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Michael Wegener, Dieter Bökemann

The SASI Model: Model Structure

Deliverable D8 of the EU Project
Socio-Economic and Spatial Impacts of
Transport Infrastructure Investments
and Transport System Improvements
(SASI)

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Institut für Raumplanung
Fakultät Raumplanung, Universität Dortmund
D-44221 Dortmund
Tel. 0231-7552291, Fax 0231-7554788

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Preface

This report originated in the project "Socio-Economic and Spatial Impacts of Transport Infrastructure Investments and Transport System Improvements" (SASI) commissioned by the General Directorate VII (Transport) of the European Commission as part of the 4th Framework Programme of Research and Technology Development.

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 Commission. With respect to the cohesion objective of the European Union the model is to answer the question 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 socio-economic impacts of transport investment decisions and policies and demonstrating the usability of the modelling system by applying it to a number of relevant case studies in the framework of various scenarios of political, social and economic developments.

The SASI project is associated with the EUNET project co-ordinated by Marcial Echenique & Partners Ltd., Cambridge, UK. SASI is carried out with two partners, the Institute of Urban and Regional Research of the Technical University of Vienna (SRF) and the Department of Town and Regional Planning of the University of Sheffield (TRP), with SRF acting as the project co-ordinator

This report, which is the eighth deliverable of the EUNET project and the fourth of the SASI sub-project, presents the SASI model based on the previous SASI Deliverables D4 (Bökemann et al., 1997), D5 (Schürmann et al., 1997) and D7 (Masser et al., 1997).

The report, although written by two team members, represents the results of the combined efforts of the whole SASI team to find the right balance between the desirable complexity of an 'ideal' model and the necessary simplifications dictated by data unavailability and the limited resources of a finite project.

The authors are particularly indebted to the conceptual ideas and critical comments of Hans Kramar and Roland Hackl (Vienna), Ian Masser, Max Craglia and Adelheid Holl (Sheffield) and Klaus Spiekermann, Carsten Schürmann and Franz Fürst (Dortmund), to Roland Hackl and Franz Fürst for their efficient empirical tests of the numerous hypotheses proposed and to Adelheid Holl and Carsten Schürmann for creatively coping with ever changing requests for data, as well as to Meinhard Lemke for his singular accomplishment to present the SASI European transport networks on a page.

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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 eighth deliverable of the EUNET project and the fourth of the SASI sub-project, presents the SASI model based on the previous SASI Deliverables D4 (Bökemann et al., 1997), D5 (Schürmann et al., 1997) and D7 (Masser et al., 1997).

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 functions 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, although in principle possible, 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 account of network congestion or intermodality of transport networks.

This deliverable describes the SASI model in general terms, i.e. its submodels and the functional form of its model equations. The precise specification of the variables and parameters of the model equations will be presented in Deliverable D11, the actual implementation and validation of the model in Deliverable D13 and the results of the demonstration scenario simulations in Deliverable D15.

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 the 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 the 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 most recent *Cohesion Report* (European Commission, 1997a) 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.

At the end of the project a report on SASI will be produced as well as a combined report on SASI and the EUNET and ECOPAC projects conducted for the Commission in the same area.

2.3 The Position of D8 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 data base 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 5.1) as well as the calculation of regional endowment factors for the *Regional GDP* submodel (see Section 5.3) require a variety of other data sources.

This report D8 describes 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 introduces and explains the major design considerations that led to the construction of the model. It presents a detailed description of each submodel and how they interact and summarises the data requirements, output and operation of the model.

D8 has a similar structure as the previous three SASI reports. Therefore topics that have been dealt with in depth in D4, D5 or D7 such as the discussion of policy goals of the European Union (D4), the specification of accessibility indicators (D5) or the detailed discussion of the data issues (D7) are not repeated. This report starts, in Section 3, with a state-of-the art review of regional economic development theory and regional development models. Section 4 repeats (and updates) the tentative overview of the SASI model structure already contained in the previous three reports. Section 5 is the central part of this report. It presents the submodels of the SASI model in detail. Section 6 summarises the socio-economic and cohesion indicators that will be produced by the model. Section 7 reviews the data requirements discussed in D7 in the light of these more refined submodel specifications. Section 8 contains information on software aspects of the SASI model, and Section 9 draws conclusions for the implementation and testing of the model.

The empirical specification of the model will be presented in the fifth SASI deliverable, or D11 of EUNET. The actual implementation and validation of the model will be presented in the sixth SASI deliverable, or D13 of EUNET. The results of the demonstration scenario simulations will be presented in the seventh SASI deliverable, or D15 of EUNET.

3. Theoretical Foundations

3.1 Issues and Trends

The important role of transport infrastructure for regional development is one of the fundamental principles of regional economics. In its most simplified form it implies that regions with better access to the locations of input materials and markets will, *ceteris paribus*, be more productive, more competitive and hence more successful than more remote and isolated regions (Jochimsen, 1966).

However, the impact of transport infrastructure on regional development has been difficult to verify empirically. There seems to be a clear positive correlation between transport infrastructure endowment or the location in interregional networks and the *levels* of economic indicators such as GDP per capita (e.g. Biehl, 1986; 1991; Keeble et al., 1982; 1988). However, this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today (cf. Bröcker and Peschel, 1988). Attempts to explain *changes* in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful. The reason for this failure may be that in countries with an already highly developed transport infrastructure further transport network improvements bring only marginal benefits. The conclusion is that transport improvements have strong impacts on regional development only where they result in removing a *bottleneck* (Blum, 1982; Biehl, 1986; 1991).

Another debate concerns the question whether transport infrastructure investments merely result in spatial reallocations of economic activity (a *zero-sum game)* or whether they cause a sustained increase in overall welfare. Large transport infrastructure projects obviously have employment effects in the construction industry and, through multiplier effects, in related industries and consumer goods industries, even though these effects are restricted to the period of construction. It is equally clear that transport infrastructure improvements, by the savings in travel and transport time and cost they provide, increase the productivity of transport users as they enable them to provide goods and services more efficiently, and this will result in more goods and services being produced and consumed and so increase the general welfare. However, public and private money spent on transport cannot be spent on other things which also might increase the general welfare, so the net effect for the total area under study may be zero. In addition, it is not certain whether the gains in productivity will indeed result in more goods and services being produced and consumed. It may well be that a large part of the savings in travel time and transport cost will be merely used for making longer trips and shipping the same amount of goods over longer distances. Even though this is recorded as an increase in GDP, it may not reflect a true gain in human well-being and certainly is harmful to the environment.

While there is uncertainty about the magnitude of the impact of transport infrastructure on regional development, there is even less agreement on its direction. It is debated whether transport infrastructure contributes to regional polarisation or decentralisation. 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 (Vickerman, 1991a), whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions (Bröcker and Peschel, 1988). 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 the 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 (Vickerman, 1991b).

While these two effects may partly cancel each other out, one factor unambiguously increases existing differences in accessibility. New transport infrastructure tends to be built not between core and periphery but within and between core regions, because this is where transport demand is highest (Vickerman, 1991a). It can therefore be assumed that the trans-European networks will largely benefit the core regions of Europe.

These developments have to be seen in the light of changes in the field of transport and communications which will fundamentally change the way transport infrastructure influences spatial development (Masser et al., 1992). Several trends combine to reinforce the tendency to reduce the impacts of transport infrastructure on regional development:

- An increased proportion of international freight comprises high-value goods for which transport cost is much less than for low-value bulk products. For modern industries the *quality* of transport services has replaced transport *cost* as the most important factor.

- Transport infrastructure improvements which reduce the variability of travel times, increase travel speeds or allow flexibility in scheduling are becoming more important for improving the competitiveness of service and manufacturing industries and are therefore valued more highly in locational decisions than changes resulting only in cost reductions.

- Telecommunications have reduced the need for some goods transports and person trips, however, they may also increase transport by their ability to create new markets.

- With the shift from heavy-industry manufacturing to high-tech industries and services other less tangible location factors have come to the fore and have at least partly displaced traditional ones. These new location factors include factors related to leisure, culture, image and environment, i.e. quality of life, and factors related to access to information and specialised high-level services and to the institutional and political environment.

On the other hand, there are also tendencies that increase the importance of transport infrastructure:

- The introduction of totally new, superior levels of transport such as the high-speed rail system may create new locational advantages, but also disadvantages for regions not served by the new networks.

- Another factor adding to the importance of transport is the general increase in the volume of goods movements (due to changes in logistics such as just-in-time delivery) and travel (due to growing affluence and leisure time).

Both above tendencies are being accelerated by the increasing integration of national economies by the Single European Market, the ongoing process of normalisation between western and eastern Europe and the globalisation of the world economy.

The conclusion is that 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.

3.2 Theoretical Approaches

In order to cope with this complexity there exists a broad spectrum of theoretical approaches to explain the impacts of transport infrastructure investments on regional socio-economic development. Originating from different scientific disciplines and intellectual traditions, these approaches presently coexist, even though they are partially in contradiction. An integrated theory of the relationship between transport infrastructure and regional socio-economic development is not in sight.

Linneker (1997) in his state-of-the-art review in this field for SASI distinguishes seven principal theoretical-methodological approaches:

National Growth Approaches

These approaches are based in the tradition of macroeconomic models which study multiplier effects of public investment in which public investment has either positive or negative (crowding-out) influence on private investment. In the context of interest here they study the effects of transport infrastructure investment on private investment and productivity. In general only national economies are studied and regional effects are ignored. Pioneered by Aschauer (1989; 1993) such studies use time-series analyses and growth model structures to link public infrastructure expenditures to movements in private sector productivity. An increase in public investment raises the marginal product of private capital and provides an incentive for a higher rate of private capital accumulation and labour productivity growth. Based on US data, Aschauer (1993) suggests that a one-percent increase in public capital will bring a 0.33 percent increase in private sector output. Based on similar assumptions, the multi-country macro-economic growth model QUEST used by the European Commission (1997b) estimates that all TETN projects of the present outline plans will result in additional 160 billion ECU in GDP per year and 800,000 additional jobs by 2025.

Critics of these approaches argue that there may be better infrastructure strategies than new construction and that policy measures aimed at increasing private investment directly rather than via public investment will have greater impact on national competitiveness. Holtz-Eakin and Schwartz (1995) also used US data to show that large-scale infrastructure provision had no appreciable effects on productivity growth. In addition, the concerns voiced above hold that the induced growth in GDP may to a large part consist of environmentally harmful additional transport.

Regional Growth Approaches

These approaches rest on the neo-classical growth model which states that regional growth in GDP per capita is a function of regional endowment factors including public capital such as transport infrastructure, and that, based on the assumption of diminishing returns to capital, regions with similar factors should experience converging per-capita incomes over time. The suggestion is that, as long as transport infrastructure is unevenly distributed among regions, transport infrastructure investments in regions with poor infrastructure endowment will accelerate the convergence process, whereas once the level of infrastructure provision becomes uniform across regions, they cease to be important. Studies along these lines for Europe in general have been able to demonstrate albeit slow convergence between European regions in GDP per capita.

