* (NAT) and *Arc Attribute Table* (AAT) files. Input files for the railway network are created by extracting the ArcInfo *Node Attribute Table* (NAT) in combination with extracting ArcInfo *Route Attribute Tables* (RAT), since railway timetable travel times are stored as route systems in the ArcInfo database. The ASCII link input files have the following record structure:

```
<from_node> <to_node> <travel_time>
```


For each year and mode a link file will be generated and stored in the mode's directory. Each link file is named LINKxxxx.yy where xxxx indicates the year that is represented in the network (1981, 1986, ... , 2016) and yy contains a two-digit scenario number. The node file is named NODESALL.DAT and contains all nodes for all scenarios.

However, the network scenario generation tool does not only extract information for the strategic modelling network and transforms binary data into ASCII data. Beyond that, link travel times are calculated and - in case of planned projects - adjusted to new situations: For instance, when a link is upgraded from 'other road' to 'motorway', the link travel time has to be re-calculated.

Scenario Selection

In addition, the network scenario generation tool enables the user to select a network scenario by choosing an appropriate menu entry. After the selection of a scenario, the network scenario generation tool will automatically run an AML routine which extracts and prepares the specified network and produces the ASCII link and node files. No additional user input is required as the ASCII files are directly be read by the SASI model.

The selection menu offers different options for the generation of transport infrastructure scenarios (Figure 4.2). The sample screenshot of Figure 4.2 shows the options for generating scenarios consisting of TEN priority road projects. It is possible to select a scenario that includes all TEN priority road projects or a special scenario which includes only one of the priority projects or another scenario that includes a combination of several priority projects.

With the help of other pull-down menus, it is possible to define other past or future network scenarios. In the pull-down menu 'Past Networks', historical networks for the years 1981, 1986, 1991 or 1996 can be generated.

The 'Do-Nothing' option generates infrastructure networks for future years that are equal to the networks of today. Such a scenario without network changes might be combined with different assumptions on future border crossing times in the course of further European integration, which are taken account in the accessibility submodel (see SASI Deliverable D11, Fürst et al., 1999).

The pull-down menu 'TEN Scenarios' offers the choice between two network scenarios, the 'TEN Scenario' and the 'Extended TEN Scenario', and user-defined policy scenario combinations. The 'TEN Scenario' includes all infrastructure developments for which construction has already started or for which the starting year of operation is defined in the TEN implementation report (European Commission, 1998). The 'Extended TEN Scenario' includes the 'TEN Scenario' and, in addition, all links which according to the TEN implementation report are still under study and for which no decision has yet been made.

The pull-down menu 'National Extensions' includes options for the selection of infrastructure projects not included in the TEN programme but included in national transport infrastructure schemes.

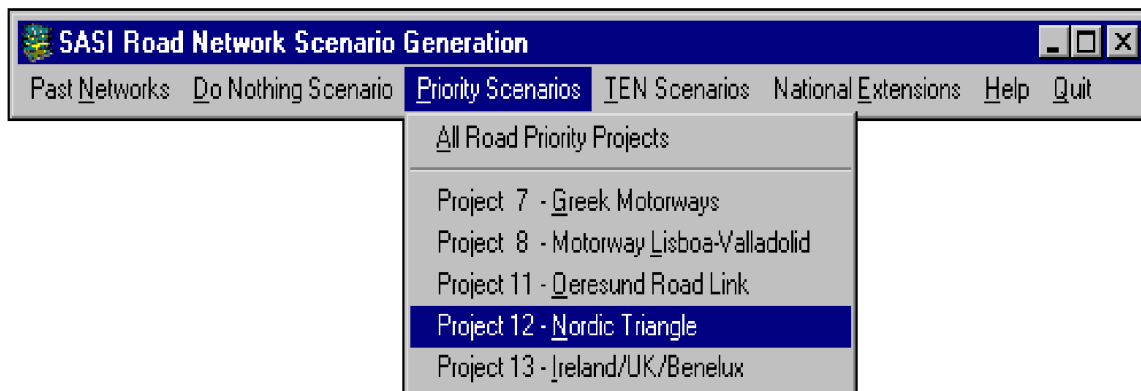


Figure 4.2. Network scenario generation interface

Having selected an infrastructure scenario, the user can make assumptions about the speed of implementation of the scenario. This option reflects the fact that in many cases an estimated completion time *corridor*, such as '2001-2006', is laid down in the TEN implementation report (European Commission, 1998). An optimistic or a delayed implementation can be selected. The optimistic option assigns the earlier date, the delayed option the later date to the link; if there is only one year stated, implementation will be delayed by five years.

A final option is the choice whether to include border delay times in the road network or not. By default, border delay times are included for the calculation of accessibilities in the SASI model. However, if the user wants to simulate network scenarios without border delays as a result of further European integration, the network scenario generation tool offers the opportunity to disable border delays when generating scenario networks.

After the definition of a particular infrastructure scenario, GIS functions are applied to generate the specified scenario subset from the base network, to update the network topology, to calculate and adjust link travel times and to produce the ASCII input files for the SASI model.

The network scenario generation tool does not yet provide tools to *edit* network topology or attributes. This has to be done with standard ArcInfo commands in the base networks.

4.2 Input Files

As shown in Figure 4.1, the model database consists of a number of input files. Input *files* are ASCII text files containing exogenous forecasts and policies entered by the user. The following input files are required (see Deliverable D11, Fürst et al., 1999):

- European data (EU)
 - Total European GDP by industrial sector, 1981-2016
 - Total European immigration and outmigration, 1981-2016
- National data (15 EU countries)
 - National GDP per worker by industrial sector, 1981-2016
 - National fertility rates by five-year age group and sex, 1981-2016
 - National mortality rates by five-year age group and sex, 1981-2016
 - National immigration limits, 1981-2016
 - National educational attainment, 1981-2016
 - National labour force participation by sex, 1981-2016
- National data (23 non-EU countries)
 - National population, 1981-2016
 - National GDP, 1981-2016
- Regional data (201 EU regions)
 - Regional GDP per capita by industrial sector in 1981
 - Regional labour productivity (GDP per worker) by industrial sector in 1981
 - Regional population by five-year age group and sex in 1981
 - Regional educational attainment in 1981
 - Regional labour force participation rate by sex in 1981
 - Regional endowment factors, 1981-2016
 - Regional transfers, 1981-2016
 - Regional raster distributions of population in 1995
 - Regional raster distributions of GDP in 1992
- Network data (pan-Europe)
 - Node and link data of different scenarios for the road network, 1981-2016
 - Node and link data of different scenarios for the rail network, 1981-2016
 - Node and link data of different scenarios for the air network, 1981-2016
- Model parameters
 - Parameters of model equations

Each of the groups of data listed above is stored in a separate input file. Besides the network data and model parameter files, all other input files have a standardised record format. Each record of the regional data input files represents one region of the SASI system of regions. The record format is as follows:

Bytes	length	type	content
1- 1	1	character	EU=blank, external=X, world zone=z
2- 6	5	character	Region code
7-10	4	character	NUTS level
11-20	10	real	Data field I
21-30	10	real	Data field II
...			

The first ten bytes of each record are identical. The region code is a four-character acronym of the name of the region and is based on the NUTS nomenclature (EUROSTAT, 1995). This code serves to unambiguously merge regional data from different files. All data files can be sorted by this code. Because the model requires also input data for NUTS-0 or NUTS-1 level regions, the data files include records for all the three NUTS levels, even where no data are available or no data are needed for that level.

In addition, there are records storing data for European countries outside of the EU (designated as 'external') and four records containing data representing the rest of the world (designated as 'world zone') (see Figure 3.2 and Annex Table A1).

The standardised first ten bytes are followed by a variable number of data fields with a width of ten bytes each. These data fields contain the input data. The number of data fields in each record depends on the kind of data.

If the SASI model is run for the first time, these input files are read from the model and transferred to the internal binary model database. Once the input files are read, they need not to be re-read again every time the model is started unless the user explicitly directs the model to read new data.

4.3 Model Database

Data transfer between the submodels as described in Section 4.4 is achieved via a common *model database*. The model database consists of a random-access file system in which all state variables of all 201 internal (EU) regions generated during a simulation run are recorded for each year of the simulation between the base year 1981 and the target year 2016. Each programme module reads data from the database and writes its results into the database. After the simulation all data contained in the model database are available for analysis and output.

