TRACC
Transport Accessibility at Regional/Local Scale and Patterns in Europe

Applied Research 2013/1/10

Interim Report | Version **21/02/2011**

EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

This report presents the interim results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

List of authors

Klaus Spiekermann (S&W)

Michael Wegener (S&W)

Viktor Květoň (PrF UK)

Miroslav Marada (PrF UK)

Carsten Schürmann (RRG)

Oriol Biosca (Mcrit)

Andreu Ulied Segui (Mcrit)

Harri Antikainen (FOGIS)

Ossi Kotavaara (FOGIS)

Jarmo Rusanen (FOGIS)

Dorota Bielańska (TRT)

Davide Fiorello (TRT)

Tomasz Komornicki (IGIPZ PAN)

Piotr Rosik (IGIPZ PAN)

Table of contents

Annexes

Figures

Tables

Introduction

The ESPON project TRACC (Transport accessibility at regional/local scale and patterns in Europe) aims at taking up and updating the results of existing studies on accessibility at the European scale, to extend the range of accessibility indicators by further indicators responding to new policy questions, to extend the spatial resolution of accessibility indicators and to explore the likely impacts of policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

The Transnational Project Group (TPG) for the ESPON project TRACC consists of the following seven project partners:

- Spiekermann & Wegener, Urban and Regional Research (S&W), Dortmund, Germany (Lead Partner)
- Charles University of Prague, Faculty of Science, Department of Social Geography and Regional Development (PrF UK), Prague, Czech Republic
- RRG Spatial Planning and Geoinformation, Oldenburg i.H., Germany
- MCRIT, Barcelona, Spain
- University of Oulu, Department of Geography (FOGIS), Oulu, Finland
- TRT Trasporti e Territorio, Milan, Italy
- S. Leszczycki Institute of Geography and Spatial Organisation, Polish Academy of Sciences (IGIPZ PAN), Warsaw, Poland

This Interim Report is a self-contained document of the TRACC project. On the one hand it provides an update from the Inception Report on the project's objectives, its theoretical framework and the research approach and methodologies to be applied. On the other hand it gives first results, mainly on methodological issues.

The report contains a review of the main literature on global, European and regional accessibility studies. Based on the previous elements, a TRACC set of accessibility indicators and impact indicators is presented for analysing global, European and regional accessibility. The case study areas selected for analysing regional accessibility pattern with a harmonised methodology across Europe are presented. The different data sources to be used for the different accessibility analyses of the project are presented based on an updated assessment of available data sources for network and socio-economic data. The report closes with an outlook on how policy conclusions might be derived from the project findings.

The annex of the report contains a list of literature used, a detailed description of the research plan, a portrait of the case study regions selected, an assessment of the data situation and a chapter with project planning towards the Draft Final Report.

Executive Summary

This Interim Report is a self-contained document of the TRACC project. On the one hand it provides an update from the Inception Report on the project's objectives, its theoretical framework and the research approach and methodologies to be applied. On the other hand, it gives first results, mainly on methodological issues.

The report contains a review of the main literature on global, European and regional accessibility studies. Based on the previous elements, a TRACC set of accessibility indicators and impact indicators is presented for analysing global, European and regional accessibility. The case study areas selected for analysing regional accessibility pattern with a harmonised methodology across Europe are presented. The different data sources to be used for the different accessibility analyses of the project are presented based on an updated assessment of available data sources for network and socio-economic data. The report closes with an outlook on how policy conclusions might be derived from the project findings.

Objectives

The project is to address the following key policy question from a European point of view:

- What are the differences between accessibility at three different levels (global, European and regional) considering the four modes road, rail, water and air?
- What is the link between accessibility at the different levels and for different modes of European regions and their economic development? How has this link changed over time? Does the strength of this link differ across the EU?
- What could be the territorial impact of rising energy prices on the future developments of road, rail, water and air transport?
- What could be the impact of various transport scenarios on climate change, access patterns and economic development?

In addition the project is to look into the regional dimension of accessibility often neglected in previous studies of accessibility:

- How does accessibility/connectivity look like at the regional level? For example, how many jobs/people can be reached in 45 minutes travel time (by road or by train), how many city centres can be reached by flying out in the morning and returning in the evening?
- In which type of regions is the level of European accessibility very different from their regional accessibility?

From these key policy and research questions the main objectives of the project are derived:

- to take up and update the results of existing studies on accessibility at the European scale using most recent available network and socio-economic data,
- to extend the range of accessibility indicators by further indicators responding to new policy questions and further developing the quality and validity of the existing indicators,
- to extend the spatial resolution of accessibility indicators by calculating, besides European accessibility, also global and regional accessibility,
- to explore the likely impacts of available policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

Conceptual framework

Accessibility is the main 'product' of a transport system. It determines the locational advantage of an area (i.e. in ESPON a region, a city or a corridor) relative to all areas (including itself). Indicators of accessibility measure the benefits households and firms in an area enjoy from the existence and use of the transport infrastructure relevant for their area.

Accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, type of transport, modes, spatial scale, equity and dynamics.

In general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them:. Different types of accessibility indicators can be generated by specifying different forms of the activity and the impedance functions:

- *Travel cost*. If only destinations of a certain kind, e.g. cities beyond a certain size, are considered and the impedance function is travel time or travel cost itself, the accessibility indicator is total or average travel cost to a predefined set of destinations.
- *Cumulated opportunities*. If only destinations within a certain travel time are considered and the destinations are taken as is, the accessibility indicator measures the number of potential destinations (customers, business contacts, tourist attractions, etc.) that can be reached in a given time, e.g. a day.
- *Potential*. If the impedance function takes travel behaviour into account, i.e. the diminishing inclination to travel long distances, the accessibility indicator is a potential indicator. The activity function may take account of agglomeration effects or economies of scale.

These dimensions and the generic types of accessibility indicators form the conceptual base of the TRACC project and guide the review of accessibility studies, the definition of the TRACC set of accessibility indicators and the subsequent implementation in the different parts of the project.

Review of accessibility studies

The review of accessibility studies ranging from a few studies addressing global accessibility down to a vast number of studies dealing with regional accessibility has shown the variety of indicators and approaches. Most frequently used are accessibility indicators of the basic type travel cost, particularly in studies at the regional or national scale. However, also the two other generic types of accessibility indicators, cumulated opportunities and potential accessibility, are used in several studies, the latter in particular in studies at the European scale and only rarely at the regional scale. The activities of interest at the destination are very often population, but also GDP, jobs, labour force, cities of different functions, different public and private services or institutions or freight terminals are used. The spatial resolution differs much. Whereas some European studies consider only a few points in space or are working at the NUTS-2 level, many studies work at the NUTS-3 level or are even based on a raster representation of Europe. Most studies at the regional scale work at the LAU-2 level, however, with the availability of high-resolution grid data, there is a tendency towards calculating accessibility at the regional scale for small raster cells. The level of network detail differs accordingly. Whereas a few studies use no network at all but airline distances, the other end of the spectrum is marked by studies working with full road networks and public transport timetables including real transfer times. Most accessibility studies deal with passenger travel, only very few are concerned with freight transport.