Critics of regional growth models built on the central assumption of diminishing returns to capital argue that they cannot distinguish between this and other possible mechanisms generating convergence such as migration of labour from poor to rich regions or technological flows from rich to poor regions. Therefore Cheshire and Carbonaro (1995) proposed a model with sixteen explanatory variables including national influences, European integration effects and variables expressing regional policy objectives, spatial adjustment through commuting and migration and knowledge spillover through research and development. European integration is represented by changes in accessibility or economic potential (see below). The model is based on *functional urban regions* or labour market regions instead of administrative regions to take account of distorting effects of commuting flows.

Production Function Approaches

This approach models economic activity in a region as a function of *production factors*. The classical production factors are capital, labour and land. In modern production function approaches infrastructure is added as a public input used by firms within the region (Jochimsen, 1966; Buhr, 1975). The assumption behind this expanded production function is that regions with higher levels of infrastructure provision will have higher output levels and that in regions with cheap and abundant transport infrastructure more transport-intensive goods will be produced. Regional production functions of GDP per capita including transport infrastructure indicators have been calculated for European regions by Biehl (1986; 1991). Blum (1982) estimated regional production functions of regional gross value added in Germany incorporating explanatory variables such as density of population, kilometres of motorways (weighted by capacity and network linkage), numbers of rail freight stations, turnover in regional ports, new commercial and industrial sites, hotel bed capacity (as a proxy for recreational and informational potential), open spaces (as a proxy for natural environment) and a factor representing the quality of regional central places.

The main problems of regional production functions is that their econometric estimation tends to confound rather than clarify the complex causal relationships and substitution effects between production factors. This holds equally for production function approaches including measures of regional infrastructure endowment. In addition the latter suffer from the fact that they disregard the network quality of transport infrastructure, i.e. treat a kilometre of motorway or railway the same everywhere, irrespective of where they lead to.

Locational Approaches

These approaches attempt to respond to the latter criticism by substituting more complex accessibility indicators for the simple infrastructure endowment in the regional production function. Except for this substitution, these approaches do not differ from the ones discussed in the previous paragraph. Accessibility indicators can be any of the indicators discussed in SASI Deliverable D5 (Schürmann et al., 1997) but in most cases have been some form of population or economic potential (see below). Frequently the indicator of regional economic development is employment, or rate of change of employment, by industry.

Accessibility and Economic Potential Approaches

In these approaches regional accessibility or economic potential is used as the only variable to explain regional economic development. In that respect they are the pure operationalisation of the concept of 'economic potential' which is simply the assumption stated at the outset of this chapter that regions with better access to markets have a higher probability of being economically successful. Pioneering examples of empirical potential studies for Europe are Keeble et al. (1982; 1988). Today approaches relying only on accessibility or potential measures have been replaced by the hybrid approaches discussed in the previous paragraph. Also the accessibility indicators used have become much more diversified by type, industry and mode as discussed in SASI Deliverable D5 (Schürmann et al., 1997).

Trade Integration Approaches

These approaches model interregional trade flows as a function of interregional transport cost. Peschel (1981) and Bröcker and Peschel (1988) estimated a trade model for several European countries as a doubly-constrained spatial interaction model with fixed supply and demand in each region in order to assess the impact of the economic integration of Europe in terms of reduced tariff barriers and border delays between European countries. By the same token their model could have been used to forecast the impacts of transport infrastructure improvements on interregional trade flows. If the origin constraint of fixed regional supply were relaxed, the model could have been used also for predicting regional economic development. Krugman (1991) and Krugman and Venables (1995) extended this simple model of trade flows by the introduction of economies of scale of firms and labour mobility.

Regional Input-Output Approaches

These approaches extend the trade flow model by the explicit consideration of inter-industry linkages using the Leontief (1966) multi-regional input-output framework. These models estimate inter-industry/interregional trade flows as a function of transport cost and a fixed matrix of technical inter-industry input-output coefficients. Final demand in each region is exogenous. Regional supply, however, is elastic, so the models can be used to forecast regional economic development. One example of a regional economic model based on the input-output paradigm is the MEPLAN model described in Section 3.3.

3.3 Regional Economic Models

In this section three contemporary models of regional development are presented. They differ in their association with one or more of the above theoretical-methodological approaches and in the way they operationalise transport infrastructure. The latter characteristic is used to order them by increasing complexity and data requirements:

(1) Infrastructure endowment

The most straightforward way of quantifying regional transport infrastructure is to measure the amount of infrastructure *within* the region. Such measures can, for instance, be used in a regional production function (e.g. Biehl, 1986; 1991; Blum, 1982):

$$Q_{ir} = \mathrm{f}\,(K_{ir}\,,\,L_{ir}\,,\,I_r)$$

where Q_{ir} is the volume of production (e.g. gross domestic product, value added or employment) of industry i in region r in a certain unit of time and K_{ir}, L_{ir} and I_r are indicators of capital, labour and infrastructure in the region, respectively. Transport infrastructure is usually represented by the amount of transport infrastructure such as motorways or railways within the region.

A recent example of this approach is the ECOPAC project conducted for DG VII within the 4th Framework RTD Programme (SETEC Economie, 1997). In the ECOPAC model the relative change in regional employment between two years, ΔE_r, is modelled as a function of the shares of agricultural and manufacturing employment in the region, E_{1r} and E_{2r}, and the infrastructure endowment R_r is expressed by the total length of motorways in the region:

$$\Delta E_r = \mathrm{f}\,(E_{1r}, E_{2r}, \ldots, R_r)$$

(2) Accessibility or potential

The infrastructure endowment approach has the advantage of having only moderate data requirements, however it fails to take account of the *network* characteristic of transport infrastructure. Another group of models tries to accomplish that by substituting the within-region indicators of infrastructure by *accessibility* or *potential* indicators:

$$Q_{ir} = \mathrm{f}\,(K_{ir}\,,\,L_{ir}\,,\,A_r)$$

where A_r is one of the accessibility indicators discussed in SASI Deliverable D5 (Schürmann et al., 1997). One possible formulation of accessibility is a potential function with respect to activity W and the transport cost between regions r and all other regions s:

$$A_r(W) = \sum_s W_s\ \exp\,(-\beta\ c_{rs})$$

If the W_s are population in regions *s*, the potential is called *market* potential because it represents potential markets, if the W_s are GDP in regions *s*, it is called *economic* potential because it represents potential suppliers and customers.

The SASI model described in this report is an example of this approach.

Cheshire and Carbonaro (1995) proposed a model of *change* in regional GDP per capita in which European integration (not transport infrastructure) is represented by changes in accessibility or economic potential:

$$\dot{q}_r(t-1,t) = \beta_0 + \beta_1 q_r(t-1) + \beta_2\, \dot{q}_{r'}(t-1,t) + ... + \beta_5 \Delta A_r(t) + \beta_6 [\Delta A_r(t)]^2 + ...$$

where $\dot{q}_r(t-1,t)$ is the change in regional GDP per capita in region *r* between years *t*–1 and *t*, $q_r(t-1)$ is GDP per capita in region *r* in year *t*–1, $\dot{q}_{r'}(t-1,t)$ is change in GDP per capita in the country *r'* to which region *r* belongs (excluding major cities) and $\Delta A_r(t)$ is the change in economic potential of region *r* in year *t*. The ellipses ... stand for eleven other variables representing national factors, indicators characterising regions as Objective 1 or Objective 2 regions, indicators taking account of spatial adjustment through commuting and migration and indicators expressing knowledge spillover through research and development. To minimise the distorting effects of interregional commuting, the model is based on *functional urban regions* or labour market regions instead of administrative regions.

(3) Multiregional input-output

Multiregional input-output models explicitly model trade flows between regions as a function of regional production costs and transport costs between regions. A recent example of a multiregional input-output model is the MEPLAN model developed by Marcial Echenique & Partners applied in the EUNET project presently conducted for DG VII within the 4th Framework RTD programme of the European Commission (Marcial Echenique & Partners Ltd., 1998). In MEPLAN the flow of goods or services of industry *i* between regions *r* and *s* is modelled as an attraction-constrained spatial interaction model:

$$T_{irs} = \frac{S_{ir}\ \exp[-\beta_i\,(c_{ir} + g_{irs} + w_r)]}{\sum_s S_{ir}\ \exp[-\beta_i\,(c_{ir} + g_{irs} + w_r)]}\, Y_{ir}$$

where S_{ir} is the supply of goods or services of industry *i* in region *r*, and c_{ir} and g_{irs} are production cost for a unit of goods or services of industry *i* in region *r* and transport cost for one unit of those goods and services between regions *r* and *s*, and w_r is a value representing attributes of region *r* not represented by S_{ir}. Y_{ir} is the demand for goods or services of industry *i* in destination region *s*:

$$Y_{is} = Y_{is}^0 + \sum_j a_{ijr} X_{jr}$$

where Y_{is}^{υ} is final demand for goods and services of industry i in region s. The a_{ijr} are technical (or input-output) coefficients indicating the pattern of inter-industry linkages. The X_{jr} are the volumes of production of goods and services of industry j in region r:

$$X_{jr} = \sum_s T_{jrs}$$

which are, of course, the totals of all shipments of goods and services of industry j between regions r and s, including r. Production costs c_{ir} of goods and services of industry i in regions r are a weighted average of the prices of their intermediate inputs:

$$c_{ir} = \sum_j a_{ijr} \hat{c}_{ir}$$

where $\hat{c}_{ir}$ is the price of a unit of goods and services of industry i in region r calculated as the average price of its inputs including transport costs:

$$\hat{c}_{ir} = \frac{\sum_r (c_{ir} + \tilde{c}_{irs})\, T_{irs}}{\sum_r T_{irs}}$$

where $\tilde{c}_{irs}$ is the transport cost of inputs. The modal split equation is a logit model dividing trade flows between regions r and s as a function of the transport cost of a unit of goods or services of industry i between regions r and s by modes m, g_{irsm}, and a mode-specific constant, κ_{im}:

$$T_{irsm} = \frac{\exp[-\lambda_i (g_{irsm} + \kappa_{im})]}{\sum_{m \in \mathbf{M}_{irs}} \exp[-\lambda_i (g_{irsm} + \kappa_{im})]}\, T_{irs}$$

where $\mathbf{M}_{irs}$ is the set of modes available to goods and services of industry i between regions r and s. Route choice is modelled by a multi-path logit model as a function of transport costs g_{irsmk} of links k

$$T_{irsmk} = \frac{\exp[-\mu_i (g_{irsmk})]}{\sum_{k \in \mathbf{K}_{irsm}} \exp[-\mu_i (g_{irsmk})]}\, T_{irsm}$$

where $\mathbf{K}_{irsm}$ is the set of feasible paths between regions r and s available to goods and services of industry i.

4. Model Overview

This section gives an overview of the structure of the SASI model. It repeats and partially updates the tentative outline of the SASI model accompanying the three previous SASI deliverables. The overview is presented here to make the reader familiar with the interactions between the seven submodels of the SASI model presented in more detail in Section 5.

4.1 Design Principles

The SASI model is to consistently forecast socio-economic and spatial impacts of transport infrastructure investment and transport system improvements in Europe. From this purpose the following requirements can be derived:

- The model must be responsive to changes in European transport policy, in particular to different scenarios and time schedules of expanding and improving the trans-European rail and road networks.

- The model must produce regional indicators of socio-economic development and cohesion that are relevant from the point of view of policy objectives of the European Union.