Output files are condensed report files with excerpts from the model database for later output, because the model database is overwritten by each new simulation. There will be one output file for each scenario. Because these files store all the output indicators for all 201 regions, they are called ‘Regional Data’ files (RD). The common designation of these files is RDxx where xx represents the scenario number.

The RD files contain for every year (1981-2016) 201 records, i.e. one for each internal region. There are no records for external regions or the world zone (see previous section). Each record contains 100 data fields of four bytes length each. Each data field contains one real variable in binary form.

The variables of each record are defined as follows:

Variables	Type	Contents
1-40	real	Population by age and sex
41-42	real	Labour force by sex
43-45	real	Educational attainment in percent of population 25-59 years of age
51-53	real	GDP by sector (million Euro of 1998)
54-56	real	GDP per worker by sector (Euro of 1998)
57-59	real	Employment by sector
60	real	Unemployment
61-63	real	Agricultural, European, national subsidies
71	real	Area
72-79	real	Other endowment variables
81-82	real	Accessibility indicators
91-93	real	Residuals GDP by sector

During model processing, each access to the model database consists of a read operation of one record, a modification of one or more variables and finally a write operation of the modified record, i.e. all variables that are not modified are written back to the file.

All analysis and presentation tools (graphical output such as trajectories, cohesion indicators and maps) retrieve data from the model database (see Section 4.5).

4.4 SASI Model

The software implementation of the model itself is a straightforward one-to-one mirror of the model submodel structure presented in Section 3.1 and illustrated in Figures 3.3 and 4.1. The software modules associated with each submodel are shown in more detail in Figure 4.3 and are described below.

4.4.1 Input

The first group of modules serves to provide the model with the appropriate input data for a specific scenario simulation. The definition of a scenario to the model occurs in the form of a dialogue in which the user specifies the scenario acronym and/or required input datasets. There are essentially three kinds of selections possible (see SASI Deliverable D11, Fürst et al., 1999, Section 4.1):

- the selection of a scenario of European developments in terms of total EU GDP and net migration by EU country,
- the selection of a set of national scenarios in terms of age-specific birth and survival rates, labour force partition rates by gender, educational attainment by level and GDP per worker by economic sector for each EU country,
- the selection of scenarios of network evolution by mode (road, rail, air).

Typically, scenario information is entered in five-year increments (for years, 1986, 1991, 1996, 2001, 2006, 2011 and 2016) but any other shorter or longer interval may be chosen. The software interpolates between years and assumes no further change after the last year for which information is entered.

4.4.2 Accessibility

The accessibility submodel calculates raster-based accessibility indicators for NUTS-2 regions. According to the regional production function (see Section 4.4.5), two kinds of accessibility indicators are calculated:

- the logsum of potential accessibility by road and rail to population,
- the logsum of potential accessibility by road, rail and air to GDP.

The method to calculate disaggregate accessibility indicators was described in SASI Deliverable D5 (Schürmann et al., 1997, Section 5.1) and SASI Deliverable D11 (Fürst et al., 1999, Section 4.2).

For practical reasons, the accessibility submodel is presently offline. However, in future versions of the model, full integration of the accessibility submodel into the model software is envisaged.

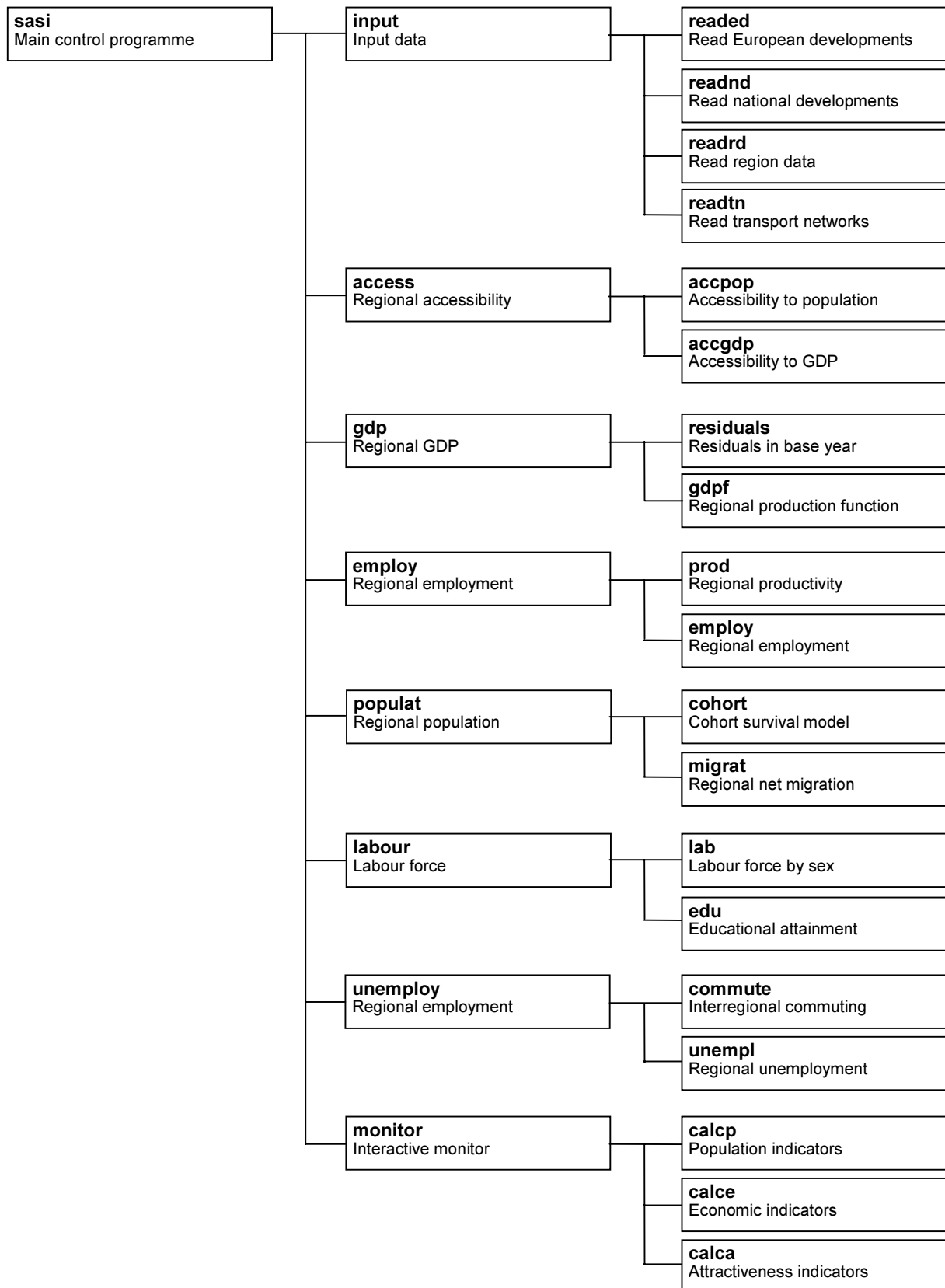


Figure 4.3. Software modules of the SASI model

4.4.3 GDP

The GDP submodel forecasts regional gross domestic product (GDP) by economic sector according to the three production functions specified in SASI Deliverable D11 (Fürst et al., 1999, Section 4.3). As explained in Deliverable D11, the predictive performance of the model is improved by calculating the residuals between predicted and observed regional GDP in the base year 1981 to take account of 'soft' factors not captured by the endowment and accessibility indicators of the model.

The results of the regional GDP per capita forecasts are adjusted such that the total of all regional forecasts multiplied by regional population meets the exogenous forecast of economic development (GDP) of the European Union as a whole by the *European Developments* submodel (see Section 5.1).

The current values of the explanatory variables of the three production functions (endowment factors, accessibility and transfer payments) are retrieved from the model database (see Section 4.3). The calculated GDP values are written to the database.

4.4.4 Employment

The employment submodel contains two modules, the productivity forecasting submodel and the employment forecasting submodel proper.

The productivity forecasting submodel predicts regional productivity by economic sector (GDP per worker per year) based on regional base values and exogenous national forecasts. The regional base values represent historical conditions in the region, i.e. its composition of industries and products, technologies and education and skill of labour. The national forecasts of productivity by sector represent technological progress and national economic conditions in each country.

The possibility provided by the model (see SASI Deliverable D8, Wegener and Bökemann, 1998, Section 5.4) to modify productivity as a function of regional accessibility, has not been used so far. The regional productivity indices calculated are then used to forecast regional employment by economic sector.