TRACC accessibility and impact indicators

The review has shown that there is no single standard accessibility indicator serving all purposes. The conclusion for TRACC is therefore to develop a systematic and consistent set of accessibility indicators which is derived from the conceptual framework as laid down in Chapter 1 and which matches the following requirements:

- As different types of accessibility indicators provide answers to different questions, the three generic types of accessibility indicators, i.e. travel cost, cumulative opportunities (daily accessibility) and potential accessibility should be used at all levels considered.
- The TRACC project is expected to analyse accessibility at very different spatial levels ranging from the global through the European to the regional level.
- The spatial coverage should be at least the ESPON space. Candidate countries and other countries of the Western Balkan should be included if possible. Regional case studies should cover different types of the regional typologies developed by ESPON.
- The spatial resolution should be appropriate. This is NUTS-3 for the Europe-wide indicators and LAU-2 for the regional case studies. In addition, raster representations of space should be explored to analyse to what extent a finer spatial resolution influences results.
- All relevant transport modes should be addressed, i.e. road, rail and public transport, air and water as well as combinations of modes in form of multimodal aggregation and intermodal trip chains.
- Traditional accessibility indicators should be amended by newer forms of accessibility. The traditional indicators should guarantee continuity with previous ESPON studies; in particular the potential accessibility indicator should be updated to a recent year.
- There should be accessibility indicators dealing with passenger travel and indicators dealing with freight transport.

Table E1 presents the resulting proposal for the TRACC set of accessibility indicators. The indicator set is differentiated by the three main spatial contexts to be taken into account (global, European, regional), and at each level further differentiated by travel and freight. For the European level, accessibility indicators for travel are further divided into traditional and newer ones. For the regional level, the indicators are differentiated into those regional indicators for both travel and freight that can be calculated for the whole of Europe and those that will be calculated in the regional case studies. For the latter, a distinction is made between traditional indicators and indicators looking at the accessibility to selected services of general interest to reflect current policy debates on the subject of services of general interest. For all levels, each generic indicator type is represented by one indicator.

The relevant impacts of accessibility at the European or national level are *economic* and *environmental* impacts. At the intraregional level, the most important impacts are *social* impacts.

- *Economic* impact indicators of accessibility will be produced by the SASI model: impacts on regional economic development expressed as gross domestic product (GDP) per capita and impacts on territorial cohesion expressed by several cohesion indicators. Cohesion indicators are either relative or absolute. Relative cohesion indicators measure relative convergence or divergence in terms of percent of GDP per capita. Absolute cohesion indicators measure absolute convergence or divergence in terms of GDP per capita in Euro. Relative cohesion indicators are the Gini coefficient, the coefficient of variation and the correlation between GDP per capita and the relative change in GDP per capita. Absolute cohesion indicators are the correlation between GDP per capita and the absolute change in GDP per capita.

Table E1. TRACC set of accessibility indicators

Spatial context	Basic characteristics	Generic type of accessibility indicator		
		Travel cost	***Cumulated opportunities***	***Potential***
Global	***Travel***	***Access to global cities*** Travel time (intermodal) to global city (New York, Tokyo)	***Global travel connectivity*** Number of flights from European airports to intercontinental destinations reachable within three hours	***Global potential accessibility travel*** Intermodal accessibility to intercontinental flights of European airports weighted by destinations as mass
	Freight	***Access to global freight hubs*** Travel time/cost (intermodal) to major intercontinental terminals (Shanghai, Detroit)	***Global freight connectivity*** Intercontinental container throughput of European sea ports reachable within 24 h travel time	***Global potential accessibility freight*** By road and rail to container throughput of European sea ports
Europe	***Travel (traditional)***	***Access to top ten MEGAs*** Average fastest travel time to top ten MEGAs	***European daily accessibility travel*** Daily accessibility to population by road, rail, air	***European potential accessibility travel*** To population by road, rail, air, multimodal
	Travel (new)	***Travel speed*** Average travel speed by road and rail	***Urban connectivity*** Urban connectivity by road, rail, intermodal	***European potential acc. intermodal travel*** To population intermodal (all modes)
	Freight	***Access to nearest maritime ports*** Average generalised cost to nearest three maritime ports	***European daily accessibility freight*** GDP accessible within allowed lorry driving time	***European potential accessibility freight*** Accessibility potential to GDP by different modes
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** ICON based access time to motorway exits, rail stations, airports	***Availability of urban functions*** Cities > 50.000 within 60 minutes by road and rail	***National potential accessibility travel*** To national population by road and rail
	Freight (Europe-wide)	***Access to freight terminals*** ICON based access time to freight terminals	***Availability of freight terminals*** Freight terminals within 2 h by lorry	***National potential accessibility freight*** To national GDP by lorries and rail freight
	Travel (case studies, traditional)	***Access to regional centres*** Travel time to nearest regional centre by road and public transport/rail	***Daily accessibility of jobs*** Jobs accessible within 60 minutes by road and public transport/rail	***Regional potential accessibility*** To population by road and public transport/rail
	Travel (case studies, to services of general interest)	***Access to health care facilities*** Travel time to nearest hospital	***Availability of secondary schools*** Number of secondary schools within 30 minutes of road travel time	***Potential accessibility to basic health care*** Potential accessibility to general practice surgeries

- *Social* impacts of accessibility, i.e. effects on social inclusion or exclusion by differences in access to services of general interest, will be measured by a number of accessibility indicators, such as travel time to the nearest urban centre, travel time to education facilities and travel time to health services.
- *Environmental* impacts of accessibility will be measured as energy consumption and greenhouse gas emissions by transport calculated with a travel and goods transport model attached to the SASI model.

Selection of case studies

Global and European accessibility are important location factors for firms and working and leisure travel of people. However, for the daily life of citizens, regional/local accessibility to jobs, services and public facilities may be more important than global or European accessibility. One part of the TRACC project is therefore concerned with regional accessibility in a set of regional/local case studies in order to gain systematic knowledge on accessibility patterns in different types of regions throughout Europe.

One of the technical objectives for the regional case studies is that the methodologies to be implemented should be as similar as possible in order to allow a comparison of the resulting accessibility patterns, i.e. should not be disturbed by artefacts induced by methodological differences. In each case study, the set of regional accessibility indicators will be calculated and analysed to arrive at comparable results as possible.

The TRACC project intends an exploratory analysis of regional accessibility patterns around Europe. A specific concept for the case study regions was developed in which each regional case study consists of two integrated spatial layers, a macro region and a set of zoom-in areas. The regional accessibility models of the case studies will be set up in a way that they calculate the accessibility indicators at least for LAU-2 regions, if possible for smaller raster cells. This allows on the one hand to analyse accessibility pattern for the wider area of the macro region with different types of regions and on the other hand more in-depth analyses for specific types of regions by looking into the zoom-in areas.

Figure E1 shows the seven TRACC macro regions selected: EURAM in Spain and France, Northern Italy, Bavaria in Germany, the Czech Republic, Poland, the Baltic Republics and Finland. Together, they form an arc stretching from the Mediterranean Sea in south-western Europe up to the far north of the Nordic countries.

The case study regions cover a wide range of different types of regions in different parts of Europe. They cover both core and peripheral areas, inland, coastal and insular territories, urban and rural territories, densely populated and sparsely populated areas, flat and mountainous territories, territories located both in EU15 countries and in new EU member states. Contrasting the case study regions with the nine standard ESPON territorial typologies, urban-rural, metropolitan regions, border regions, island regions, sparsely populated regions, outermost regions, mountainous regions, coastal regions, regions and regions in industrial transition, yields that the 275 NUTS-3 regions of the macro regions have almost for each regional typology the same share of regions of each type of region as the whole ESPON space

Case study regions

Figure E1. TRACC regional case studies

Database

The calculation of global, European and regional accessibility indicators requires comprehensive input data. Network data and socio-economic data for describing origin and destination features are needed at different spatial scales. Since TRAC C covers the ESPON space and the Western Balkan as well as global destinations, data are also needed for countries beyond the ESPON space.