The first of these two requirements is addressed by calculating regional accessibility indicators expressing the location of each region within the strategic European rail and road networks defined for SASI. Changes in the trans-European networks affect the distribution of accessibility and the economic advantage across regions. However, regional socio-economic development cannot be explained by transport changes alone. Therefore other, non-transport factors determining regional socio-economic development are included in the model. These factors include assumptions about European developments as well as factors expressing the endowment, or suitability and capacity for economic activities, of regions. When comparing different scenarios of transport network development, the non-transport factors have to be kept constant across scenarios.

The second requirement determines the output and hence the necessary submodels of the model. As indicated in Section 2.1 and in SASI Deliverable D4, the goals of the European Union are 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. Since sustainability objectives are (for the time being) excluded from SASI, efficiency and equity objectives are the relevant goals. As argued in SASI Deliverable D4, despite their acknowledged weaknesses, the most commonly used indicators of regional economic efficiency are regional output and employment or, in operational terms, gross domestic product (GDP) per capita and rate of unemployment. This implies that not only economic output and employment but also population and labour force have to be modelled. Equity or cohesion indicators finally express the distribution of accessibility, GDP per capita and unemployment across regions (see SASI Deliverable D4, Bökemann et al., 1997).

Based on the above considerations, the SASI 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.

This defines the minimum scope of the SASI model. More submodels may be added later if desired. However, to achieve the objectives of SASI as outlined in Section 2.2, the above submodels are necessary.

4.2 Submodels

In this section the seven submodels of the SASI model and the interrelationships between them are briefly described. Figure 1 visualises the interactions between the seven submodels.

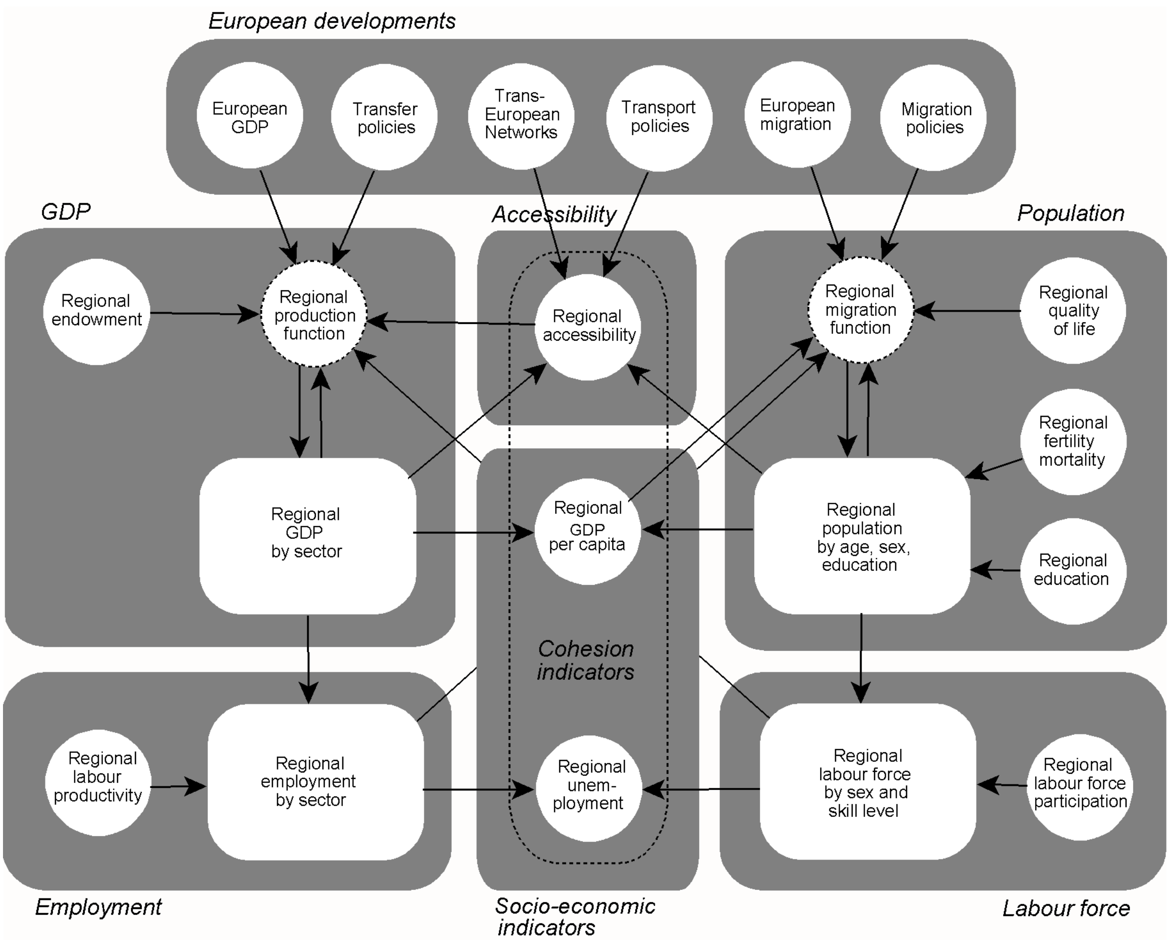

Figure 1. The SASI model.

European Developments
Here assumptions about European developments are entered that are processed by the subsequent 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 via the Structural Funds or the Common Agricultural Policy or by national governments to assist specific regions, which, because of their concentration on peripheral regions, are responsible for a sizeable part of their economic growth. The last group of assumptions are those about policy decisions on the trans-European networks. As these are of focal interest in SASI, they are modelled with considerable detail. A network scenario is a time-sequenced investment programme for addition, upgrading or closure of links of the road, rail or air networks. Besides a 'baseline' scenario several TETN scenarios will be specified.

Regional Accessibility
This 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 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) per capita by industrial sector (agriculture, manufacturing, services) generated in each region as a function of endowment indicators and accessibility. Endowment indicators are indicators measuring the suitability or capacity of the region for economic activity. Endowment indicators may 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, or institutions of higher education, cultural facilities, good housing and a pleasant climate and environment. Accessibility indicators are derived from the *Regional Accessibility* submodel. In addition to endowment and accessibility indicators, monetary transfers to regions by the European Union such as assistance by the Structural Funds or the Common Agricultural Policy or 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 such that the total of all regional forecasts multiplied by regional population meets the exogenous forecast of economic development (GDP) of Europe as a whole by the *European Developments* submodel.

Regional Employment
Regional employment is derived from regional GDP by exogenous forecasts of regional labour productivity by industrial sector (GDP per worker) modified by effects of changes in regional accessibility.

Regional Population
Regional population changes 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. Interregional migration within the European Union 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, whereas immigration to and outmigration from the European Union are modelled separately. 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 GDP 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.

4.3 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 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 (see Figures 3 to 5). The SASI system of regions and the strategic networks used in SASI are also used in the concurrent 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.

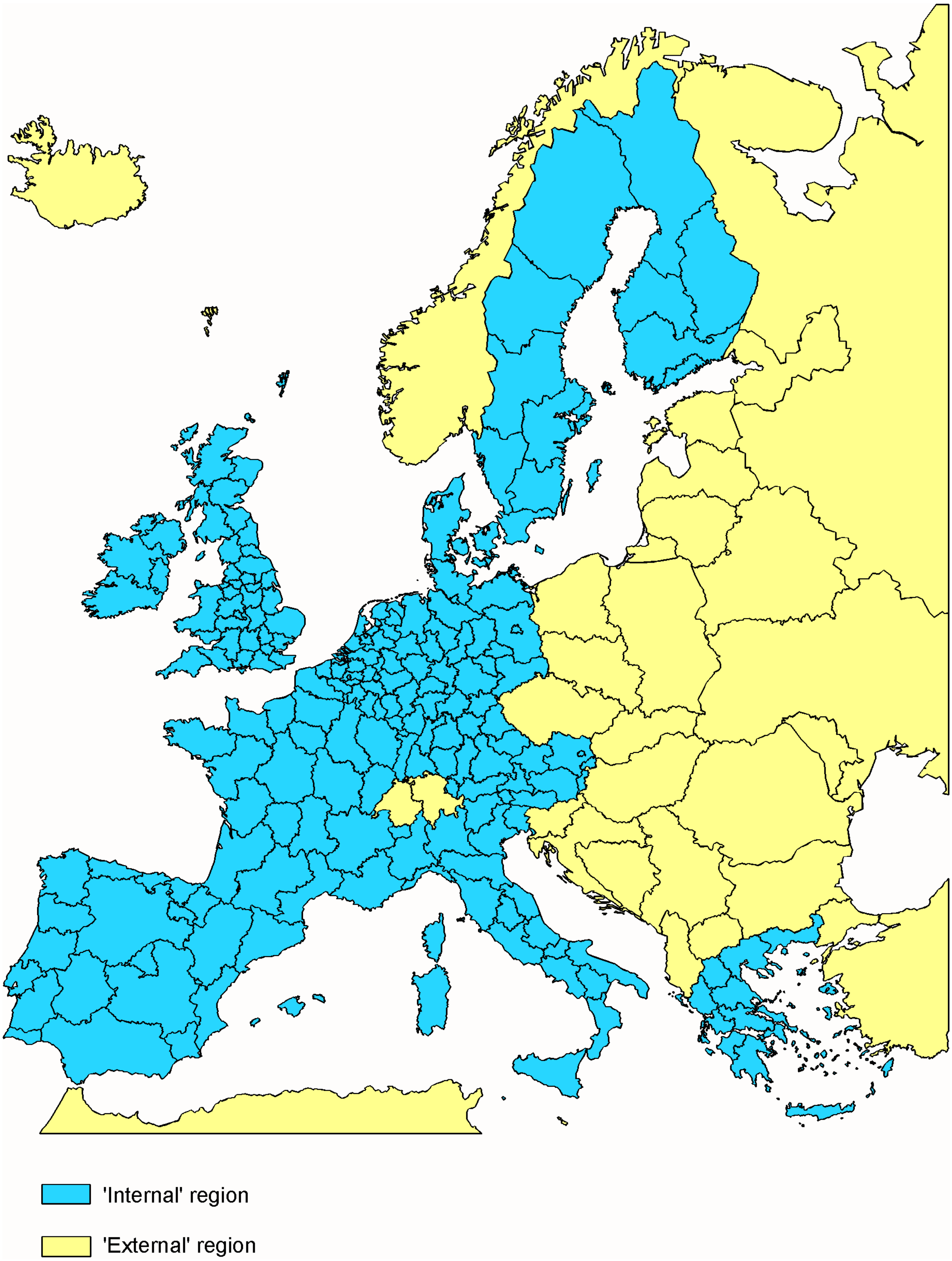

Figure 2. The SASI system of regions.