The employment submodel retrieves regional GDP, productivity and employment of the previous simulation period from the model database and writes the employment forecasts to the database.

4.4.5 Population

The population forecasting submodel projects regional population by age and sex as well as regional net migration as described in SASI Deliverable D11 (Fürst et al., 1999, Section 4.5). It consists of two submodels, the cohort-survival demographic projection model and the migration forecasting submodel.

The cohort-survival demographic projection model uses cohort-survival techniques based on exogenous national fertility and survival rates. The model operates annually with five-year age groups and uses smoothing techniques to calculate survivors according to the algorithm presented in Deliverable D8 (Wegener and Bökemann, 1998).

Net migration is based on the migration function specified in SASI Deliverable D11 (Fürst et al., 1999, Section 4.5) and is subsequently adjusted to conform with exogenously specified national net migration forecasts.

The population of the previous year is retrieved from the model database. The population forecast resulting from the cohort survival and migration models is written to the model database.

4.4.6 Labour Force

The labour force submodel projects regional labour force by sex based on regional base values and exogenous national forecasts of labour force participation rates as specified in SASI Deliverable D11 (Fürst et al., 1999, Section 4.6). The regional base values represent historical conditions in the region, i.e. cultural and religious traditions and education, whereas the national forecasts represent the outcome of social change and national labour policy.

In addition, educational attainment is forecast by applying exogenous national forecasts to regional population.

Regional labour force and population by educational attainment of the previous period are retrieved from the model database and the forecasts are written to the database.

4.4.7 Unemployment

Regional unemployment is calculated as the current difference between regional labour force and regional employment.

To take account of interregional commuting, the resulting numbers of unemployed persons are reduced by outcommuters and increased by incommuters derived from a doubly constrained spatial-interaction work trip model.

Because NUTS-2 regions are too large to yield realistic commuter flows, the work trip model is based on NUTS-3 shares of NUTS-2 population (see SASI Deliverable D11, Fürst et al., 1999, Section 4.7). Before executing the work trip model, regional labour force is adjusted such that total labour force of all regions equals total employment of all regions. The work trip model converges reasonably well with about 200 iterations.

Regional labour force and employment data are retrieved from the model database. The travel time matrix for the work trip model is entered in list form, in which only travel times below 120 minutes are contained. The resulting numbers of unemployed persons are written to the model database.

4.4.8 Monitor

During the simulation run the user may monitor change processes in the model by observing trajectories of selected variables of interest on the computer display. It is possible to interactively change the selection of variables to be displayed during processing by pressing a hot key. The following options can be selected:

Population indicators

- Population (1981=100)
- Percent population 0-5 years
- Percent population 6-14 years
- Percent population 15-29 years
- Percent population 30-59 years
- Percent population 60+ years
- Labour force (1981=100)
- Labour force participation rate (%)
- Percent lower education
- Percent medium education
- Percent higher education
- Net migration per year (%)
- Net commuting (% of labour force)

Economic indicators

- GDP (1981=100)
- Percent non-service GDP
- Percent service GDP
- GDP per capita (in 1,000 Euro of 1998)
- GDP per capita (EU15=100)
- GDP per worker (in 1,000 Euro of 1998)
- Employment (1981=100)
- Percent non-service employment
- Percent service employment
- Unemployment (%)
- Agricultural subsidies (% of GDP)
- European subsidies (% of GDP)
- National subsidies (% of GDP)

Attractiveness indicators

- Accessibility rail/road (logsum, million)
- Accessibility rail/road/air (logsum, million)
- Soil quality (yield of cereals in t/ha)
- Developable land (%)
- R&D investment (% of GDP)
- Quality of life (0-100)

Figures 4.4 and 4.5 present the interactive menu overlaid over the current display showing first the region selection menu (Figure 4.4) and then the indicator selection menu (Figure 4.5).



Figure 4.4. The region selection menu of the monitor programme module

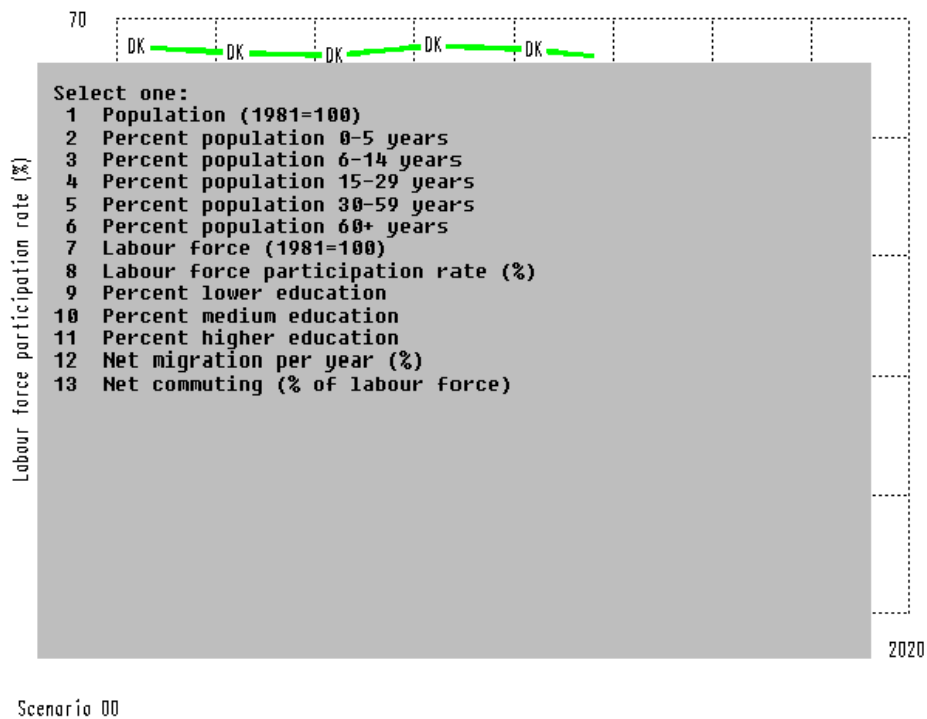


Figure 4.5. The indicator selection menu of the monitor programme module

Figure 4.6 to 4.9 show examples of trajectories of indicators that can be selected. By intention examples are presented that are not used in the presentation of results in SASI Deliverable D15 (Fürst et al., 2000) in order to show the broad range of variables processed in the model which goes far beyond the economic data analysed in D15 to compare TETN scenarios.

Figure 4.6 presents the evolution of total population by EU country as index value (1981=100). Each coloured line represents one EU country, with the two-letter acronym indicating a country; the heavy black line represents the European Union (EU). It can be seen that in the scenario the population of the European Union grows until about 2005 and then starts to decline as a result of insufficient immigration to compensate for declining births rates. However, the decline in population is most pronounced in central European countries such as Germany and Austria but also in southern countries such as Greece, Italy and Portugal, whereas population growth occurs in countries such as France, the Netherlands and Denmark. The extraordinary population growth in Ireland is mainly due to high birth rates in this country.

Figure 4.17 presents the evolution of labour force by country, again as index value (1981=100). The labour force of all countries grows due to rising labour force participation by women and starts to decline only in a few countries because of reasons of demographic composition. Note that in the model labour force participation is co-determined by labour-market conditions (see SASI Deliverable D8, Wegener and Bökemann, 1998, Section 5.6).

Figure 4.8 is an example for the possibility to show trajectories of only a subset of regions. Here the Baltic regions of Denmark, Finland and Sweden were selected in connection with the Øresund case study (see SASI Deliverable D15, Fürst et al., 2000). The indicator selected is percent population 0-5 years of age showing the typical generation cycles of demographic processes. The two-letter acronyms represent region names, where CP stands for Copenhagen (Hovestadsregionen and Øst for Storebælt), ML for Malmö (Sydsverige) and ST for Stockholm. It can be seen that the metropolitan regions display different demographic cycles than the more rural regions.

Figure 4.9 shows GDP per capita in constant money terms for just three regions: central, northern and southern Europe. Central Europe (CE) is represented by Austria, Belgium, Germany, France, Luxembourg, the Netherlands and the United Kingdom. Northern Europe (NE) consists of Denmark, Finland, Ireland and Sweden. Southern Europe (SE) includes Spain, Greece, Italy and Portugal. The simple diagram confirms that there is still a considerable north-south disparity in Europe, which persists over the simulation period even though real incomes more than double.