Based on a detailed assessment of data needs the data sources to be used have been identified including potential data sources that eventually have not been selected. For the European accessiblity modelling, two network datasets have been selected: the TRANS-TOOLS networks will be used for the calculation of freight accessibility indicators, while the RRG GIS Database (RRG, 2011) will be used for the calculation of passenger travel accessibility indicators at the European level. The selected networks include all required modes with sufficient density (i.e. connectivity of centroids is ensured) for the most recent year, with network topologies already built in, and with all relevant attributes that are needed for accessibility modelling. Both data sets have been widely used in previous EU and ESPON projects, by that ensuring continuity of the TRACC results with previous indicator calculations. The TRANS-TOOLS and RRG networks are already available at the project partners free of charge in the required GIS formats, so that no additional data collection or data harmonisation are needed. Most of the socio-economic data are already available with the project partners.

Concerning the network data for the regional case studies, apart from some necessary updates, in general network data for all required modes are already available in GIS format at sufficient detail with the project partners. Also the statistical data for most case studies are already available with high resolution (i.e. municipality level, raster level). However, for some case studies some data are missing or are available at higher spatial levels only. The project partners will be responsible for collecting and updating the data necessary for their regional case studies at the required spatial resolution.

Towards policy conclusions

The final objective of the TRACC project is to create awareness and provide guidance for rational tradeoffs between the conflicting goals of competitiveness, territorial cohesion and environmental sustainability in the European transport policy. The project will evaluate the policy instruments available to the European Union to maintain and improve regional accessibility in order to support and thrust regional development while minimising negative implications for territorial cohesion and the environment. It will also formulate policy conclusions which can stimulate and enlighten the ongoing political discourse on transport and accessibility policy for decision makers, experts and the wider public.

It will be discussed to what extend the accessibility patterns in the European territory can contribute to generate development opportunities and how policy options take into account the cohesion and environment policy orientations. At the end of the TRACC project, the findings of the project on accessibility patterns will be summarised in relation to the goals of the European Union in terms of competitiveness, territorial cohesion and environmental sustainability, and it will be discussed to what extent the European transport policy documents currently under revision, mostly the White Paper on Transport and the TEN-T programme, can contribute to the above mentioned objectives in the field of accessibility.

1 Objectives

Accessibility is the main 'product' of a transport system. It determines the locational advantage of an area (i.e. in ESPON a region, a city or a corridor) relative to all areas (including itself). Indicators of accessibility measure the benefits households and firms in an area enjoy from the existence and use of the transport infrastructure relevant for their area.

The important role of transport infrastructure (i.e. networks and transport services) for spatial development in its most simplified form implies that areas 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 areas.

However, the impact of transport infrastructure on spatial 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. However, in most countries this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today.

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. A different situation can be observed in some regions of the new EU member states where the lack of modern infrastructure (motorways, high-speed trains) is still a major barrier to economic development and where the rapid increase of freight flows by road on the main transport corridors between western and eastern Europe was not followed by new road, rail or multimodal transport investment.

While there is uncertainty about the magnitude of the impact of transport infrastructure on spatial development, there is even less agreement on its direction. It is debated whether transport infrastructure improvements contribute to spatial polarisation or decentralisation. 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 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.

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. Several trends combine to reinforce the tendency to diminish 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 freight transports and person trips but they also increase the demand for 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 environ-

ment, i.e. quality of life, and factors related to access to information and specialised high-level services and 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 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).
- In the future rising energy prices and the need to reduce greenhouse gas emission of transport may increase the importance of transport cost for regional development.

Both above tendencies are being accelerated by the increasing integration of national economies within the European Union and by the continuing globalisation of the world economy.

Key policy questions

In this situation the project is to address the following key policy question from a European point of view:

- What are the differences between accessibility at three different levels (global, European and regional) considering the four modes road, rail, water and air?
- What is the link between accessibility at the different levels and for different modes of European regions and their economic development? How has this link changed over time? Does the strength of this link differ across the EU?
- What could be the territorial impact of rising energy prices on the future developments of road, rail, water and air transport?
- What could be the impact of various transport scenarios on climate change, access patterns and economic development?

In addition the project is to look into the regional dimension of accessibility often neglected in previous studies of accessibility:

- How does accessibility/connectivity look like at the regional level? For example, how many jobs/people can be reached in 45 minutes travel time (by road or by train), how many city centres can be reached by flying out in the morning and returning in the evening?
- In which type of regions is the level of European accessibility very different from their regional accessibility?

From a research point of view, the following key research questions are to be addressed:

- What is the accessibility of European regions for travel by different modes (road, rail, air) at the European level?
- What is the accessibility of European regions for air travel at the global level?
- What is the potential of intermodal travel, in particular the combination of high-speed rail and air?
- What would be the impacts of different policies to make rail more competitive on the modal share of travel and travel accessibility?

- What would be the impacts of different policies to make rail and water more competitive on the modal share of freight transport and freight accessibility?
- What are the most favoured urban centres and most disadvantaged regions with respect to travel accessibility (island, mountain areas)?

Project objectives

From these key policy and research questions the main objectives of the project are derived:

- to take up and update the results of existing studies on accessibility at the European scale using most recent available network and socio-economic data,
- to extend the range of accessibility indicators by further indicators responding to new policy questions and further developing the quality and validity of the existing indicators,
- to extend the spatial resolution of accessibility indicators by calculating, besides European accessibility, also global and regional accessibility,
- to explore the likely impacts of available policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

Geographical coverage of all analyses should be according to the project specification NUTS-3 or equivalent regions in all countries participating in the ESPON 2013 Programme plus ideally the EU candidate countries Croatia, FYR Macedonia and Turkey and the other countries of the Western Balkans Bosnia and Herzegovina, Serbia, Montenegro, Albania and Kosovo.

When calculating accessibility indicators transport connections to destinations outside the study area are to be considered. When calculating European accessibility, also links to destinations in neighbouring countries, such as Belarus, Moldova, Russia and Ukraine, are to be considered, and when calculating global accessibility, links to destinations in all world regions.

2 Conceptual framework

In this section first a introduction into the state of the art of calculating accessibility indicators is given showing the major dimensions of accessibility, the most frequently types of accessibility indicators and important extension of these. Based on this conceptual framework, the research concept of the project is outlined.

2.1 Accessibility dimensions

Accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, type of transport, modes, spatial scale, equity and dynamics. These dimensions are summarised in Table 1.

Origins

Accessibility indicators are calculated for areas such as regions or cities. From a pure semantic point of view, an area is called accessible if it can be easily reached from other areas. However, in practice a reverse view is used: an area is called highly accessible if many attractive destinations can be reached from it in a short time. In that sense the area can be considered the origin of trips to destinations of interest. In both perspectives the notion of accessibility is closely linked to movement, and so it matters who moves. Different actors such as business travellers, tourists or commuters are attracted by different destinations and have different travel preferences and travel budgets. By the same token different firms have different views of destinations as purveyors, customers or other firms and require different transport services depending on the kind of goods they ship. Accessibility indicators therefore have to be calculated with different types of actors or transport users in mind.

Destinations

Different actors are attracted by different destinations. Business travellers find their clients most likely in city centres. Tourists are attracted by tourist attractions such as beach resorts, mountains or historical towns. Commuters are interested in job opportunities. Consumer-oriented firms want to reach their customers, whereas business-oriented firms deliver their goods and services to other firms. Accessibility indicators therefore have to be calculated with respect to different destinations such as economic activities, population or tourist attractions.