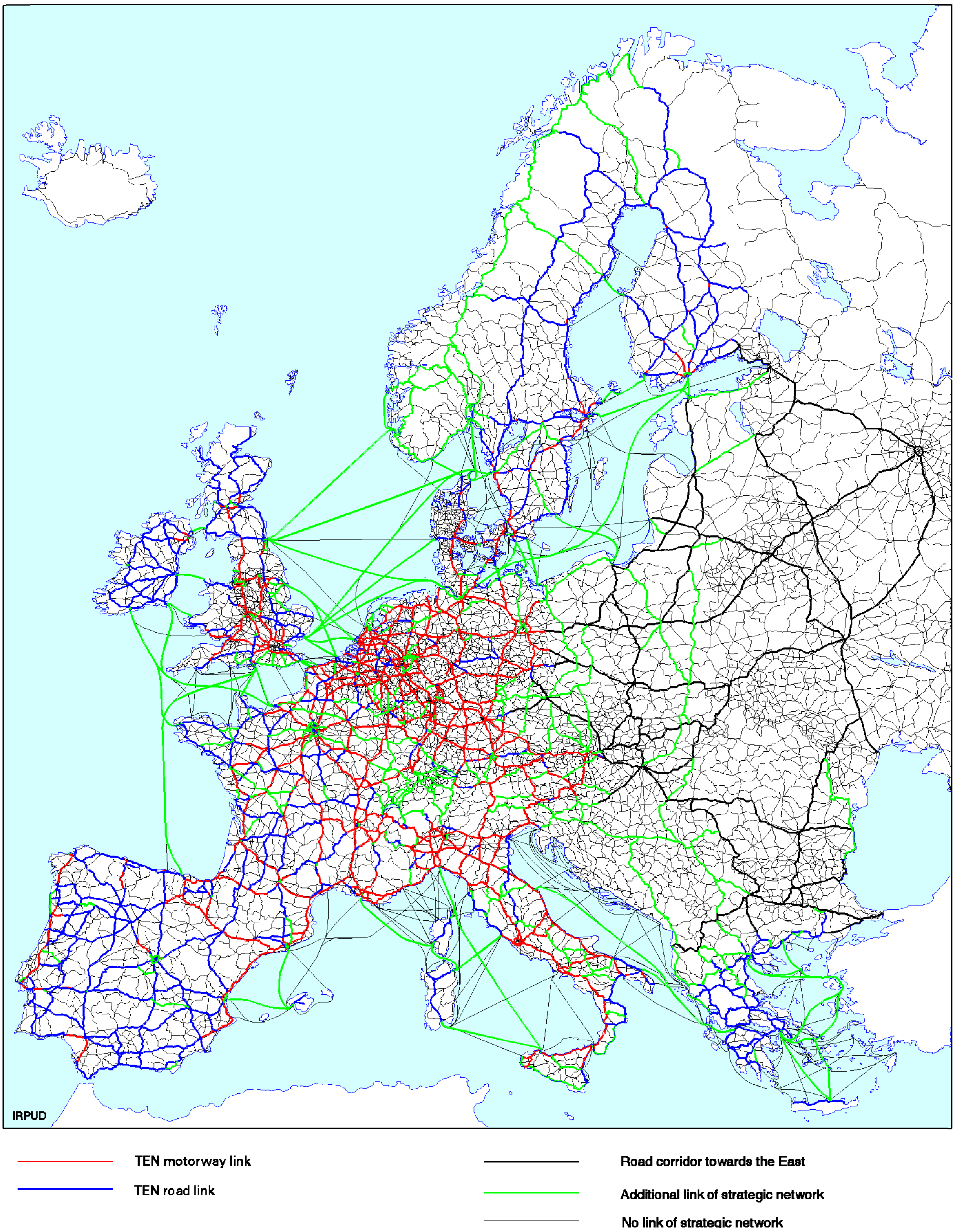

Figure 3. The SASI strategic road network in 1996.

Figure 4. The SASI strategic rail network in 1996.

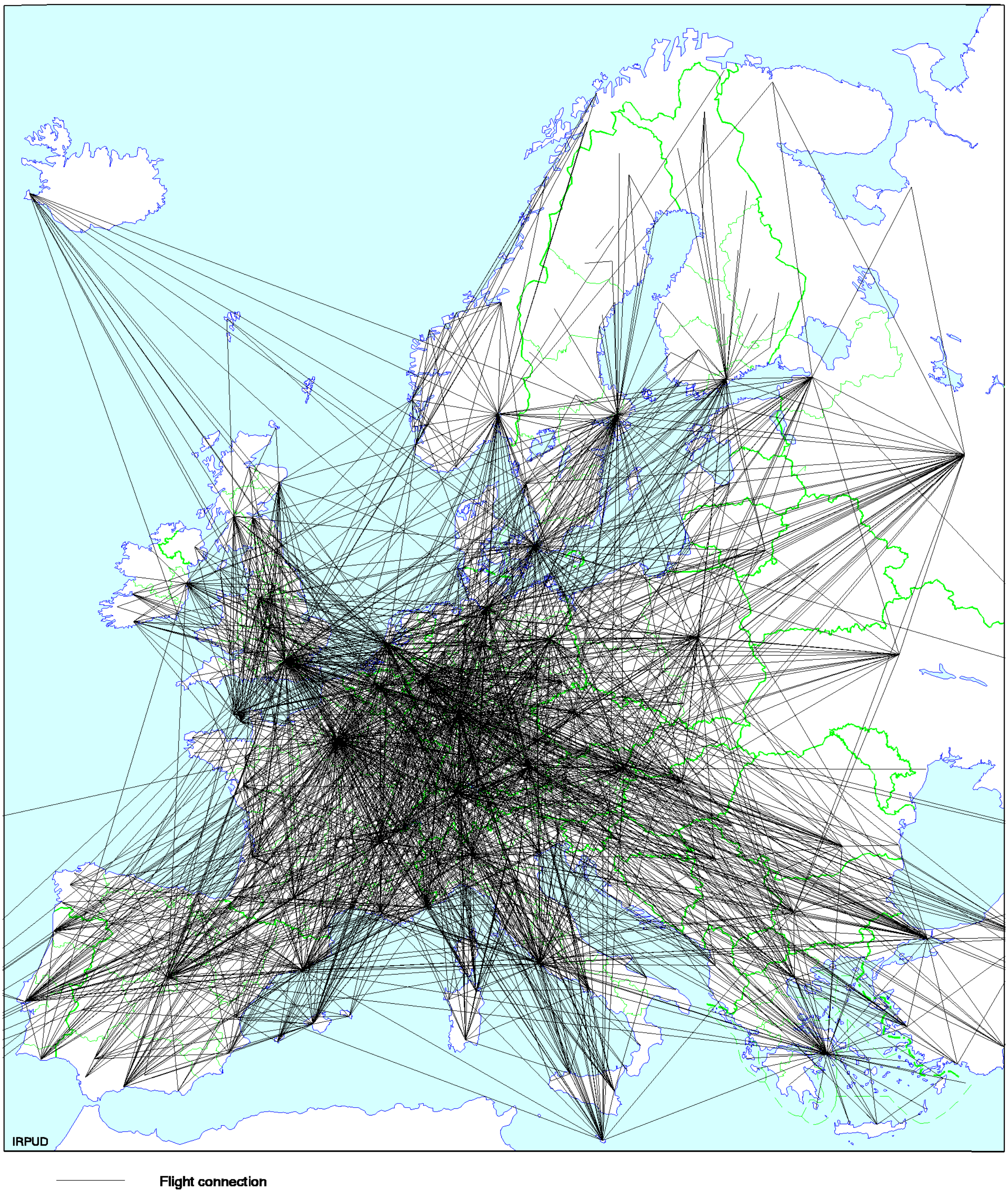

Figure 5. The SASI strategic air network in 1996.

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 6 illustrates the recursive organisation of the model:

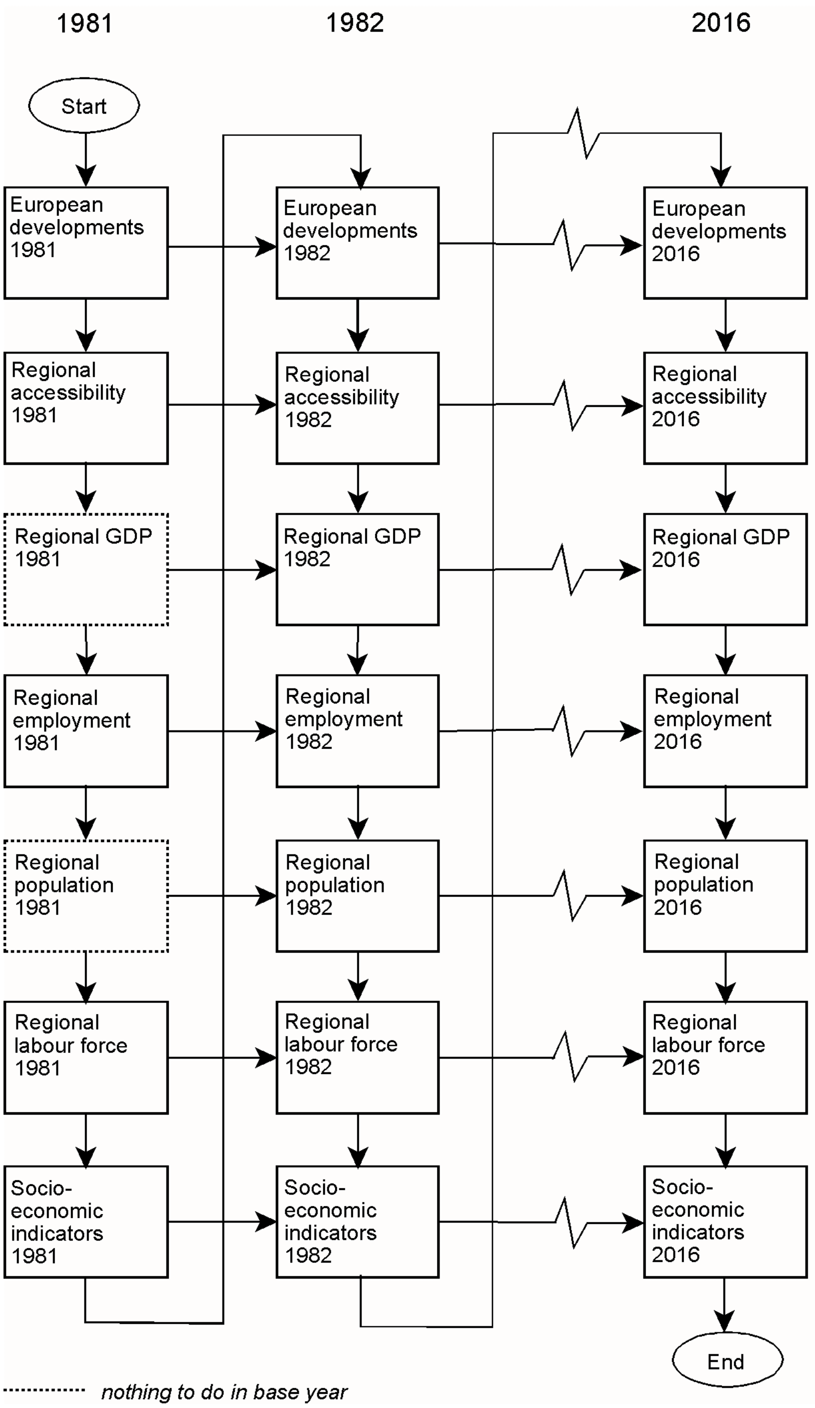

Figure 6. The recursive organisation of the SASI model.

4.4 Strengths and Weaknesses of the SASI Model

The SASI model differs from other approaches to modelling the impacts of transport on regional development by modelling not only regional production (the demand side of regional labour markets) but also regional population (the supply side of regional labour markets). This makes the model capable to predict regional unemployment. As full employment is one of the major policy objectives of the European Union, this is an important advantage.