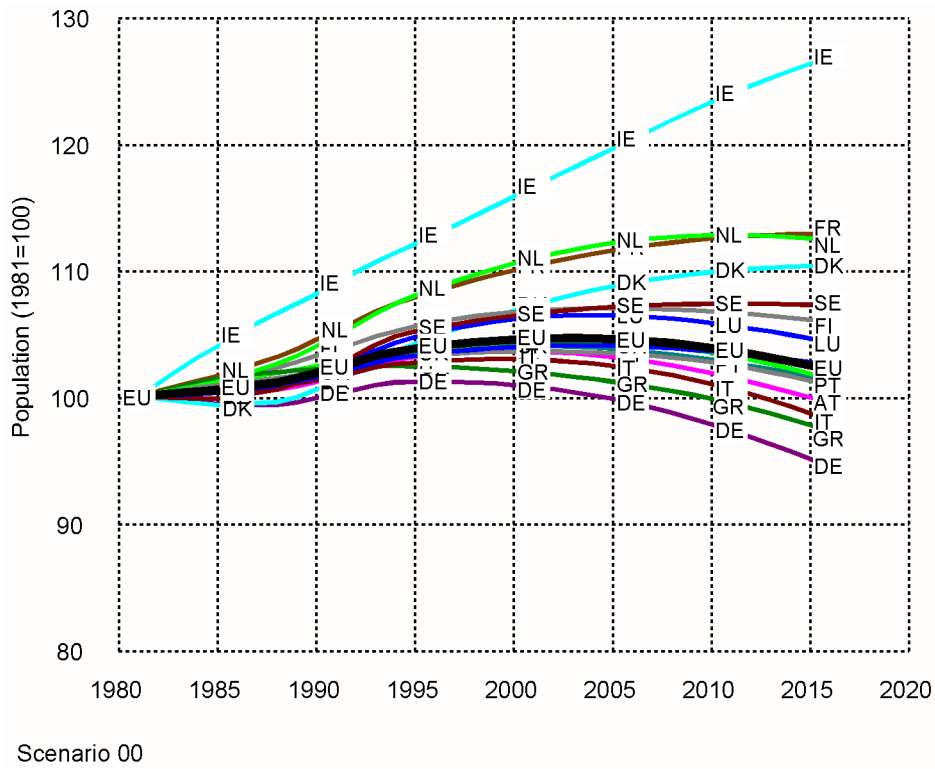


Figure 4.6. Monitor output for countries: population 1981-2016 (1981=100)

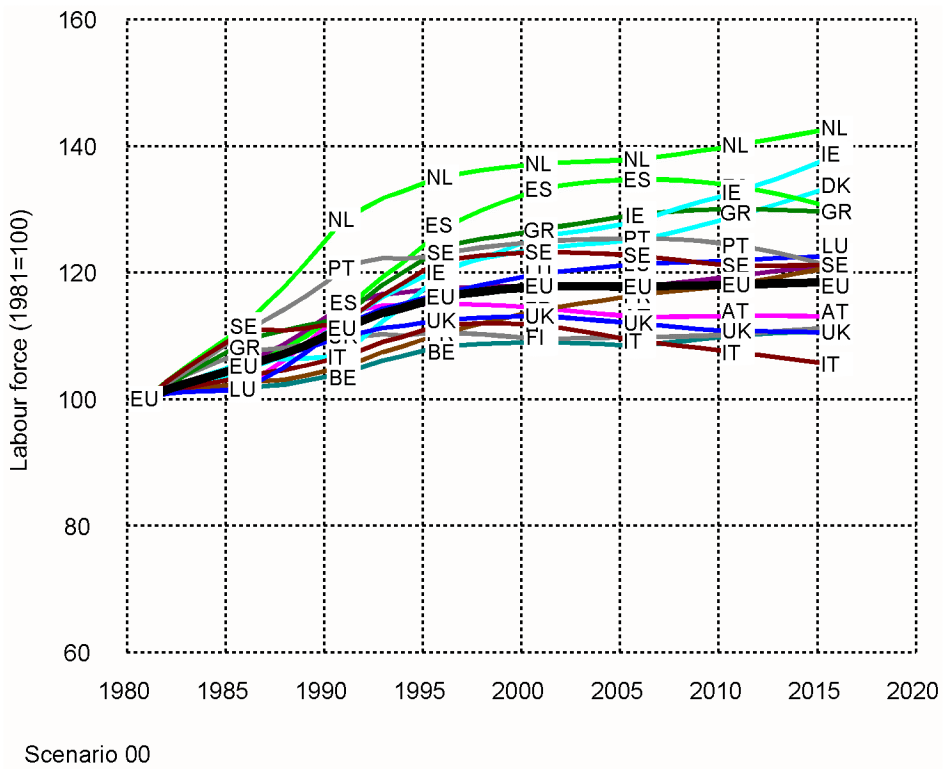


Figure 4.7. Monitor output for countries: labour force 1981-2016 (1981=100)