Impedance

Simple accessibility indicators consider only transport infrastructure in the area itself, expressed by measures such as total length of motorways or number of railway stations, or in the vicinity of the area, expressed by measures such as access to the nearest nodes of interregional networks like motorway exits, intercity stations, freight terminals or airports. More complex accessibility indicators distinguish between destinations in the area itself and those in other areas. The effort needed to overcome that distance is measured as spatial impedance. Spatial impedance is calculated as a function of distance or time or money or a combination of the latter two (generalised cost). There are two different approaches:

- *Euclidean distance*. If no transport network is considered, geographical or Euclidean distance between areas is taken as spatial impedance: Origins and destinations are assumed to be concentrated in nodal points in the centre of the areas called centroids, so distances between the centroids are calculated. In this case other attributes such as travel time, travel cost, capacity, congestion, convenience, reliability or safety have no meaning. The mean length of internal trips in the origin area is estimated as a function of its size.

Table 1. Dimensions of accessibility

Dimension	Comments
Origins	Accessibility indicators may be calculated from the point of view of different population groups such as social or age groups, different occupations such as business travellers or tourists or different economic actors such as industries or firms.
Destinations	Accessibility indicators may measure the location of an area with respect to opportunities, activities and assets such as population, economic activities, universities or tourist attractions. The activity function may be rectangular (all activities beyond a certain size), linear (of size) or non-linear (to express agglomeration effects).
Impedance	The spatial impedance term may be a function of one or more attributes of the links between areas such as distance (Euclidean or network distance), travel time, travel cost, convenience, reliability or safety. The impedance function applied may be linear (mean impedance), rectangular (all destinations within a given impedance) or non-linear (e.g. negative exponential).
Constraints	The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types of maximum driving hours) or by capacity constraints (road gradients or congestion).
Barriers	In addition to spatial impedance also non-spatial, e.g. political, economic, legal, cultural or linguistic barriers between areas may be considered. In addition, non-spatial linkages between areas such as complementary industrial composition may be considered.
Types of transport	Only travel or only freight transport, or both, may be considered in the analysis.
Modes	Accessibility indicators may be calculated for road, rail, inland waterways or air. Multimodal accessibility indicators combine several modal accessibility indicators. Intermodal accessibility indicators include trips by more than one mode.
Spatial scale	Accessibility indicators at the continental, transnational or regional scale may require data of different spatial resolution both with respect to area size and network representation, intra-area access and intra-node terminal and transfer time.
Equity	Accessibility indicators may be calculated for specific groups of areas in order to identify inequalities in accessibility between rich and poor, central and peripheral, urban and rural, nodal and interstitial areas.
Dynamics	Accessibility indicators may be calculated for different points in time in order to show changes in accessibility induced by TEN projects or other transport policies, including their impacts on convergence or divergence in accessibility between areas.

- *Network impedance*. If one or more transport networks are considered, the travel time or cost along the minimum path between areas over the network(s) are taken as spatial impedance between the areas. Besides distance, link attributes such as travel time, travel cost, capacity, congestion, convenience, reliability or safety may be considered. Origins and destinations are assumed to be concentrated in the centroids, and the centroids are linked to the nearest network node by non-network access links. The mean length or travel time or cost of access links and internal trips in the origin area is estimated as a function of the size of the area as above.

If the assumption that origins and destinations of areas are concentrated in their centroids is abandoned, additional access links are estimated between the micro locations of origins and destinations in the areas and their centroids.

Constraints

The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types of maximum driving hours) or by capacity constraints (road gradients or congestion). It is relatively straightforward to take account of regulation constraints when calculating accessibility. Speed limits can be directly converted to link travel times. Regulations on maximum driving hours can be converted to a barrier at the link on the minimum path where the maximum driving time is exceeded. Taking account of capacity constraints when calculating accessibility is more difficult since it requires the consideration of link capacity and network flow characteristics. To restrict the use of certain links by certain vehicle types (e.g. of Swiss transalpine roads by 40-ton lorries) is only possible if different lorry types are distinguished in the accessibility model. To take account of road congestion would actually require a full-scale traffic assignment model, something rarely available when calculating accessibility. As a workaround sometimes time penalties are assigned to links passing through urbanised areas.

Barriers

In addition to spatial impedance also non-spatial, e.g. political, economic, legal, cultural or linguistic barriers between areas may be considered:

- Political barriers are, for instance, national boundaries with delays at the borders for passport control, visas, customs declarations, etc. Significant reductions of barriers between countries of the European Union have been achieved through the Schengen Protocol. However, movement of people from immigration countries across the external boundaries of the European Union has become more restricted.
- Economic barriers are customs, tariffs and other fees imposed on the exchange of goods and services between different countries. Due to the Maastricht Treaty, economic barriers between EU countries have been greatly reduced.
- Legal barriers are non-tariff restrictions imposed on movement of people and goods between countries through different standards, safety regulations, legal provisions, employment restrictions, etc.
- Cultural barriers are invisible barriers discouraging the exchange of people or goods because of different traditions, values, life styles and perceptions at two sides of a border between or within countries.
- Linguistic barriers are invisible barriers discouraging the exchange of people or goods across a border between countries or regions with different languages.

By the same token, non-spatial linkages between areas may be considered. For instance, economic exchange between regions with complementary industrial composition will be more intensive than it is to be expected form their distance and size. Barriers may also be expressed as negative linkages. For instance, exchange of people and goods between regions with the same culture and language will be more intensive than between regions that differ in this respect.

Types of transport

The majority of accessibility indicators are expressed in terms of travel. However, if origins and destinations are economic activities (firms or employment), clearly exchange of goods and services is intended. Accessibility for freight transport is explicitly addressed where freight transport is explicitly modelled. Advanced freight accessibility indicators take account of freight-specific terminals such as intermodal terminals or ports or freight-specific modes such as inland waterways. There are to date only few Europe-wide studies on freight accessibility.

Modes

Network-based accessibility indicators may be calculated for road, rail, ferry, inland waterways or air and can be unimodal, multimodal or intermodal: Unimodal accessibility indicators consider only one mode. Multimodal accessibility indicators are aggregates of two or more unimodal accessibility indicators. Intermodal accessibility indicators consider trips by more than one mode taking account of transfers between modes. Among the accessibility indicators reported in the literature, intermodal accessibility indicators are rare, except for rail and maritime freight transport where the start and end of a trip is assumed to be by road..

Spatial resolution

Origins and destinations are located in *areas* representing regions or cities. However, accessibility indicators can be calculated only for *points*, which are defined either by geographical coordinates (when calculating Euclidean distance) or as network nodes (when calculating network impedance). It is therefore not useful to classify accessibility indicators as area-oriented or nodal. All accessibility indicators are nodal, and if accessibility indicators for areas are required, some generalisation is needed.

The most common generalisation is to assume that all origin and destination activities are concentrated in nodal points in the centre of the areas called centroids. This generalisation is acceptable if the areas are small or if only the accessibility of the city centres is of interest in the study.

However, there are important issues of spatial equity concerned with the decline of accessibility with increasing distance from network nodes. If accessibility is represented as a continuous three-dimensional surface, the nodes of the (high-speed) networks are 'mountains' representing, for instance, high-speed rail stations in the city centres, whereas the areas away from the network nodes are 'valleys' representing the 'grey zones' with low accessibility between the network nodes. Accessibility indicators that are to show not only the 'mountains' but also the 'valleys' need to be more spatially disaggregate.

The most straightforward way of calculating more disaggregate accessibility indicators is to increase the number of areas. This is, however, frequently not possible because high-resolution socio-economic data are not available.