A second major advantage of the model is its comprehensive geographical coverage. Its study area are all regions of the fifteen member states of the European Union at NUTS-2 level. In addition, the other European countries, including the European part of Russia, are included as external regions. This makes the model especially suited to model spatial redistribution effects of the TETN within the European Union. Accordingly, this is the major focus of the model. Although in principle it would be possible to model aggregate macroeconomic multiplier effects of transport investments on the European economy as a whole, this is not presently intended because of the many factors and uncertainties related to global economic developments that would have to be considered. Therefore all model results are constrained by exogenous forecasts of economic development, immigration and outmigration of the European Union as a whole.

A third unique feature of the model is the way impacts of transport infrastructure investments and transport system improvements on regional production are modelled. The model uses regional production functions in which transport infrastructure is represented by accessibility. Accessibility is measured by spatially disaggregate accessibility indicators which take into account that accessibility within a region is not homogenous but rapidly decreases with increasing distance from the nodes of the networks (Schürmann et al., 1997).

A fourth significant feature of the model is its flexibility in incorporating 'soft' non-transport factors of regional economic development beyond the economic factors traditionally included in regional production functions. These may be indicators describing the spatial organisation of the region, i.e. its settlement structure and internal transport system, or institutions of higher education, cultural facilities, good housing and a pleasant climate and environment. In addition to these tangible endowment indicators, regional residuals taking account of intangible factors not considered are included in the production functions.

A fifth important characteristic of the model is its dynamic character. Regional socio-economic development is determined by interacting processes with a vast range of different dynamics. Whereas changes of accessibility due to transport infrastructure investments and transport system improvements become effective immediately, their impacts on regional production are felt only two or three years later as newly located industries start operation. Regional productivity and labour force participation are affected even more slowly. The sectoral composition of the economy and the age structure of the population change only in the course of many years or even decades. A model that is to capture these dynamics cannot be an equilibrium model but has to proceed in time increments shorter than the time lags of interest.

A characteristic important for the policy relevance of the model are the cohesion indicators calculated. As the model predicts accessibility, GDP per capita and unemployment of each region for each year of the simulation, it can also calculate cohesion indicators measuring the convergence (or divergence) of these indicators in the regions over time. These measures indicate whether transport infrastructure investments or transport system improvements contribute to the achievement of the cohesion goals of the Union or whether they tend to reinforce the existing disparities between rich and poor regions.

A final property of the model are its relatively moderate data requirements. As it will be shown in Section 7, the model does not require a highly disaggregate classification of industries nor an input-output table. The population and migration model works with minimum input data such as five-year age groups and net migration. Due to the method used to calculate disaggregate accessibility indicators, the road, rail and air networks do not need to be coded with excessive detail. The data requirements for calibrating the model are also moderate because many model equations are validated against a long period of the past.

Compared with these significant advantages of the modelling approach chosen, its few limitations seem acceptable. As total economic and population development are exogenous, it does not predict the macroeconomic multiplier effects of transport infrastructure investments and transport system improvements such as elasticity of demand. Direct effects of transport infrastructure investment during the construction period are not considered. Labour productivity is linked to changes of accessibility but not to other factors in the production function, so no substitution between factors are modelled. The migration model based only on net migration is simplistic as is the labour force participation model, which may affect the validity of the unemployment forecasts. Finally, as the model does not contain a full transport submodel, it cannot take account of network congestion or intermodality.

5. Submodels

In this section the seven submodels of the SASI regional economic model will be described in conceptual terms. The detailed specification of model variables and parameters will be presented in Deliverable D11, the actual model implementation and validation in Deliverable D13 and the results of demonstration scenario simulations in Deliverable D15.

5.1 European Developments

In this submodel assumptions about European developments are entered that are processed by the subsequent submodels. The *European Developments* submodel is not a 'submodel' in the narrow sense because it does not calculate anything. It simply prepares the exogenous assumptions about the wider economic and policy framework of the simulations and makes sure that they are entered into the model at the beginning of each simulation period.

For each simulation period the simulation model requires the following assumptions about European developments:

(1) *Assumptions about the future performance of the European economy as a whole*. These assumptions have the form of observed values of GDP of industrial sectors agriculture, manufacturing and services for the European Union as a whole and for the 23 non-EU countries of the SASI system of regions (see Figure 1 and Annex) for the years 1981 to 1997 and of forecasts of the same for the years 1998 to 2016. All GDP values are entered in ECU of 1998.

(2) *Assumptions about immigration and outmigration across Europe's borders*. These assumptions have the form of total observed annual immigration from the 23 non-EU countries to the European Union and total annual outmigration to these countries from the European Union for the years 1981 to 1997 and of forecasts of the same for the years 1998 to 2016.

These two groups of assumptions serve as constraints to ensure that the regional forecasts of economic development and population remain consistent with external developments not modelled. To keep the total economic development exogenous to the model means that the model is prevented from making forecasts about the general increase in production through transport infrastructure investments, although in principle its parameters are estimated in a way that makes it capable to do that. Alternatively, it is possible to experimentally let the model itself determine the total level of annual GDP and use the observed values of the period from 1981 to 1997 to validate these forecasts.

(3) *Assumptions about transfer payments by the European Union via the Structural Funds and the Common Agricultural Policy or by national governments to assist specific regions.* These assumptions have the form of annual transfers (in ECU of 1998) received by any of the 201 regions in the European Union during the period 1981 to 1997 and forecasts of the same for the period 1998 to 2016. These data only need to be provided for those regions that actually received aid in the past or are assumed to receive aid in the future.

(4) *Assumptions about immigration policies by European countries*. Given the expected rapid population growth and lack of economic opportunity in many origin countries, total European immigration will be largely a function of migration policy decisions by national governments. These assumptions have the form of upper limits for annual immigration from non-EU countries to the countries of the European Union for the years 1981 to 1997 and of forecasts of the same for the years 1998 to 2016.

The data for the above four types of assumptions do not need to be provided for each year nor for time intervals of equal length as the model performs the required interpolation.

(5) *Assumptions about the development of trans-European transport networks.* These assumptions have the form of 'backcasts' of the road, rail and air networks representing their evolution between 1981 and 1996 as well as forecasts of their development between 1996 and 2016, both in five-year increments. The *base forecast* or *base scenario* is defined as the implementation of all new or upgraded TETN links on which definite decisions already have been taken.

(6) *Assumptions about policy decisions on the trans-European networks*. A *policy scenario* is a time-sequenced investment programme for addition, upgrading or closure of links of the trans-European road, rail or air networks. Policy scenarios are specified by adding different subsets of the remaining TETN links such as all planned TETN road projects, all planned TETN rail projects or all planned TETN road and rail projects (Spiekermann and Wegener, 1998).

5.2 Regional Accessibility

This 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 the travel time or travel cost (or both) needed to reach these destinations by the strategic road, rail and air networks.

The method to calculate disaggregate accessibility indicators used for the SASI model was described in SASI Deliverable D5 (Schürmann et al., 1997). For calculating quasi-continuous accessibility surfaces of Europe, the European territory is disaggregated to some 70,000 raster cells of 10 kilometres width. Accessibility is calculated by using each raster cell both as origin and destination, i.e. by generating a 70,000 by 70,000 origin-destination matrix. The results are accessibility values for all raster cells, which are then aggregated to regions.

The generation of the disaggregate input data base with population and GDP by raster cell for 1995 was described in SASI Deliverable D5 (Schürmann et al., 1997, Section 5.1). This method was used to generate disaggregate distributions of population and GDP for the years 1995 and 1992, respectively. These distributions are used during the simulation as ancillary information to allocate population and GDP as predicted by the model for each region *pro rata* to the raster cells belonging to that region.

For the selection of accessibility indicators to be used in the model three, possibly conflicting, objectives are relevant: First, the accessibility indicators should contribute as much as possible to explaining regional economic development. Second, the accessibility indicators should be meaningful by itself as indicators of regional quality of life. Third, the accessibility indicators should be consistent with theories and empirical knowledge about human spatial perception and behaviour.

In the light of these objectives, three types of accessibility indicator were tested (see SASI Deliverable D5, Schürmann et al., 1997, Section 3.2). In all cases $a_{im}(t)$ is the accessibility of raster cell i by mode m in year t and $A_{rm}(t)$ is the accessibility of region r by mode m in year t:

(1) Travel time or cost:

This indicator measures average travel time or cost from each raster cell i to a predefined set of destinations as the total of travel time or cost from raster cell i to the centre of each destination city j by mode m in year t, c_{ijm}(t), divided by the number $n(\mathbf{C})$ of cities in the set $\mathbf{C}$ of cities with population $P_j(t)$ greater or equal to $P_{\min}$ of 250,000 or 1,000,000:

$$a_{im}(t) = \frac{1}{n(\mathbf{C})} \sum_{j \in \mathbf{C}} c_{ijm}(t) \qquad \text{with } \mathbf{C} = \left\{ j, P_j(t) \geq P_{\min} \right\}$$

In a second version of the indicator travel time or cost is weighted by population $P_j(t)$:

$$a_{im}(t) = \sum_{j \in \mathbf{C}} \frac{P_j(t)}{\sum_{j \in \mathbf{C}} P_j(t)} c_{ijm}(t) \quad \text{with } \mathbf{C} = \left\{ j, P_j(t) \geq P_{\min} \right\}$$

(2) Daily accessibility:

This indicator measures the activities or opportunities $W_j(t)$ that can be reached from raster cell i by a return trip by mode m during a work day with a minimum stay of a certain time. Five hours one-way travel time was assumed to be the maximum for allowing five hours of activities at the destination.

$$a_{im}(t) = \sum_j W_j(t)\, k_j \qquad \text{with } k_j = \begin{cases} 1 & \text{if } c_{ijm}(t) \leq c_{\max} \\ 0 & \text{if } c_{ijm}(t) > c_{\max} \end{cases}$$

The indicator is calculated by accumulating for each raster cell i population or GDP, $W_j(t)$, of all destination cells j that can be reached within a travel time $c_{\max}$ of five hours or less.

(3) Potential accessibility:

The potential model assumes that the attraction of a destination increases with size and declines with distance or travel time or cost. The modal potential accessibility of raster cell i is the sum of destination activities $W_j(t)$ in all 70,000 destination cells j in year t weighted by a negative exponential function of travel time or cost by mode m, $c_{ijm}(t)$, between cell i and destination cells j:

$$a_{im}(t) = \sum_j W_j(t) \exp[-\beta\, c_{ijm}(t)]$$

Aggregation of accessibilities of raster cells, $a_{im}(t)$, to accessibilities of regions, $A_{rm}(t)$, can be performed in three different ways:

(a) Average value

The accessibility of region r by mode m in year t, $A_{rm}(t)$, is the average of the accessibilities of the raster cells i belonging to region r (where $\mathbf{R}_r$ is the set of raster cells of region r and $n(\mathbf{R}_r)$ the number of raster cells in that set):

$$A_{rm}(t) = \frac{1}{n(\mathbf{R}_r)} \sum_{i \in \mathbf{R}_r} a_{im}(t)$$

or with raster cells weighted by their population $P_i(t)$, where $P_r(t)$ is regional population:

$$A_{rm}(t) = \frac{1}{P_r(t)} \sum_{i \in \mathbf{R}_r} a_{im}(t)\ P_i(t)$$

(b) Maximum value

The accessibility of region r by mode m in year t, $A_{rm}(t)$, is the maximum of the accessibilities of the raster cells i belonging to region r:

$$A_{rm}(t) = \max_{i \in \mathbf{R}_r} [a_{im}(t)]$$

(c) Centroid value

The accessibility of region r by mode m in year t, $A_{rm}(t)$, is the accessibility of the raster cell k of its centroid:

$$A_{rm}(t) = a_{km}(t)$$

This way of aggregating regional accessibilities has the advantage that the accessibility of only one raster cell per region has to be calculated, which vastly reduces the computational load of the model.