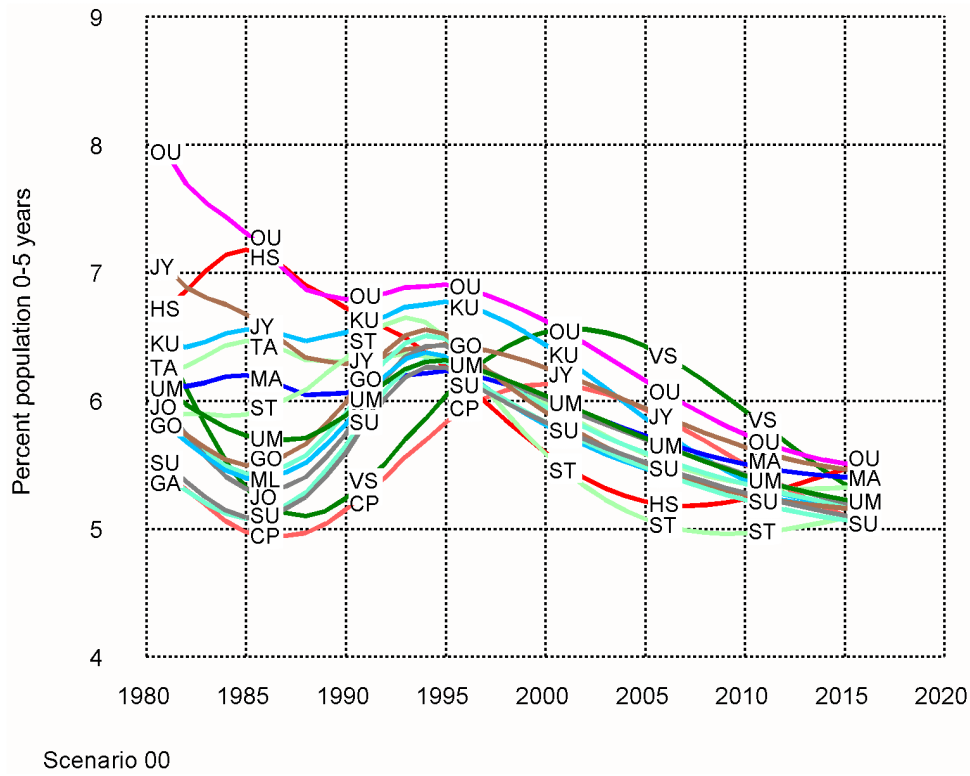


Figure 4.8. Monitor output for Baltic regions: population 0-5 years 1981-2016

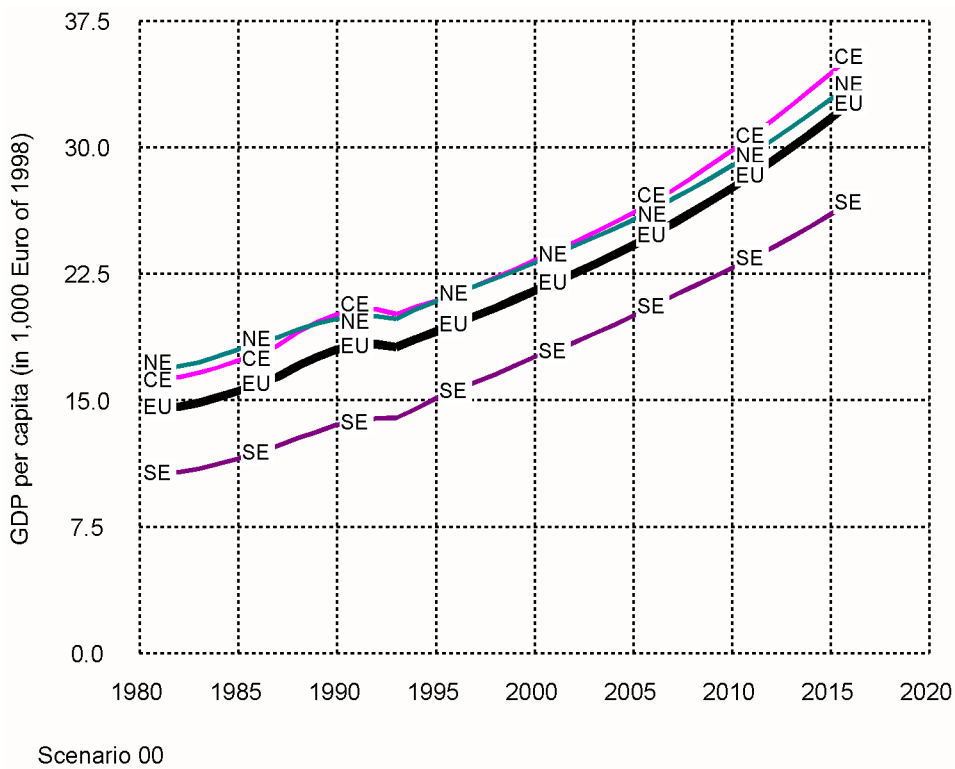


Figure 4.9. Monitor output for countries: labour force 1981-2016 (1981=100)

4.5 Analysis and Graphics

After each simulation run, the binary model database described in Section 4.3 is copied to a result directory under a scenario-specific name as a report file. Using one or more report files, the user can subsequently select from a range of output options to prepare tables, diagrams or maps showing the results of a particular scenario or comparing the results of several scenarios.

To analyse and display scenario results, three different programme tools were developed. Currently, the three programmes are stand-alone utilities which are applied independently from the SASI model. However, it is planned to combine them into one single assessment tool and integrate them into the SASI model software:

- *COMPARE*. The COMPARE programme draws trajectories for different output indicators and enables comparisons between scenarios for all regions or subsets of regions. COMPARE is an expanded offline version of the interactive monitor facility contained within the SASI model software (see Section 4.4.8) and is the main graphics output tool for analysing scenario results. In principle, two ways of comparing scenarios are offered:
 - The 'Regions' option compares results of all regions or subsets of regions of one scenario.
 - The 'Scenarios' option compares results of several scenarios.

When starting the COMPARE programme the user is asked to select one of these two options. If the 'Regions' option is chosen, the user is asked to enter the scenario number of the scenario of interest. After that, she can select all or a subset of regions at various levels of aggregation (e.g. countries or macro regions) and the output indicator to be displayed. If the 'Scenarios' option is chosen, two or more scenarios to be compared can be specified, before as above the regions and output indicator are specified. The COMPARE programme offers the same selection of output indicators and interactive functionality as the monitor programme of the SASI model (see Section 4.4.8).

The results of the COMPARE programme are displayed on the screen and written to a file in vector graphics format for later editing and conversion to bitmap format and integration into documents.

- *COHESION*. The COHESION programme generates diagrams displaying the evolution of cohesion indicators such as the coefficient of variation or GINI coefficient for one or more selected indicators over time or draws Lorenz curves for the comparison of two output indicators, two scenarios or two points in time of one scenario.
- *DRAWMAP*. The DRAWMAP programme draws pan-European maps of absolute and relative values of regional output indicators or absolute or relative differences between output indicators of two scenarios or two points in time of one scenario.

Figure 4.10 to 4.14 show examples of analysis and presentation diagrams that can be generated with the above tools:

- Figures 4.10 and 4.11 illustrate sample trajectories produced by the COMPARE programme showing accessibility and GDP development in two scenarios for one particular set of regions (in this case all regions of Germany). The scenarios compared are the do-nothing scenario mentioned above as the reference scenario for the comparison of scenarios and a TEN scenario, which will be explained in Deliverable D15.
- Figure 4.12 and 4.13 present indicators of cohesion produced with the COHESION programme. Figure 4.12 shows the development of the coefficient of variation for the two accessibility indicators used in the SASI model between 1981 and 2016. Again the TEN scenario used for the example will be explained in Deliverable 15. Figure 4.13 shows Lorenz curves comparing the spatial distribution of potential accessibility by road/rail in 1996 and 2016 in the same scenario.
- Figure 4.14 shows an example of DRAWMAP output. The map displayed relative differences in GDP per capita for the same two scenarios used in Figures 4.10 and 4.11. The content of the map will be discussed in Deliverable D15.