Another way to calculate spatially disaggregate accessibility indicators is to disaggregate the socio-economic data from large areas to much smaller uniform raster cells or pixels probabilistically using land cover information from geographical information systems or remote sensing images as ancillary information. By calculating accessibility indicators for each of these pixels, quasi-continuous accessibility surfaces showing not only the 'mountains' of high accessibility but also the adjacent 'valleys' of low accessibility can be created. As with larger areas, estimates of non-network travel times or cost between pixel centroids and nearest network nodes need to be made.

Equity

Issues of spatial equity arise with respect to differences in accessibility both within and between areas:

- At a regional scale, the decline in accessibility from centroids or network nodes to interstitial areas affects decisions on linkages between interregional and intraregional transport networks.
- At a European scale, spatial equity is related to the territorial cohesion objective of the European Union to reduce disparities in income between regions. To analyse territorial cohesion, accessibility indicators may be calculated for specific groups of regions or cities to identify inequalities in accessibility between rich and poor, central and peripheral, urban and rural, nodal and interstitial areas.

In addition, accessibility indicators can be used to study peripherality. The political and economic significance of peripherality issues has grown as a result of the enlargement of the European Union by the accession of the new member states in central and eastern Europe. A peripheral region is a region which is distant in terms of travel time and travel cost from opportunities, activities or assets existing in other regions – in short, a peripheral region is characterised by low accessibility. Accessibility indicators are conditioned by a number of factors. Transport networks cover the territory of the European Union unevenly and differ in relevance with respect to the requirements of individual regions, partly due to the fact that the regional division of labour and social stratification has been adapted to differences in accessibility.

This implies that accessibility indicators which may be highly relevant to core regions might be of secondary relevance for peripheral regions. This has implications for policy-making: the priorities for improving accessibility are likely to differ between peripheral and core regions. However, even if the interests of peripheral regions were given more weight in European transport policy, it is unlikely that the locational disadvantage of peripheral regions will ever be completely compensated by transport infrastructure. To analyse the difference between accessibility due to 'pure' geographical position and accessibility in transport networks, accessibility indicators based on Euclidean distance may be used as benchmarks against which improvements in network accessibility can be measured.

Dynamics

Accessibility is not static. Accessibility based on Euclidean distance changes with the distribution of socio-economic variables. Network-based accessibility changes both with socio-economic variables and with transport networks or levels of service of transport. To analyse the dynamics of accessibility, accessibility indicators can be calculated for different points in time, for instance to show changes in accessibility induced by TEN projects or other transport policies. By comparing the spatial distribution of accessibility with and without the projects or policies, it can be assessed whether the projects or policies would lead to convergence or divergence in accessibility between areas. A critical issue here is to apply meaningful measures of convergence and divergence, as commonly used cohesion indicators measure only relative and not absolute differences between distributions. However, with appropriate cohesion indicators, accessibility analysis can be used to monitor and forecast the achievement of cohesion goals of the European Union.

2.2 Generic accessibility indicators

In this section a classification of accessibility indicators is proposed that encompasses a great variety of possible indicators in three generic types.

In general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them:

$$A_i = \sum_j \mathrm{g}(W_j)\ \mathrm{f}\ (c_{ij})$$

where A_i is the accessibility of area *i*, W_j is the activity *W* to be reached in area *j*, and c_{ij} is the generalised cost of reaching area *j* from area *i*. The functions g(W_{ij}) and f(c_{ij}) are called *activity functions* and *impedance functions*, respectively. They are associated multiplicatively, i.e. are weights to each other. That is, both are necessary elements of accessibility. A_i is the total of the activities reachable in areas *j* weighted by the ease of getting from *i* to *j*. It is easily seen that this is a general form of potential, a concept dating back to Newton's Law of Gravitation. According to the Law of Gravitation, the attraction of a distant body is equal to its mass divided by its squared distance. The gravity model of regional science is somewhat more general, it states that the attraction of a distant location is proportional to its size (e.g. population) weighted by a decreasing function of its distance.

In the context of accessibility, the 'size' are the activities or opportunities in areas *j* (including area *i* itself), and the 'distance' is the spatial impedance c_{ij}. The interpretation here is that the greater the number of attractive destinations in areas *j* is and the more accessible areas *j* are from area *i*, the greater is the accessibility of area *i*. This definition of accessibility is referred to as destination-oriented accessibility. In a similar way an origin-oriented accessibility can be defined: The more people live in areas *j* and the easier they can visit area *i*, the greater is the accessibility of area *i*. Because of the symmetry of most transport connections, destination-oriented and origin-oriented accessibility tend to be highly correlated.

However, the generic equation of accessibility above is more general than the gravity model. Different types of accessibility indicators can be generated by specifying different forms of functions g(W_j) and f(c_{ij}):

- *Travel cost*. If only destinations of a certain kind, e.g. cities beyond a certain size, are considered (the activity function is rectangular), and the impedance function is travel time or travel cost itself (i.e. the impedance function is linear), the accessibility indicator is total or average travel cost to a predefined set of destinations.
- *Cumulated opportunities*. If only destinations within a certain travel time are considered (the impedance function is rectangular), and the destinations are taken as is (the activity function is linear), the accessibility indicator measures the number of potential destinations (customers, business contacts, tourist attractions, etc.) that can be reached in a given time, e.g. a day.
- *Potential*. If the impedance function takes travel behaviour into account, i.e. the diminishing inclination to travel long distances (the impedance function is nonlinear, e.g. exponential), the accessibility indicator is a potential indicator. The activity function may take account of agglomeration effects or economies of scale (i.e. may be nonlinear, e.g. a power function).

Table 2 shows the most frequent specifications of g(W_j) and f(c_{ij}) for the three types of accessibility indicator, where W_{min} and c_{max} are constants and α and β parameters:

Table 2. Accessibility indicators

Type of accessibility	**Activity function** $\mathrm{g}(W_j)$	**Impedance function** $\mathrm{f}(c_{ij})$
Travel cost Travel cost to a set of activities	$W_j \left\| \begin{array}{l} 1 \text{ if } W_j \geq W_{\min} \\ 0 \text{ if } W_j < W_{\min} \end{array} \right.$	c_{ij}
Cumulated opportunities Activities in a given travel time	W_j	$\begin{array}{l} 1 \text{ if } c_{ij} \leq c_{\max} \\ 0 \text{ if } c_{ij} > c_{\max} \end{array}$
Potential Activities weighted by a function of travel cost	W_j^{α}	$\exp(-\beta\, c_{ij})$

Travel cost

This indicator is based on the assumption that not all possible destinations are relevant for the accessibility of an area but only a specified set. This set may, for instance, consist of all cities over a specified size or level of attraction W_{min}. The indicator measures the accumulated generalised travel costs to the set of destinations. In the simplest case no distinction is made between larger and smaller destinations, i.e. all destinations in the set get equal weight irrespective of their size and all other destinations are weighted zero (the activity function is rectangular). In many applications, however, destinations are weighted by size (the activity function is linear). The impedance function is always linear, i.e. does not take into account that more distant destinations are visited less frequently.

Travel cost indicators are popular because they are easy to interpret, in particular if they are expressed in familiar units such as average travel cost or travel time. Their common disadvantage is that they lack a behavioural foundation because they ignore that more distant destinations are visited less frequently and that therefore their values depend heavily on the selected set of destination, i.e. the arbitrary cut-off point of the W_j included.