Modal accessibility indicators can be used separately or can be aggregated to one indicator expressing the combined effect of alternative modes. There are essentially two ways of aggregating accessibility indicators across modes:

(i) Fastest mode

In this case the fastest or least-cost mode to each destination is used for calculating the accessibility indicator. For travel time this will in general be air for distant destinations and road or rail for short- or medium-distance destinations; the other modes are ignored. This is achieved by replacing in each of the above accessibility equations the impedance term $c_{ijm}(t)$ by the composite impedance term

$$c_{ij}(t) = \min_{m \in \mathbf{M}_{ij}} [c_{ijm}(t)]$$

where $\mathbf{M}_{ij}$ is the set of modes available between raster cells i and j.

(ii) Logsum

Another way to integrate modal accessibilities into one indicator is to replace the impedance term c_{ijm}(t) by the composite or logsum impedance (Williams, 1977):

$$c_{ij}(t) = -\frac{1}{\lambda} \ln \sum_{m \in \mathbf{M}_{ij}} \exp[-\lambda\, c_{ijm}(t)]$$

In all cases the impedance term c_{ijm}(t) can be travel time or travel cost or a combination of both, i.e. generalised cost (for *daily accessibility* usually travel time is used). Rail travel times are time table travel times, whereas road travel times are calculated from road-type specific travel speeds. Travel costs are calculated from link-type specific cost parameters. It is possible to associate extra travel times or costs with specific links to represent border delays or toll roads.

A final issue when calculating accessibility indicators is whether to standardise them or not. One way of standardisation is to express accessibility in percent of the average accessibility of all regions of the European Union weighted by population. Standardisation has the advantage of showing *relative* changes in regional accessibility. Relative changes disclose that even when accessibility grows everywhere, there may be winner and loser regions as some regions become less accessible in relative terms although in absolute terms their accessibility has increased. Absolute accessibility, on the other hand, may be more appropriate when calculating the effect of accessibility on regional labour productivity (see Section 5.4).

The choice of accessibility indicators and the way of aggregation and standardisation eventually used in the model will be presented in SASI Deliverable D11.

5.3 Regional GDP

This submodel forecasts gross domestic product (GDP) generated annually in each region as a function of endowment factors, accessibility and transfers (for a discussion of the choice of GDP as indicator see SASI Deliverable D4 (Bökemann et al., 1997). The regional production function predicts annual GDP per capita:

$$q_{ir}(t) = \mathrm{f}[\mathbf{C}_{ir}(t), L_{ir}(t), \mathbf{A}_{ir}(t), s_r(t), R_{ir}]$$

where q_{ir}(t) is annual GDP of industrial sector i per capita in region r in year t, $\mathbf{C}_{ir}(t)$ *is* a vector of endowment factors relevant for industrial sector i in region r in year t, L_{ir}(t) is labour relevant for industrial sector i in region r in year t, $\mathbf{A}_{ir}$ is a vector of accessibility indicators relevant for industrial sector i in region r in year t, s_r are annual transfers per capita received by the region r in year t and R_{ir} is a region-specific residual taking account of factors not modelled (see below). Note that, even though annual GDP is in fact a flow variable relating to a particular time interval (year), it is modelled like a stock variable.

An alternative version of the production function predicts regional GDP per capita *minus* transfers disaggregated by industry:

$$q_{ir}(t) - s_{ir}(t) = \mathrm{f}[\mathbf{C}_{ir}(t), L_{ir}(t), \mathbf{A}_{ir}(t), R_{ir}]$$

The functional form of the above equations can be either additive or multiplicative, where the multiplicative form is the Cobb-Douglas production function. The specification of the function will be presented in SASI Deliverable D11.

From GDP per capita $q_{ir}(t)$ and population $P_r(t\text{-}1)$ of the previous year t-1 total annual GDP produced in region *r* by industrial sector *s* in year *t* is calculated as

$$Q_{ir}(t) = q_{ir}(t)\ P_r(t-1)$$

Because at the time of execution of the *Regional GDP* submodel population in year *t* is not yet known, population in the previous year t–1 is used.

Endowment factors

Endowment factors are indicators measuring the suitability of the region for economic activity. Endowment factors include traditional location factors such as 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, or institutions of higher education, cultural facilities, good housing and a pleasant climate and environment. The selection and specification and data sources of the endowment factors will be presented in SASI Deliverable D11.

Accessibility indicators

Accessibility indicators are derived from the *Regional Accessibility* submodel (see Section 5.2). The selection and specification of the accessibility indicators will be presented in SASI Deliverable D11.

Transfers

In addition to endowment factors and accessibility indicators, monetary transfers to regions by the European Union such as assistance by the Structural Funds or the Common Agricultural Policy or by national governments are considered, as these account for a sizeable portion of the economic development of peripheral regions. Regional transfers per capita $s_r(t)$ are provided by the *European Developments* submodel (see Section 5.1).

Adjustments

To take account of 'soft' factors not captured by the endowment and accessibility indicators of the model, a region-specific, sector-specific residual constant R_{ir} is added to the GDP forecasts of each region *r*. R_{ir} is the difference between the GDP per capita predicted for region *r* in the base year 1981 and observed GDP per capita in *r* in 1981. R_{ir} is kept constant over all simulation periods.

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).

5.4 Regional Employment

Regional employment by industrial sector is derived from regional GDP by industrial sector and regional labour productivity.

Regional labour productivity by industrial sector is partly forecast exogenously and partly affected endogenously by changes in accessibility. It is assumed that labour productivity by economic sector in a region is predominantly determined by historical conditions in the region, i.e. by its composition of industries and products, technologies and education and skill of labour and that it grows by an average sector-specific growth rate. However, it is also assumed that it is positively affected by growth in accessibility:

$$p_{ir}(t) = p_{ir}(t-1)\; p_{ir'}(t) / p_{ir'}(t-1) + \varepsilon_i \; A_r(t) / A_r(t-1) \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $p_{ir}(t)$ is labour productivity, i.e. annual GDP per worker, of industrial sector i in region r in year t, $p_{ir'}(t)$ is average labour productivity in sector i in year t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs, $A_r(t)$ is accessibility of region r in year t (aggregated across modes as above), and ε_i is a linear elasticity indicating how much the growth in labour productivity is accelerated by a growth in accessibility. As indicated above, absolute rather than relative accessibility is preferable here. Regional employment by industrial sector is then

$$E_{ir}(t) = Q_{ir}(t) / p_{ir}(t)$$

where $E_{ir}(t)$ is employment in industrial sector i in region r in year t, $Q_{ir}(t)$ is the GDP of industrial sector i in region r in year t and $p_{ir}(t)$ is the annual GDP per worker of industrial sector i in region r in year t.

5.5 Regional Population

The *Regional Population* submodel forecasts regional population by five-year age groups and sex through natural change (fertility, mortality) and migration. Population forecasts are needed to represent the demand side of regional labour markets.

Fertility and mortality

Changes of population due to births and deaths are modelled by a cohort-survival model subject to exogenous forecasts of regional fertility and mortality rates. To reduce data requirements, a simplified version of the cohort-survival population projection model with five-year age groups is applied. The method starts by calculating survivors for each age group and sex:

$$P'_{asr}(t) = P_{asr}(t-1)\,[1 - d_{asr'}(t-1,t)] \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $P'_{asr}(t)$ are surviving persons of age group a and sex s in region r in year t, $P_{asr}(t-1)$ is population of age group a and sex s in year $t-1$ and $d_{asr'}(t-1,t)$ is the average annual death rate of age group a and sex s between years $t-1$ and t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs.

Next it is calculated how many persons change from one age group to the next through ageing employing a smoothing algorithm:

$$g_{asr}(t-1,t) = 0.12\,P'_{asr}(t) + 0.08\,P'_{a+1sr}(t) \qquad \text{for } a = 1,19$$

where $g_{asr}(t-1,t)$ is the number of persons of sex s changing from age group a to age group $a+1$ in region r. Surviving persons in year t are then

$$P_{asr}(t) = P'_{asr}(t) + g_{a-1sr}(t-1,t) - g_{asr}(t-1,t) \qquad \text{for } a = 2,19$$

with special cases

$$P_{20sr}(t) = P'_{20sr}(t) + g_{19sr}(t-1,t)$$

and

$$P_{1sr}(t) = P'_{1sr}(t) + B_{sr}(t-1,t) - g_{1sr}(t-1,t)$$

where $B_{sr}(t-1,t)$ are births of sex s in region r between years $t-1$ and t:

$$B_{sr}(t-1,t) = \sum_{a=4}^{10} 0.5\,[P'_{a2r}(t) + P_{a2r}(t)]\; b_{asr'}(t-1,t)\;[1 - d_{0sr'}(t-1,t)] \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $b_{asr'}(t-1,t)$ are average number of births of sex s by women of child-bearing five-year age groups a, $a = 4,10$ (15 to 49 years of age) in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs between years $t-1$ and t, and $d_{0sr'}(t-1,t)$ is the death rate during the first year of life of infants of sex s in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs.

The exogenous forecasts of death and birth rates in the above equations may be national rates or rates for specific groups of comparable regions.

Migration

Interregional migration within the European Union is modelled in a simplified migration model as annual net migration as a function of the regional unemployment rate $u_r(t\text{-}1)$ in year t-1 (see below) and a vector $\mathbf{X}_r(t)$ of regional indicators expressing the attractiveness of a region as a place of employment and a place to live (quality of life):

$$M_r(t) = \mathrm{f}\;[u_r(t-1), \mathbf{X}_r(t)]$$

Because at the time of execution of the *Regional Population* submodel regional unemployment in year t is not yet known, unemployment in the previous year $t-1$ is used.

The form and parameters of the above functions and of the vector $\mathbf{X}_r(t)$ will be presented in SASI Deliverable D11. Immigration from countries outside the European Union is modelled by country as

$$I_r(t) = \mathrm{f}\ [u_r(t-1), \mathbf{X}_r(t)]$$

where $I_r(t)$ is annual immigration into region r from outside the European Union, whereas it is assumed that outmigration from the European Union is not location-specific, i.e. occurs *pro rata* of immigration from non-EU countries. The forecasts of regional immigration and outmigration across Europe's borders are adjusted to comply with total European immigration and outmigration forecast by the *European Developments* submodel and the limits to immigration from non-EU countries set by individual countries.

Educational attainment

Regional educational attainment, i.e. the proportion of residents with higher education in region r, is forecast exogenously assuming that it grows as in the country or group of regions to which region r belongs:

$$h_r(t) = h_r(t-1)\, h_{r'}(t) / h_{r'}(t-1) \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $h_r(t)$ is the proportion of residents with higher education in region r in year t, and $h_{r'}(t)$ is the average proportion of residents with higher education in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs.