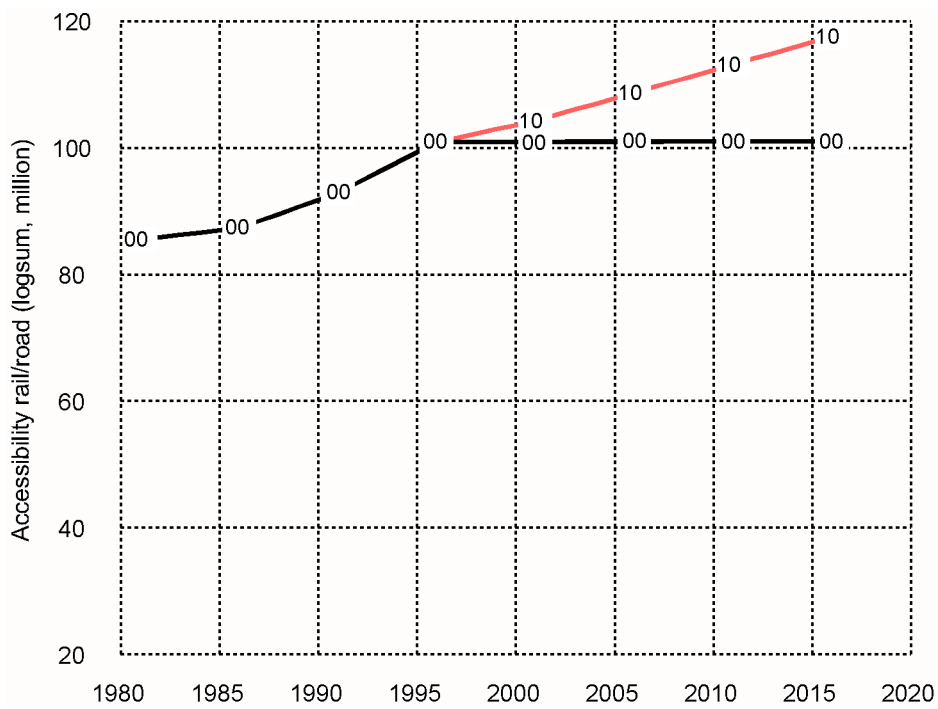


Figure 4.10. Example output: differences in accessibility between two scenarios

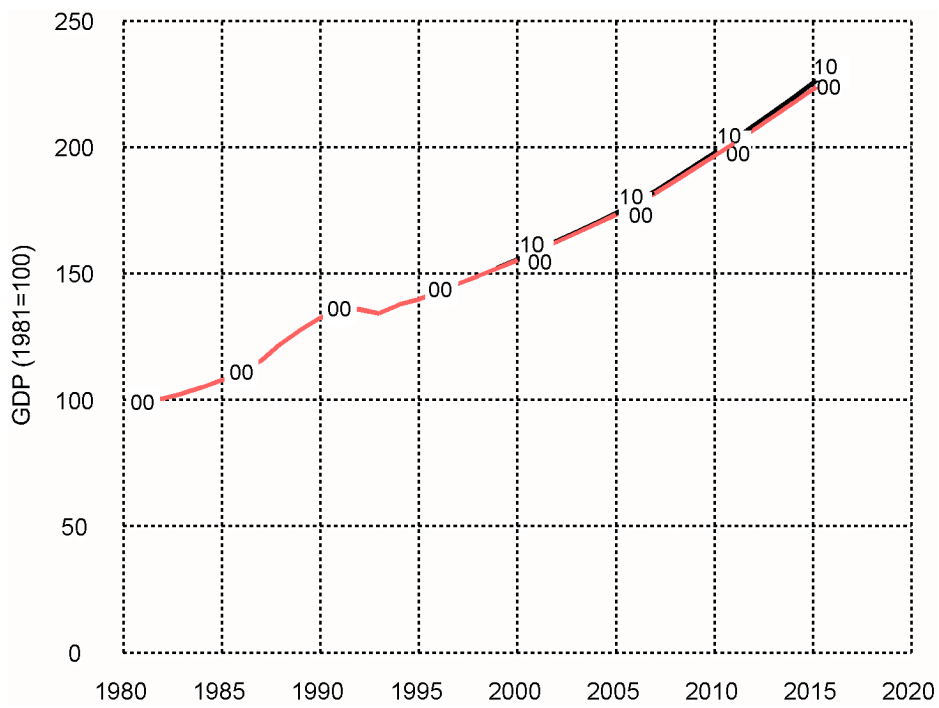


Figure 4.11. Example output: differences in GDP for two scenarios

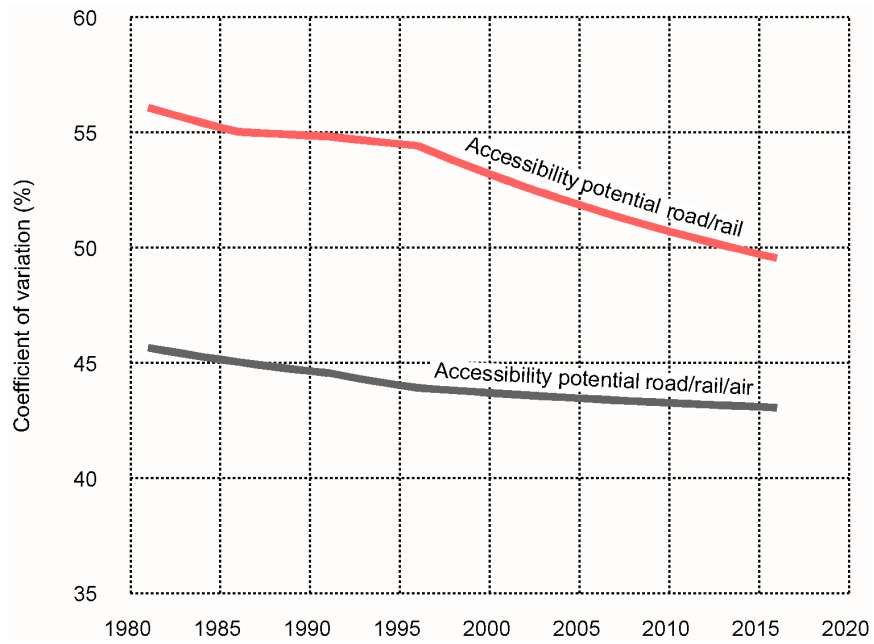


Figure 4.12. Example output: coefficient of variation of accessibility indicators 1981-2016

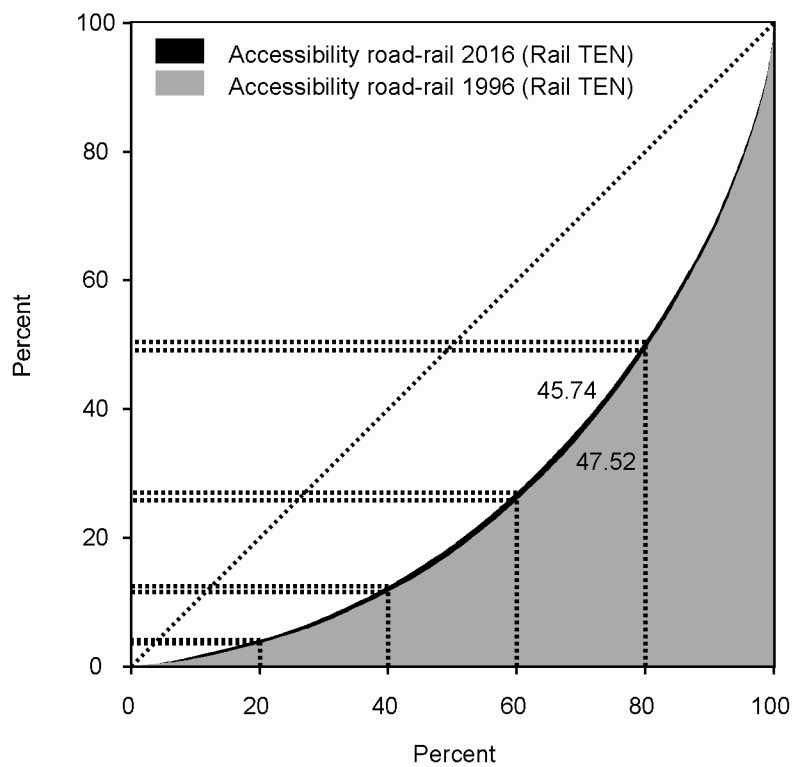


Figure 4.13. Example output: Lorenz curves of accessibility at two points in time

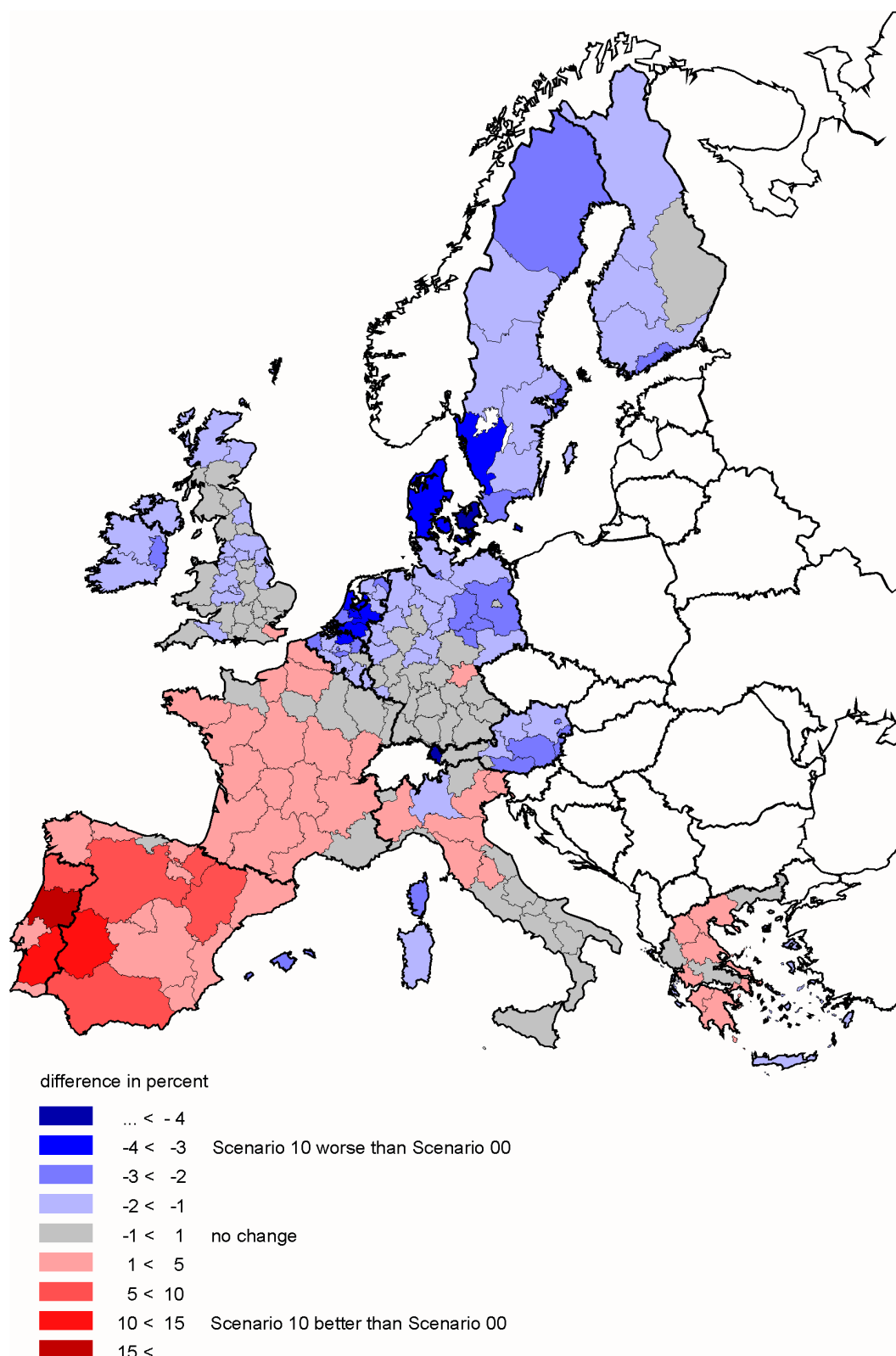


Figure 4.12. Example output: differences in GDP per capita between two scenarios

5. Conclusions

The model software developed for the SASI model has proved to be an efficient and flexible work environment for developing, testing and running the model and for analysing and visualising its results:

- The network scenario generation tool provides a user-friendly interface between the road, rail and air networks stored and updated in the ArcInfo GIS environment and the model.
- The internal binary model database achieves the integration between the individual submodels and serves as report files for post-processing of the results for analysis and display.
- The model software itself, by its modular design, has proved to be an extremely flexible platform for experimenting with different options of model specification and operation.
- Its interactive monitor facility permits online viewing of model progress and switching between views on different processes occurring in the model during operation.
- The analysis and presentation programmes developed provide a rich repertoire of methods for interpretation, visualisation and comparison of model results.