Cumulated opportunities

This indicator is based on the notion of a fixed budget for travel, generally in terms of a maximum time interval in which a destination has to be reached to be of interest. The rationale of this accessibility indicator is derived from the case of a business traveller who wishes to travel to a certain city, conduct business there and return home in the evening. Maximum travel times of three to five hours one-way are used at the European scale. Because of its association with a one-day business trip this type of accessibility is often called 'daily accessibility'.

The cumulated opportunities indicator is equivalent to a potential accessibility indicator (see below) with a linear activity function and a rectangular impedance function, i.e. within the selected travel time limit destinations are weighted only by size, whereas beyond that limit no destinations are considered at all. Cumulated opportunities indicators, like the travel cost indicators above, have the advantage of being expressed in easy-to-understand terms, e.g. the number of people one can reach in a given number of hours. However, they also share their disadvantage that they heavily depend on the arbitrarily selected maximum travel time beyond which destinations are no more considered.

Potential accessibility

This indicator is based on the assumption that the attraction of a destination increases with size *and* declines with distance or travel time or cost. Therefore both size and distance of destinations are taken into account. The size of the destination is usually represented by area population or some economic indicator such as total area GDP or total area income. The activity function may be linear or nonlinear. Occasionally the attraction term W_j is weighted by an exponent α greater than one to take account of agglomeration effects, i.e. the fact that larger facilities may be disproportionally more attractive than smaller ones. One example is the attractiveness of large shopping centres which attract more customers than several smaller ones that together match the large centre in size. The impedance function is nonlinear. Generally a negative exponential function is used in which a large value of the parameter β indicates that nearby destinations are given greater weight than remote ones.

Indicators of potential accessibility are superior to travel cost accessibility and cumulated opportunities in that they are founded on sound behavioural principles of stochastic utility maximisation. Their disadvantages are that they contain parameters that need to be calibrated and that their values cannot be easily interpreted in familiar units such as travel time or number of people. Therefore potential indicators are frequently expressed in percent of average accessibility of all areas or, if changes of accessibility are studied, in percent of average accessibility of all areas in the base year of the comparison.

Extensions

There is a large number of extensions of the above generic accessibility indicators. Four of them will be addressed in this project:

Multimodal accessibility

All three types of accessibility indicator can be calculated for any mode. At a European scale, accessibility indicators for road, rail and air are most frequently calculated. In most studies accessibility indicators were calculated for passenger travel only; there are to date only few studies calculating freight accessibility indicators. Differences between modes are usually expressed by using different generalised costs taking into account travel time, travel distance and convenience of travel. In addition, there may be a fixed travel cost component as well as cost components taking account of network access at either end of a trip, waiting and transfer times at stations, waiting times at borders or congestion in metropolitan areas.

Modal accessibility indicators may be presented separately in order to demonstrate differences in accessibility between modes. Or they may be integrated into one indicator expressing the combined effect of alternative modes for a location. There are essentially two ways of integration. One is to select the fastest mode to each destination, which in general will be air for distant destinations and road or rail for short- or medium-distance destinations, and to ignore the remaining slower modes. Another way is to calculate an aggregate accessibility measure combining the information contained in the modal accessibility indicators by replacing the generalised cost c_{ij} by the 'composite' generalised cost

$$\bar{c}_{ij} = -\frac{1}{\lambda} \ln \sum_m \exp(-\lambda\, c_{ijm})$$

where c_{ijm} is the generalised cost of travel by mode m between i and j and λ is a parameter indicating the sensitivity of travellers to travel cost. This formulation of composite travel cost is superior to average travel cost because it makes sure that the removal of a mode with higher cost (i.e. closure of a rail line) does not result in a – false – reduction in aggregate travel cost. This way of aggregating travel costs across modes is theoretically consistent only for potential accessibility. No consistent ways of calculating multimodal accessibility indicators for travel cost and cumulated opportunities exist.

Intermodal accessibility

A further refinement is to calculate *intermodal* accessibility. Intermodal accessibility indicators take account of trips involving two or more modes. Intermodal accessibility indicators are most relevant for logistic chains in freight traffic such as rail freight with feeder transport by lorry at either end. Intermodal accessibility indicators in passenger travel involve mode combinations such as Rail-and-Fly or car rentals at railway stations and airports. The intermodal generalised cost function consequently contains further additional components to take account of intermodal waiting and transfer times, cost and inconvenience. The calculation of intermodal accessibility indicators requires the capability of minimum path search in a multimodal network.

Regional accessibility

Intermodality is also an issue when calculating *intra-area* or regional accessibility. Most accessibility studies concentrated on the accessibility of cities, i.e. network nodes which are assumed to represent the whole metropolitan area or even a larger region. This presents two problems:

- Accessibility indicators calculated for network nodes ignore that accessibility is continuous in space. The decline of accessibility from the central node (centroid) of a region to smaller towns and less urbanised parts of the region is not considered.
- The quality of the interconnections between the high-speed interregional and the low-speed local transport networks cannot be taken into account. Yet the ease of getting from home or office to the nearest station of the high-speed rail network or the nearest airport may be more important for the accessibility of a location than the speed of the long-distance connection from there.

Global accessibility

Only a few accessibility studies have so far addressed issues of global accessibility. It will be part of the research of the project to propose and calculate meaningful accessibility indicators for global accessibility.

In addition the estimation of access times from locations within the area to the centroid as well as of travel times between locations within the area itself ('self-potential'), which greatly influence the accessibility of an area, increases in difficulty with spatial aggregation. There have been numerous proposals for approximate solutions to the problem of 'self-potential'. Most of them concentrate on the selection of an appropriate fictitious 'internal' distance or travel time estimated as a function of the radius of the area. A really satisfactory solution of the problem of calculating intra-area accessibility requires high-resolution data on the spatial distribution of activities in the region. If also the quality of the intraregional transport network and its connection with the long-distance interregional networks are to be assessed, detailed information on the intraregional road and public transport networks and the transfer possibilities at railway stations and airports are required.

2.3 Research concept

The project is based on and extends the state of the art of accessibility analysis presented in the previous sections:

- It takes up and updates the results of existing studies on accessibility at the European scale using most recent available network and socio-economic data.
- It extends the range of accessibility indicators by further indicators responding to new policy questions and further developing the quality and validity of the existing indicators.
- It extends the spatial resolution of accessibility indicators by calculating accessibility indicators for both the global and the regional scale.
- It explores the likely impacts of available policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

To achieve this, the research in the project is divided into seven Tasks. Figure 1 shows the Work Packages and Tasks of the project and the main linkages between them. A detailed presentation of the research tasks and their subtasks was given in the TRACC Inception Report.

Task 1: Methodology/indicators

The objective of the first Task is to review the existing methods and indicators for different types of transport, transport modes and spatial scales, to improve the methods to measure European accessibility by calculating other indicators than potential accessibility and to extend them by calculating not only European travel accessibility as done so far in ESPON but also freight accessibility and global and regional accessibility. Based on this review, this Task is to define the methodology of the project, in particular to define a set of accessibility indicators for the ESPON Programme for all spatial levels considered, which will be implemented in the subsequent Tasks.

Task 2: Network and socio-economic data

The objective of this Task is to provide an assessment of network and socio-economic data including an assessment of data availability in the EU candidate countries and Western Balkan and to provide network and socio-economic datasets customised for all accessibility and impact modelling in the project at all scales addressed based on a comprehensive overview and assessment of available network and socio-economic databases.