5.6 Regional Labour Force

Regional labour force is derived from regional population and regional labour force participation.

Regional labour force participation by sex is partly forecast exogenously and partly affected endogenously by changes in job availability or unemployment. It is assumed that labour force participation in a region is predominantly determined by historical conditions in the region, i.e. by cultural and religious traditions and education and that it grows by an average country-specific growth rate. However, it is also assumed that it is positively affected by availability of jobs (or negatively by unemployment):

$$\ell_{sr}(t) = \ell_{sr}(t-1)\, \ell_{sr'}(t) / \ell_{sr'}(t-1) - \varphi_s\, u_r(t-1) \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $\ell_{sr}(t)$ is labour force participation, i.e. the proportion of economically active persons of sex s of regional population of sex s 15 years of age and older, in region r in year t, $\ell_{sr'}(t)$ is average labour participation of sex s in year t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs, $u_r(t-1)$ is unemployment in region r in the previous year $t-1$ (see below), and φ_s is a linear elasticity indicating how much the growth in labour productivity is accelerated or slowed down by regional unemployment. Because at the time of execution of the *Regional Labour Force* submodel regional unemployment in year t is not yet known, unemployment in the previous year $t-1$ is used.

Regional labour force by sex s in region r, $L_{sr}(t)$, is then

$$L_{sr}(t) = P_{sr}(t)\ \ell_{sr}(t)$$

where $P_{sr}(t)$ is population of sex s 15 years of age and older in region r at time t and $\ell_{sr}(t)$ is the labour force participation rate of sex s in region r in year t. Regional labour force is disaggregated by skill level in proportion to educational attainment in the region calculated in the *Population* submodel (see Section 5.5):

$$L_{sr1}(t) = h_r(t)\ L_{sr}(t)$$

with $L_{sr1}(t)$ being skilled labour and the remainder unskilled labour:

$$L_{sr2}(t) = L_{sr}(t) - L_{sr1}(t)$$

5.7 Socio-Economic Indicators

Total GDP and employment represent only the supply side of regional socio-economic development. To derive policy-relevant indicators, they have to be related to the demand side, i.e. to population and labour force. This is done be calculating total regional GDP per capita and regional unemployment.

Since accessibility, besides being a factor determining regional production (see Section 5.2), is also an indicator of regional locational advantage and quality of life, accessibility indicators are a considered policy-relevant output of the model.

Accessibility, GDP per capita and unemployment are therefore the main socio-economic and spatial indicators produced by the SASI model.

In addition, equity or cohesion indicators describing the distribution of accessibility, GDP per capita and unemployment across regions are calculated.

Accessibiliy

Regional accessibility indicators are calculated in the *Regional Accessibility* submodel (see Section 5.2)

GDP per capita

Total regional GDP per capita is calculated as the sum of GDP per capita by industrial sector:

$$q_r(t) = \sum_i q_{ir}(t)$$

Unemployment

The regional unemployment rate $u_r(t)$ in year t is

$$u_r(t) = \frac{L_r(t) - \sum_s T_{rs}(t) + \sum_s T_{sr}(t) - E_r(t)}{L_r(t)}$$

where $L_r(t)$ is total labour in region r in year t, $E_r(t)$ is total employment in region r in year t and $T_{rs}(t)$ are commuters from region r to region s in year t calculated from an attraction-constrained spatial-interaction work trip model:

$$T_{rs}(t) = \frac{L_r(t)\ \exp[-\beta\ c_{rs}(t)]}{\sum_r L_r(t)\ \exp[-\beta\ c_{rs}(t)]} E_s(t) \qquad \text{with} \sum_s T_{rs}(t) \leq L_r(t)$$

where $c_{rs}(t)$ is travel time and/or cost between regions r and s in year t and the additional constraint ensures that there are no more workers than labour force in a region.

It is important to note that this unemployment rate only serves to compare different scenarios within the SASI project and is not comparable to the standardised unemployment rates calculated by Eurostat.

Cohesion indicators

From the policy-relevant indicators so derived, equity or cohesion indicators describing their distribution across regions are calculated. Cohesion indicators are macroanalytical indicators combining the indicators of individual regions into one measure of their spatial concentration. Changes in the cohesion indicators predicted by the model for future transport infrastructure investments reveal whether these policies are likely to reduce or increase existing disparities in those indicators between the regions. SASI Deliverable D4 (Bökemann et a., 1997, Section 3.2.3) provided a comprehensive list of possible cohesion indicators also applicable here:

- Statistical measures such as maximum, mean, minimum, standard deviation of regional indicator values and ratios between the highest and lowest (or the five, ten or twenty highest and lowest) regional indicator values give an impression of the distribution of indicator values between regions.

- The graphical representation of a rank distribution of regions by decreasing or increasing order of indicator values visualises the degree of inequality between regions. If two rank-size distributions of different years are compared, decreasing or increasing inequality in indicator values can be detected.

- The rank correlation coefficient by Spearman compares two rank orders of regions by decreasing or increasing indicator values. If two rank orders of two different years are compared, the coefficient informs about the degree of stability of the rank positions of the regions. A Spearman correlation coefficient of one indicates that there has been no change in the rank order of regions, a coefficient of minus one indicates that the rank order has been reversed. In the context of transport infrastructure policy a high rank correlation between the situation without and with policy implementation is desirable for equity reasons (see SASI Deliverable D4, Bökemann et al., 1997, Section 3.2.3).

- The Lorenz curve compares a rank-ordered cumulative distribution of indicator values of regions with a distribution in which all regions have the same indicator values. This is done graphically by sorting regions by increasing indicator value and drawing their cumulative distribution against a cumulative equal distribution (an upward sloping line). The area between the two cumulative distributions indicates the degree of polarisation of the distribution of indicator values of regions. The GINI coefficient calculates the ratio between that area and the triangle under the upward sloping line of the equal distribution. The equation for the GINI coefficient is

$$G = 1 + 1/n - 2/(n^2 \overline{V}) \sum_i i V_i$$

- where the V are indicator values of regions sorted in decreasing order. The equation is used to measure the inequality in indicator values between regions, with V_i being the indicator value of region i, $\overline{V}$ the average indicator value of all regions, and n the number of regions. A GINI coefficient of zero indicates that the distribution is equal-valued, i.e. that all regions have the same indicator values. A GINI coefficient close to one indicates that the distribution of indicator values is highly polarised, i.e. few regions have very high indicator values and all other regions very low values. The GINI coefficient is used in SASI to compare the inequality in accessibility and socio-economic indicators between regions for two different years. A growing GINI coefficient indicates that inequality in accessibility and socio-economic indicators between regions has increased, a declining coefficient indicates that disparities have been reduced. It is possible to take account of the different size of regions by treating each region as a collection of individuals having the same indicator values.

- In addition, disparities between regions can be visualised by maps or three-dimensional diagrams (see SASI Deliverable D5, Schürmann et al., 1997, Section 5). The disaggregate method of calculating accessibility applied in SASI permits to calculate microanalytic indicators of intraregional dispersion in accessibility (see SASI Deliverable D5, Schürmann et al., 1997, Section 5). These microanalytic indicators can be used to analyse whether a particular infrastructure investment largely benefits the central nodes or whether its impacts are evenly distributed across all parts of the regions.

6. Model Output

Output of the SASI model are indicators measuring socio-economic and spatial impacts of the simulated policy scenarios. In order to be useful they need to correspond to and be interpretable in terms of European policy goals (see Section 2.1). As indicated in the previous section, the main three groups of output indicators of the model are (see Section 5.7):

- *Accessibility*. The output of the *Regional Accessibility* submodel (see Section 5.2) is of three kinds. The first output option provides accessibility indicators for raster cells. The second output option presents accessibility indicators aggregated to regions. Accessibility indicators may be modal or multimodal, either by fastest mode or aggregated across modes by logsum. Regional accessibility may be expressed in three ways: as average accessibility, maximum accessibility or centroid accessibility. Accessibility may be standardised as percent of EU average accessibility or not.

- *Gross domestic product (GDP) per capita* calculated in the *Regional GDP* submodel (see Section 5.3) was selected as indicator to represent the economic performance of a region. Despite its well-known theoretical and methodological drawbacks GDP per capita continues to be the most commonly used indicator of regional economic development. With certain qualifications, e.g. for regions with a large amount of commuting across their boundaries, GDP per capita allows to draw conclusions on regional income.

- *Rate of unemployment* calculated in the *Socio-Economic Indicators* submodel (see Section 5.7) is used to indicate the social conditions in a region. This indicator, too, presents measurement problems because there exist large differences in the definition of unemployment in European countries. Therefore the unemployment rate calculated in the SASI model only serves to compare different scenarios within the SASI project and is not comparable to the standardised unemployment rates calculated by Eurostat. Nevertheless unemployment remains the most widely used social indicator and is closely related to policy goals of the European Union.

In addition to the above regional indicators *cohesion indicators* expressing the distribution of accessibility, GDP per capita and unemployment across regions are policy-relevant output of the model (see Section 5.7). Cohesion indicators inform about the degree of spatial concentration or dispersion of accessibility, GDP per capita and unemployment and show whether the implementation of a transport scenario will contribute to the political goal of reducing socio-economic disparities or lead to further spatial polarisation.

7. Model Data

Two major groups of data can be distinguished: data required for running the model (simulation data) and data needed for the calibration or validation of the model. In each of these categories, the data can be classified by spatial and temporal reference.

7.1 Simulation Data

Simulation data are the data required to perform a typical simulation run. They can be grouped into *base-year* data and *time-series* data.

Base-year data

Base-year data describe the state of the regions and the strategic road, rail and air networks in the base year 1981. Base-year data are either regional or network data.

Regional base-year data are required to provide base values for the *Regional GDP* submodel (see Section 5.1) and the *Regional Population* submodel (see Section 5.5) as well as base values for exogenous forecasts of changes in regional labour productivity (see Section 5.4), regional educational attainment (see Section 5.5) and regional labour force participation (see Section 5.6). All other regional base-year values such as GDP, employment or labour force are calculated by the model (even where regional base-year data for these variables are available). Network base-year data specify the road, rail and air networks used for accessibility calculations in the base year.

- 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
- Network data (pan-Europe)
  - Node and link data of strategic road network in 1981
  - Node and link data of strategic rail network in 1981
  - Node and link data of air network in 1981

In addition, for the allocation of regional population and GDP to raster cells in the *Regional Accessibility* submodel, the disaggregate raster distributions of population and GDP referred to in Section 5.2 are required. For simplicity, population of 1995 and GDP of 1992 are used for the distribution in all years.

Time-series data

Time-series data describe 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. All GDP data are converted to ECU of 1998.

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 endowment factors, 1981-2016
- Regional transfers, 1981-2016

Network data (pan-Europe)
- Changes of node and link data of strategic road network, 1981-2016
- Changes of node and link data of strategic rail network, 1981-2016
- Changes of node and link data of air network, 1981-2016

The data problems encountered during the collection of the simulation data and the solutions adopted to cope with these problems will be presented in SASI Deliverable D11.

7.2 Calibration/Validation Data

The regional production function in the *Regional GDP* submodel and the migration function in the *Regional Population* submodel are the only model functions *calibrated* using statistical estimation techniques. All other model functions are *validated* by comparing the output of the whole model with observed values for the period between the base year and the present. In this way the amount of data needed for calibration/validation is minimised.