However, the present software components are still designed to be used and modified by the model designers within the project team. Future software development will be directed towards the aim of integrating the existing software components into a unified user-friendly software environment with a self-explanatory user interface that permits operation of the model also by other researchers.

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7. Annex

The Annex contains a list of the regions used in the SASI model as discussed in Sections 3.2 and 4.2 (Table A1).

Table A1. SASI regions

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Österreich	1	Burgenland	AT11	Internal	Eisenstadt
	2	Niederösterreich	AT12	Internal	St.Pölten
	3	Wien	AT13	Internal	Wien
	4	Kärnten	AT21	Internal	Klagenfurt
	5	Steiermark	AT22	Internal	Graz
	6	Oberösterreich	AT31	Internal	Linz
	7	Salzburg	AT32	Internal	Salzburg
	8	Tirol	AT33	Internal	Innsbruck
	9	Vorarlberg	AT34	Internal	Dornbirn
Belgique/ België	10	Bruxelles/Brussel	BE1	Internal	Bruxelles/Brussel
	11	Antwerpen	BE21	Internal	Antwerpen
	12	Limburg (BE)	BE22	Internal	Hasselt
	13	Oost-Vlaanderen	BE23	Internal	Gent
	14	Vlaams Brabant	BE24	Internal	Leuven
	15	West-Vlaanderen	BE25	Internal	Brugge
	16	Brabant Wallon	BE31	Internal	Wavre
	17	Hainaut	BE32	Internal	Charleroi
	18	Liege	BE33	Internal	Liege
	19	Luxembourg (BE)	BE34	Internal	Arlon
20	Namur	BE35	Internal	Namur	
Deutschland	21	Stuttgart	DE11	Internal	Stuttgart
	22	Karlsruhe	DE12	Internal	Mannheim
	23	Freiburg	DE13	Internal	Freiburg i.Br.
	24	Tübingen	DE14	Internal	Tübingen
	25	Oberbayern	DE21	Internal	München
	26	Niederbayern	DE22	Internal	Landshut
	27	Oberpfalz	DE23	Internal	Regensburg
	28	Oberfranken	DE24	Internal	Bamberg
	29	Mittelfranken	DE25	Internal	Nürnberg
	30	Unterfranken	DE26	Internal	Würzburg
	31	Schwaben	DE27	Internal	Augsburg
	32	Berlin	DE3	Internal	Berlin
	33	Brandenburg	DE4	Internal	Potsdam
	34	Bremen	DE5	Internal	Bremen
	35	Hamburg	DE6	Internal	Hamburg
	36	Darmstadt	DE71	Internal	Frankfurt am Main
	37	Giessen	DE72	Internal	Giessen
	38	Kassel	DE73	Internal	Kassel
	39	Mecklenburg-Vorpommern	DE8	Internal	Rostock
	40	Braunschweig	DE91	Internal	Braunschweig
	41	Hannover	DE92	Internal	Hannover
	42	Lüneburg	DE93	Internal	Lüneburg
	43	Weser-Ems	DE94	Internal	Oldenburg
	44	Düsseldorf	DEA1	Internal	Düsseldorf
	45	Köln	DEA2	Internal	Köln
	46	Münster	DEA3	Internal	Münster
	47	Detmold	DEA4	Internal	Bielefeld
	48	Arnsberg	DEA5	Internal	Dortmund
	49	Koblenz	DEB1	Internal	Koblenz
	50	Trier	DEB2	Internal	Trier
	51	Rheinessen-Pfalz	DEB3	Internal	Mainz
	52	Saarland	DEC	Internal	Saarbrücken

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Deutschland (continued)	53	Sachsen	DED	Internal	Leipzig
	54	Dessau	DEE1	Internal	Dessau
	55	Halle	DEE2	Internal	Halle
	56	Magdeburg	DEE3	Internal	Magdeburg
	57	Schleswig-Holstein	DEF	Internal	Kiel
	58	Thüringen	DEG	Internal	Erfurt
Danmark	59	Hovedstadsregionen and Øst for Storebælt	DK11 (DK001-7)	Internal	København
	60	Vest for Storebælt	DK12 (DK008-F)	Internal	Århus
España	61	Galicia	ES11	Internal	Santiago
	62	Principado de Asturias	ES12	Internal	Oviedo
	63	Cantabria	ES13	Internal	Santander
	64	Pais Vasco	ES21	Internal	Bilbao
	65	Comunidad Foral de Navarra	ES22	Internal	Pamplona
	66	La Rioja	ES23	Internal	Logrono
	67	Aragón	ES24	Internal	Zaragoza
	68	Comunidad de Madrid	ES3	Internal	Madrid
	69	Castilla y Leon	ES41	Internal	Valladolid
	70	Castilla-la Mancha	ES42	Internal	Toledo
	71	Extremadura	ES43	Internal	Mérida
	72	Cataluña	ES51	Internal	Barcelona
	73	Comunidad Valenciana	ES52	Internal	Valencia
	74	Islas Baleares	ES53	Internal	Palma de Mallorca
75	Andalucia	ES61	Internal	Sevilla	
76	Región de Murcia	ES62	Internal	Murcia	
Suomi/ Finland	77	Uusimaa	FI11	Internal	Helsinki
	78	Etelä-Suomi	FI12	Internal	Tampere
	79	Itä-Suomi	FI13	Internal	Kuopio
	80	Väli-Suomi	FI14	Internal	Jyväskylä
	81	Pohjois-Suomi	FI15	Internal	Oulu
	82	Ahvenanmaa/Åland	FI2	Internal	Maarianhamina
France	83	Île de France	FR1	Internal	Paris
	84	Champagne-Ardenne	FR21	Internal	Reims
	85	Picardie	FR22	Internal	Amiens
	86	Haute-Normandie	FR23	Internal	Le Havre
	87	Centre	FR24	Internal	Orleans
	88	Basse-Normandie	FR25	Internal	Caen
	89	Bourgogne	FR26	Internal	Dijon
	90	Nord-Pas-de-Calais	FR3	Internal	Lille
	91	Lorraine	FR41	Internal	Metz
	92	Alsace	FR42	Internal	Strasbourg
	93	Franche-Comté	FR43	Internal	Besancon
	94	Pays de la Loire	FR51	Internal	Nantes
	95	Bretagne	FR52	Internal	Brest
	96	Poitou-Charentes	FR53	Internal	Poitiers
97	Aquitaine	FR61	Internal	Bordeaux	
98	Midi-Pyrénées	FR62	Internal	Toulouse	
99	Limousin	FR63	Internal	Limoges	
100	Rhône-Alpes	FR71	Internal	Lyon	
101	Auvergne	FR72	Internal	Clermont-Ferrand	
102	Languedoc-Roussillon	FR81	Internal	Montpellier	
103	Provence-Alpes-Côte d'Azur	FR82	Internal	Marseille	
104	Corse	FR83	Internal	Ajaccio	