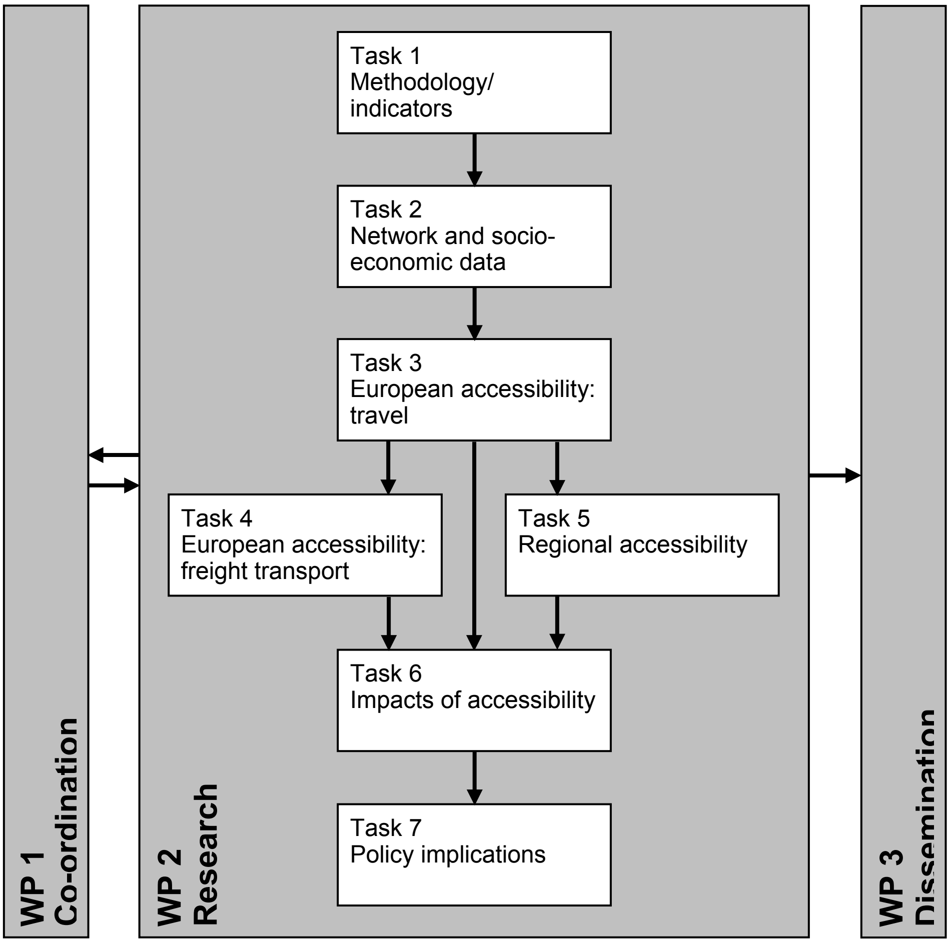


Figure 1. Work Packages and Tasks

Task 3: European accessibility: travel

The objective of Task 3 is to calculate a unique set of standard and new travel accessibility indicators. Those indicators are to address European as well as global accessibility for the regions of the ESPON space and the Western Balkan. Some basic accessibility travel indicators are to show the development of accessibility patterns in Europe for the last decade and for possible future situations. The accessibility patterns are to be transformed into European and global accessibility typologies. The results are to be presented in maps of the ESPON territory and the Western Balkan showing the spatial distribution of the different travel accessibility indicators by road, rail, air and combinations of these modes at the global and European level.

Task 4: European accessibility: freight transport

The objective of this Task is to calculate a set of freight accessibility indicators for European as well as global accessibility for the regions of the ESPON space and the Western Balkan. The accessibility pattern are to be transformed into European and global accessibility typologies. The results will be presented in maps of the ESPON territory showing the spatial distribution of the different freight accessibility indicators computed for various modes and with reference to the different types of accessibility.

Task 5: Regional accessibility

The objective of this Task is to measure and analyse accessibility at the regional scale in Europe. This is to be done by two different approaches. On the one hand, a set of regional case studies encompassing different types of regions in Europe are to provide in-depth insight into regional accessibility indicators with as much as possible harmonised approaches across the different case studies. On the other hand, accessibility indicators are to be calculated that show accessibility to regional destinations, but are covering the whole ESPON space and the Western Balkan on a raster base. Finally, regional accessibility results and European accessibility results are to be compared to gain insight into the relationship of regional and European accessibility.

Task 6: Impacts of accessibility

The objectives of this task are to analyse the relationship between different types of accessibility and regional economic development and the environment (energy consumption and greenhouse gas emissions) and to forecast the development of accessibility and GDP per capita, employment and population and energy consumption and greenhouse gas emissions of transport subject to a set of long-term scenarios of European transport policies and assumptions about future developments in vehicle technology and alternative fuels and fuel price increases. In addition the results are to be analysed by different cohesion indicators expressing the impacts of the policies modelled on the convergence (or divergence) of accessibility and socio-economic development in the regions of the ESPON space and the Western Balkan.

Task 7: Policy implications

This Task is to summarise the findings of the project in relation to the goals of the European Union competitiveness, territorial cohesion and environmental sustainability for different types of regions and to evaluate the policy instruments available to the European Union and its member states to maintain and improve the different types of regional accessibility in order to draw as much benefit for regional development from accessibility with the smallest possible negative implications for territorial cohesion and the environment and to formulate policy conclusions which can stimulate and enlighten the ongoing political discourse on transport and accessibility policy for decision makers, experts and the wider public.

With this research concept the project starts from the standard accessibility indicators developed in ESPON 1.2.1, 1.1.1, 2.1.1 and 1.1.3 and the recent Accessibility Updates and extends these to first freight accessibility and global accessibility and then to the regional/local level of intraregional accessibility in regional case studies and eventually looks at impacts of accessibility changes. By exploring several alternative ways of calculating regional/local accessibility indicators and comparing them with European accessibility indicators, the added value of more detailed accessibility indicators will be assessed.

The expected results of the project will be:

- a consistent set of European network and regional socio-economic data,
- an analysis and a database of various European and global accessibility indicators at NUTS-3 level for travel and freight accessibility by different modes,
- case studies of regional accessibility in different types of regions and exploratory research on Europe-wide regional accessibility,
- evidence on the relationship between accessibility and regional development (GDP per capita, energy consumption and greenhouse gas emissions by transport),
- policy-relevant findings, policy conclusions and suggestions for further research.

3 Review of accessibility studies

This chapter contains a comprehensive review of accessibility studies done in Europe. A focus is on studies published during the last decade. The review is organised in three main parts which address different spatial contexts of the accessibility models, i.e. global, European and regional. In each subchapter, selected studies will be briefly presented and then systematically compared along the dimensions of accessibility and with respect to the accessibility patterns observed.

3.1 Global accessibility studies

The understanding of global accessibility studies in this report is that studies are included that analyse the accessibility of Europe and its regions to the world. This starts with short summaries of the few global accessibility studies available and compares these along the dimensions of accessibility identified in Chapter 2 and with respect to the accessibility patterns observed.

BAK Basel Economics (2004; 2005) developed a global accessibility indicator of the potential type. About 120 non-European airports were selected as destinations, and the GDP of their hinterland area constituted their attractiveness. It was stated that 99 % of the global economy outside Europe is covered. Origins were about 220 European regions of which 150 are located in the extended Alpine space. Travel times were based on intermodal trip chains from the origin regions to the airports plus the flight time to the final destination and included waiting and transfer time.

Certet (2010) computed an indicator of global accessibility for air cargo of 13 European airports. This indicator was updated on a yearly basis to monitor the performance of the airports and their relative position in competitive terms. The indicator was a sort of multicriteria index based on four main items: relevance of the destinations served by the airport, frequency of connections, quality of service and tariffs for freight forwarding.