Calibration data

Calibration data are data needed for calibrating the regional production functions in the *Regional GDP* submodel (see Section 5.3) and the migration function in the *Regional Population* submodel (see Section 5.5). The three calibration years 1981, 1986 and 1991 are suggested to gain insights into changes in parameter values over time; however, the calibration is also possible with less calibration years. The calibration data of 1981 are partly identical with the simulation data for the same year.

Regional data (201 EU regions)
- Regional GDP per capita by industrial sector in 1981, 1986, 1991
- Regional endowment factors in 1981, 1986, 1991
- Regional labour force in 1981, 1986, 1991
- Regional transfers in 1981, 1986, 1991
- Regional net migration in 1981, 1986, 1991
- Regional unemployment rates in 1981, 1986, 1991

Network data (pan-Europe)

Node and link data of strategic road network in 1981, 1986, 1991
Node and link data of strategic rail network in 1981, 1986, 1991
Node and link data of air network in 1981, 1986, 1991

Validation data

Validation data are reference data with which the model results in the period between the base year and the present are compared to assess the validity of the model. Validation is preferable over calibration where processes simulated in the model are unobservable or unobserved because of lack of data. Validation can be used to experimentally adjust model parameters that cannot be calibrated until the model results match available aggregate data. The validation years suggested below are indicative; the validation can be performed with less observations. Also the disaggregations indicated in brackets are optional.

Regional data (201 EU regions)

Regional population (by age and sex) in 1981, 1986, 1991, 1996
Regional GDP (by industrial sector) in 1981, 1986, 1991, 1996
Regional labour force (by sex) in 1981, 1986, 1991, 1996
Regional employment (by industrial sector) in 1981, 1986, 1991, 1996
Regional unemployment rate in 1981, 1986, 1991, 1996

The data problems encountered during the collection of the calibration/validation data and the solutions adopted to cope with these problems will be presented in SASI Deliverable D11.

8. Model Software

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 5 is a separate programme module calling further sub-modules.

Data transfer between submodels 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.

Besides the model database there are input files and output files. *Input files* are ASCII text files containing exogenous forecasts and policies entered by the user. The following input files are required (see Section 7.1):

- 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 strategic road network, 1981-2016
  - Node and link data of strategic rail network, 1981-2016
  - Node and link data of air network, 1981-2016
- Model parameters
  - Parameters of model equations

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.

Figure 7 shows the interaction of the modelling software with the model database and the input and output files:

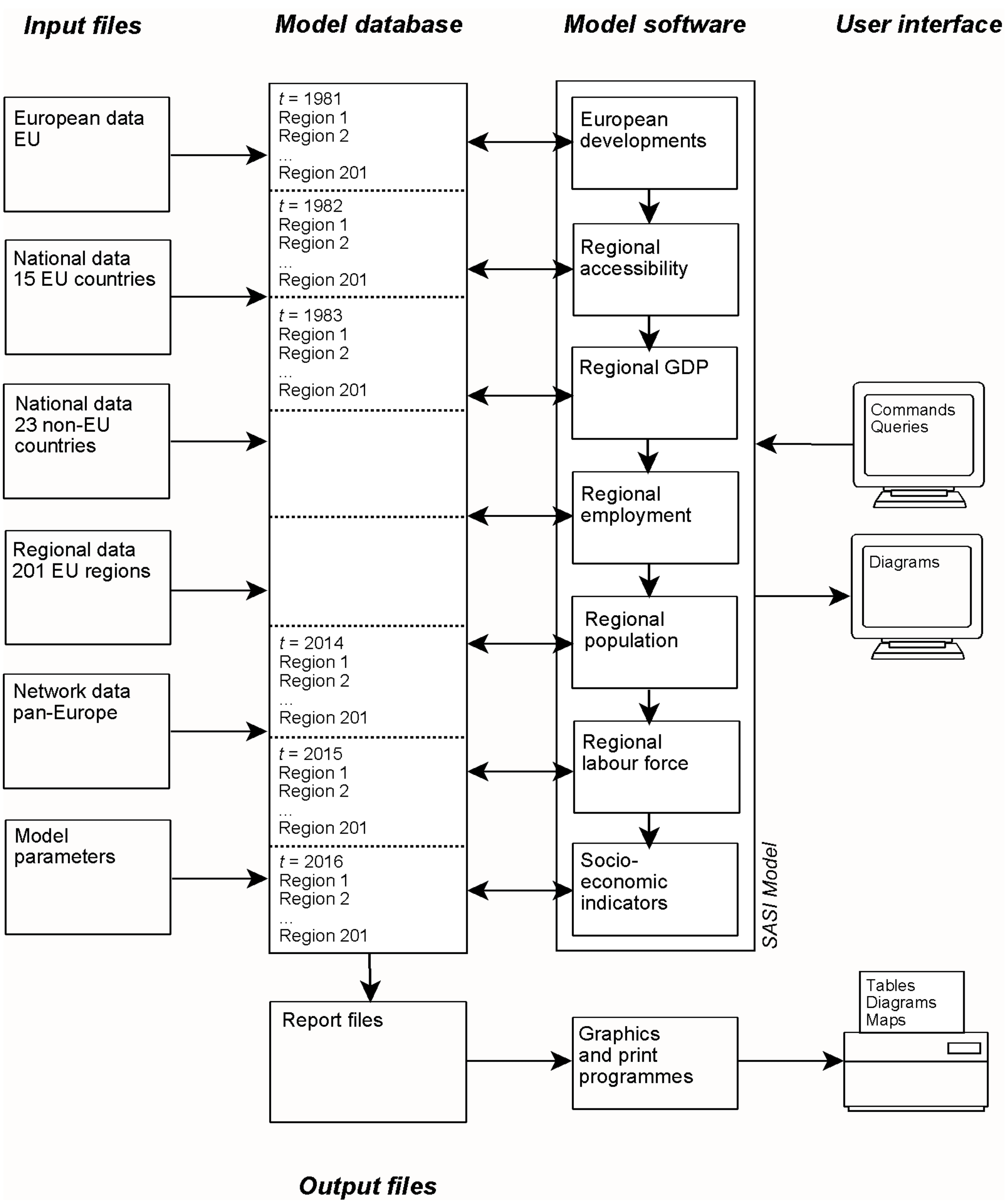

Figure 7. Software organisation of the SASI model.

The model is operated by first simulating the *base scenario*. The base 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 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 TETN links on which definite decisions already have been taken.

The base scenario serves as reference scenario for all other scenarios. In the SASI project other scenarios differ from the base scenario by different policies on transport infrastructure investments and transport system improvements. 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 5.1). Policy scenarios are specified by adding different subsets of the remaining TETN links such as all planned TETN road projects, all planned TETN rail projects or all planned TETN road and rail projects (Spiekermann and Wegener, 1998).

As in the 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 (see Section 5.1), 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 1998 and the target year. The organisation of the model database allows to start a new simulation or resume processing at each year previously simulated.

Policy scenarios are in general simulated by editing ASCII input files. However, network scenarios are generated in the geographical information system ARC/INFO. Network input files are modified by exporting the ARC/INFO *Node Attribute Table (NAT)* and *Arc Attribute Table (AAT)* files. For each network state of each scenario a separate pair of NAT and AAT export files is generated.

As in the present SASI project policy scenarios differ only in the selection and timing of TETN infrastructure investments and transport system improvements, generating ARC/INFO export files is the only way of creating scenarios. All other input files remain unchanged.

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.

After each simulation run the report files described above are written and stored under a scenario-specific name. 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.

9. Conclusions

This report 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 conceptual description of each submodel and how they interact and summarised the data requirements, output and operation of the model.

Main results

It was shown that the SASI model has a number of important advantages compared with other approaches to modelling the impacts of transport infrastructure investments and transport system improvements:

- The model predicts not only regional production but also regional population and so is capable of modelling regional unemployment, which is of major importance for policy making of the European Union.

- The model stands out by its comprehensive geographical coverage including all regions of the fifteen member states of the European Union at NUTS-2 level and as external regions the rest of Europe with the European part of Russia. Because of this the main focus of the SASI model is to model spatial redistribution effects of the TETN within the European Union.

- In methodological terms the model steers a middle course between the complexity of a multiregional input-output framework and aggregate econometric modelling approaches by modelling transport infrastructure investments and transport system improvements on regional production by regional production functions in which transport infrastructure is represented by spatially disaggregate accessibility indicators.

- The model is particularly flexible in incorporating 'soft' non-transport factors of regional economic development beyond the economic factors traditionally included in regional production functions.

- The dynamic character of the model enables it to appropriately deal with the range of different dynamics associated with interactions processes determining regional socio-economic development.

- The cohesion indicators calculated by the model make it particularly relevant for studying the impacts of transport infrastructure investments and transport system improvements on the convergence (or divergence) of socio-economic development in the regions over time.

- The model has relatively moderate data requirements and does not require highly disaggregate classifications of industries or population or an input-output table nor road, rail and air networks coded with excessive detail.

Compared with these advantages, the few limitations of the model such as its neglect of macroeconomic multiplier effects, elasticity of demand, substitution between factors or direct effects of construction or the fact that it models only net migration and it does not take account of network congestion or intermodality seem to be acceptable.

Further work

The ongoing work phase in the SASI project concentrates on making the model operational and completing the calibration of the model equations.

Programming work for implementing a prototype of the model as outlined in this report is underway. The completion of the air network will soon make it possible to calculate accessibility by air and multimodal (fastest-mode and logsum) accessibility. Data collection and estimation of missing data are nearing completion.

In parallel the statistical analyses to test different hypotheses about factors to be included in the regional production and migration functions are making progress. This work is guided by the following four guidelines:

(1) All factors (explanatory variables) included in both functions should be based on theory-based hypotheses about direction and intensity of causal relationships; statistical correlations that cannot be clearly interpreted or proxies, i.e. variables that are only indicators for unobserved or unobservable factors are to be avoided.

(2) Preference should be given to positive (pull) factors; negative (push) factors ("lack of ...") are to be avoided wherever possible.

(3) Except where factors can reasonably be considered to be time-invariant over the whole forecasting horizon (e.g. climate), factors should be either exogenous policy variables or endogenous variables updated in each simulation period by the model.

(4) Factors that may lead to unreasonable policy conclusions should be avoided. For instance the fact that accessibility correlates negatively with agricultural GDP per capita (which merely indicates that agriculture is more important for peripheral than for central regions) should not lead to the conclusion that transport infrastructure investments in peripheral regions are counterproductive for agriculture.

The results of the current work phase will be presented in the forthcoming Deliverables D11 and D13, the results of demonstration scenario simulations in Deliverable D15.

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11. Annex

The Annex contains a list of the regions used in the SASI model as discussed in Section 4.3 (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	Rheinhessen-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	Hovedstadtsregionen and Øst for Storebælt	DK11 (DK001-7)	Internal	København
	60	Vest for Storebælt	DK12 (DK008-F)	Internal	Arhus
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	Sterea 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	Dublin
	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	Brigthon
	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
B?lgarija	204	B?lgarija	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
Republica 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
România	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 Danmark and Ireland. NUTS-0/1/2 regions DK (Danmark) 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 theses, 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.