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Ellada	105	Anatoliki Makedonia, Thraki	GR11	Internal	Kavala
	106	Kentriki Makedonia	GR12	Internal	Thessaloniki
	107	Dytiki Makedonia	GR13	Internal	Kozani
	108	Thessalia	GR14	Internal	Larissa
	109	Ipeiros	GR21	Internal	Ioannina
	110	Ionia Nisia	GR22	Internal	Kerkyra
	111	Dytiki Ellada	GR23	Internal	Patrai
	112	Stereia Ellada	GR24	Internal	Lamia
	113	Peloponnisos	GR25	Internal	Tripolis
	114	Attiki	GR3	Internal	Athinai
	115	Voreio Aigaio	GR41	Internal	Mytilini
	116	Notio Aigaio	GR42	Internal	Ermoupolis
	117	Kriti	GR43	Internal	Irakleion
	Ireland	118	Dublin, Mid-East	IE11 (IE002-3)	Internal
119		Border, Midland-West	IE12 (IE001, IE004, IE008)	Internal	Galway
120		Mid-West, South-East, South-West	IE13 (IE005-7)	Internal	Cork
Italia	121	Piemonte	IT11	Internal	Torino
	122	Valle d'Aosta	IT12	Internal	Aosta
	123	Liguria	IT13	Internal	Genova
	124	Lombardia	IT2	Internal	Milano
	125	Trentino-Alto Adige	IT31	Internal	Bolzano
	126	Veneto	IT32	Internal	Venezia
	127	Friuli-Venezia Giulia	IT33	Internal	Trieste
	128	Emilia-Romagna	IT4	Internal	Bologna
	129	Toscana	IT51	Internal	Firenze
	130	Umbria	IT52	Internal	Perugia
	131	Marche	IT53	Internal	Ancona
	132	Lazio	IT6	Internal	Roma
	133	Abruzzo	IT71	Internal	Pescara
	134	Molise	IT72	Internal	Campobasso
	135	Campania	IT8	Internal	Napoli
	136	Puglia	IT91	Internal	Bari
	137	Basilicata	IT92	Internal	Potenza
138	Calabria	IT93	Internal	Reggio	
139	Sicilia	ITA	Internal	Palermo	
140	Sardegna	ITB	Internal	Cagliari	
Luxembourg	141	Luxembourg	LU	Internal	Luxembourg
Nederland	142	Groningen	NL11	Internal	Groningen
	143	Friesland	NL12	Internal	Leeuwarden
	144	Drenthe	NL13	Internal	Emmen
	145	Overijssel	NL21	Internal	Enschede
	146	Gelderland	NL22	Internal	Apeldoorn
	147	Flevoland	NL23	Internal	Lelystad
	148	Utrecht	NL31	Internal	Utrecht
	149	Noord-Holland	NL32	Internal	Amsterdam
	150	Zuid-Holland	NL33	Internal	Rotterdam
	151	Zeeland	NL34	Internal	Middelburg
	152	Noord-Brabant	NL41	Internal	Eindhoven
	153	Limburg (NL)	NL42	Internal	Maastricht

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/external	Centroid
Portugal	154	Norte	PT11	Internal	Porto
	155	Centro (PT)	PT12	Internal	Coimbra
	156	Lisboa e Vale do Tejo	PT13	Internal	Lisboa
	157	Alentejo	PT14	Internal	Evora
	158	Algarve	PT15	Internal	Faro
Sverige	159	Stockholm	SE01	Internal	Stockholm
	160	Östra Mellansverige	SE02	Internal	Uppsala
	161	Småland med Öarna	SE03	Internal	Jönköping
	162	Sydsverige	SE04	Internal	Malmö
	163	Västsverige	SE05	Internal	Göteborg
	164	Norra Mellansverige	SE06	Internal	Gävle
	165	Mellersta Norrland	SE07	Internal	Sundsvall
	166	Övre Norrland	SE08	Internal	Umea
United Kingdom	167	Cleveland, Durham	UK11	Internal	Middlesbrough
	168	Cumbria	UK12	Internal	Carlisle
	169	Northumberland, Tyne and Wear	UK13	Internal	Newcastle upon Tyne
	170	Humberside	UK21	Internal	Kingston upon Hull
	171	North Yorkshire	UK22	Internal	Harrogate
	172	South Yorkshire	UK23	Internal	Sheffield
	173	West Yorkshire	UK24	Internal	Leeds
	174	Derbyshire, Nottinghamshire	UK31	Internal	Nottingham
	175	Leicestershire, Northamptonshire	UK32	Internal	Leicester
	176	Lincolnshire	UK33	Internal	Lincoln
	177	East Anglia	UK4	Internal	Cambridge
	178	Bedfordshire, Hertfordshire	UK51	Internal	Luton
	179	Berkshire, Buckinghamshire, Oxfordshire	UK52	Internal	Reading
	180	Surrey, East-West Sussex	UK53	Internal	Brighthelm
	181	Essex	UK54	Internal	Southend-On-Sea
	182	Greater London	UK55	Internal	London
	183	Hampshire, Isle of Wight	UK56	Internal	Southampton
	184	Kent	UK57	Internal	Maidstone
	185	Avon, Gloucestershire, Wiltshire	UK61	Internal	Bristol
	186	Cornwall, Devon	UK62	Internal	Plymouth
	187	Dorset, Somerset	UK63	Internal	Bournemouth
	188	Hereford & Worcester, Warwickshire	UK71	Internal	Warwick
	189	Shropshire, Staffordshire	UK72	Internal	Newcastle-under-Lyme
	190	West Midlands (County)	UK73	Internal	Birmingham
191	Cheshire	UK81	Internal	Warrington	
192	Greater Manchester	UK82	Internal	Manchester	
193	Lancashire	UK83	Internal	Blackpool	
194	Merseyside	UK84	Internal	Liverpool	
195	Clwyd, Dyfed, Gwynedd, Powys	UK91	Internal	Wrexham Maelor	
196	Gwent, Mid-South-West Glamorgan	UK92	Internal	Cardiff	
197	Borders, Central, Fife, Lothian, Tayside	UKA1	Internal	Edinburgh	
198	Dumfries & Galloway, Strathclyde	UKA2	Internal	Glasgow	
199	Highlands, Islands	UKA3	Internal	Inverness	
200	Grampian	UKA4	Internal	Aberdeen	
201	Northern Ireland	UKB	Internal	Belfast	

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Shqipëria	202	Shqipëria	AL	External	Tiranë
Bosna i Hercegovina	203	Bosna i Hercegovina	BA	External	Sarajevo
Balgarija	204	Balgarija	BG	External	Sofija
Belarus	205	Belarus	BY	External	Minsk
Schweiz	206	Schweiz (West)	CH1	External	Bern
	207	Schweiz (East)	CH2	External	Zürich
Česko	208	Česko	CZ	External	Praha
Eesti	209	Eesti	EE	External	Tallinn
Hrvatska	210	Hrvatska	HR	External	Zagreb
Magyarország	211	Magyarország	HU	External	Budapest
Island	212	Island	IS	External	Reykjavik
Lietuva	213	Lietuva	LT	External	Vilnius
Latvija	214	Latvija	LV	External	Riga
Moldova	215	Moldova	MD	External	Chisinau
Republika Makedonija	216	Makedonija	MK	External	Skopje
Norge	217	Norge	NO	External	Oslo
Polska	218	Polska (East)	PL1	External	Warszawa
	219	Polska (North-West)	PL2	External	Poznan
	220	Polska (South-West)	PL3	External	Wroclaw
	221	România	RO	External	Bucuresti
Rossija	222	Rossija (Moskva)	RU1	External	Moskva
	223	St. Peterburg	RU2	External	St. Peterburg
Slovenija	224	Slovenija	SI	External	Ljubljana
Slovensko	225	Slovensko	SK	External	Bratislava
Türkiye	226	Türkiye	TR	External	Istanbul
Ukraina	227	Ukraina	UA	External	Kyiv
Jugoslavija	228	Jugoslavija	YU	External	Beograd
West Africa and the Americas	229	America	AM	External	Model node
East Africa, Asia, Australasia	230	Asia	AS	External	Model node
Egypt and the Middle East	231	Middle East	ME	External	Cairo
Morocco, Algeria, Tunisia, Libya	232	North Africa	NA	External	Alger

Note:

The system of regions consists of 232 regions. There are 201 'internal' regions. Of these there are 196 NUTS-2 regions for all EU countries except Denmark and Ireland. NUTS-0/1/2 regions DK (Denmark) and IE (Ireland) were further subdivided into two and three groups of NUTS-3 regions, respectively, because of modelling requirements. NUTS-2 region ES63 (Ceuta e Mellila) and NUTS-1 regions ES7 (Canarias), FR9 (Départements d'outre mer), PT2 (Açores) and PT3 (Madeira), which are not part of the European continent, are not included in the system of regions. There are 27 'external' regions for other European countries outside the EU. Of these, 20 countries are handled as whole countries. Three countries are further subdivided: Poland into three regions, Switzerland into two regions, and Russia has a separate region for St. Peterburg. There are four external regions for the rest of the world indicating the direction from where commodity flows enter or leave Europe.