The ESPON project "Europe in the World" (ESPON 3.4.1, 2007) did an analysis of intercontinental air connectivity of European airports. The global accessibility offered by the European airports was measured in terms of global passenger km travelled from the airport which might be considered a variant of the cumulative opportunities indicator of the three generic types. In addition, the main orientation of the individual airports was assessed by analysing the share of different world regions in the transport volume.

A somewhat different global accessibility indicator was produced by the Joint Research Centre of the European Commission (Nelson, 2008) and developed for the World Development Report 2009 (World Bank, 2009). The indicator was travel time by road or rail from subnational territorial units to the nearest of 8,500 major cities in the world. The indicator was different than the other global accessibility indicators presented before, because it calculated accessibility to regional destinations. But as this was done for the whole globe, the indicator is incorporated here as a unique example of a global accessibility indicator.

Comparison

Table 3 presents the global accessibility studies with respect to the dimensions of accessibility. All generic types of accessibility indicators were represented. The indicators, however, were in most cases calculated for the airport or the airport city, consequently, air transport was the only transport mode. The only exception from this are the studies by BAK Basel Economics (2004; 2005) which calculated global accessibility for a set of regions by incorporating the access time from the regions to the airports into an overall intermodal travel time. Most studies considered travel, but air freight was addressed in only one study. In the freight study, not only travel time, but also other criteria such as quality of service and tariffs were included in the accessibility indicator.

Table 3. Dimensions of global accessibility models

Authors	**Indicator type**	**Origins**	**Destinations**	**Impedance**	**Constraints**	**Barriers**	**Type of transport**	**Modes**	**Spatial scope**
BAK Basel Economics (2004; 2005)	Potential	220 regions of which 150 in the extended Alpine space.	GDP represented by 120 non-European airports	Travel time	Timetable restrictions	-	Travel	Intermodal	Extended Alpine Space, Europe (partly)
ESPON 3.4.1 (2006); ESPON (2007)	Cumulative	European airports	Airports in the world	-	-	-	-	Air	ESPON space
Certet (2010)	Travel cost	13 European airports	260 airports outside Europe	Travel time, travel cost	Frequency, quality of service	-	Freight	Air	Selected airports in Europe
Nelson (2008); World Bank (2009)	Travel cost	Subnational regions	8,500 major cities world wide	Travel time	-	-	Travel	Road, rail	World

Spatial pattern

Table 4 gives the main results of the four global accessibility studies with respect to the accessibility patterns, spatial disparity and its changing patterns over time.

The studies looking at global accessibility by using the airports as origins and either indicators of the travel cost or cumulated opportunities type came to the result of a strong hierarchy of airport cities in Europe. The study looking at global accessibility for a set of regions by using a potential accessibility indicator stated much less disparities in Europe. This might be traced back to the fact that the different access time from the regions to the airports play a much lower role for the accessibility value, because the higher proportion of the total travel times consists of airport terminal times and the travel times of long-distance flights.

Table 4. Accessibility pattern stated in global accessibility studies

Authors	Destinations considered	Accessibility patterns
BAK Basel Economics (2004; 2005)	120 airports outside Europe weighted by GDP of their hinterland area	European metropolitan regions have the highest accessibility. Frankfurt, London, Paris and Amsterdam are leading with standardised index values of about 120 (Alpine regions = 100). Standardised accessibility values vary only between 69 and 124, the lowest values are found in some Alpine regions.
ESPON 3.4.1 (2007)	Airports outside Europe	The most important European gateway cities are London, Paris, Frankfurt and Amsterdam which stand also at the top of the list of world cities in terms of air connectivity. Other European cities are less important for global connectivity but play a role for connections to southern and eastern the neighbourhood of Europe.
Certet (2010)	260 airports outside Europe	Frankfurt airport has the highest intercontinental accessibility, followed by London, Amsterdam and Paris. Intercontinental accessibility of other European airports is significantly lower.
Nelson (2008); World Bank (2009)	8,500 major cities worldwide	Europe has very short travel times to the nearest cities compared with other parts of the world. Only 15 % of the population in developed countries are more than one hour away from a city, in developing countries 65 %.

Assessment

There are only a few global accessibility models available, but they are mostly concerned with the different intercontinental accessibility provided by airports, i.e. points in space, and not by the way how this translates into the global accessibility of regions. This is considered by one study only, however, its regional system is mainly confined to one European macro region. In conclusion, a systematic evaluation of the global accessibility of European regions is lacking so far.

3.2 European accessibility studies

Over the last decades a vast number of accessibility studies addressing European core-periphery issues have been published. This chapter extends earlier reviews (Rietveld and Bruinsma, 1998; Wegener et al., 2001; ESPON 1.2.1, 2005). It starts with short summaries of prominent European accessibility studies and compares these along the dimensions of accessibility identified in Chapter 2 and with respect to equity and cohesion.

There is a growing number of accessibility models addressing Europe-wide accessibility. This section briefly introduces European accessibility models developed in the last three decades and classifies them and compares the accessibility indicators they produce by applying the dimensions of accessibility presented in Chapter 2. The dimensions equity and dynamics are discussed separately. The order of the models presented is chronological.

Keeble et al. (1982, 1988) in a project for DGXVI of the European Commission analysed economic core-peripherality differences between the regions of the Community and investigated whether any differences can be explained by relative location. For this purpose, they developed a gravity potential model with regional GDP as destination activity and road distance costs as impedance. The results were expressed as economic potential index and presented in maps as contour lines.

Törnqvist had already in the 1970s developed the notion of 'contact networks' based on the hypothesis that the number of interactions with other cities by visits such as business trips is a good indicator of the position of a city in the urban hierarchy. Based on this, Cederlund et al. (1991) and Erlandsson and Törnqvist (1993) calculated daily accessibility indicators of European cities expressed as the number of people that can be reached from a city by a return trip during a work day with four hours minimum stay using the fastest available mode (*outbund* accessibility).

The *Bundesforschungsanstalt für Landeskunde und Raumordnung* (Lutter et al., 1992, 1993) in a study for DG Regio of the European Commission calculated the accessibility of NUTS-3 regions in the then twelve member states of the European Community as average travel time by intermodal transport (road, rail, air) to 194 economic centres in Europe. In the same study they used also other destinations such as the nearest three agglomerations, the nearest high-speed train stop or the nearest airport. In addition, they calculated a daily accessibility indicator expressed as the number of people that can be reached in three hours using the fastest connection. Modes considered included road, rail and air with and without planned infrastructure investments (new motorways, high-speed rail lines and more frequent flight connections).

Bruinsma and Rietveld (1993) calculated the population potential of European cities with similar results as Keeble et al. (1982; 1988) once again demonstrating the spatial correlation between economic and population centres.

Spiekermann and Wegener developed three-dimensional surfaces of daily and potential rail accessibility for Europe using raster-based GIS technology (Spiekermann and Wegener, 1994; 1996; Vickerman et al., 1999), road and air accessibility were added later (Schürmann et al., 1997; Fürst et al., 2000). The quasi-homogenous accessibility surfaces were achieved by subdividing Europe into some 70,000 square raster cells of 10 km width and calculating accessibility indicators for each raster cell with respect to all other raster cells. Population of raster cells was estimated by allocating the population of NUTS-3 regions to raster cells with the help of a hypothetical negative-exponential gradient of population density around population centres. Access travel time from each raster cell to the nearest network node was approximated using an airline travel speed of 30 km/h.

Chatelus and Ulied (1995) developed several accessibility indicators for the evaluation of trans-European networks at the level of NUTS-2 regions in the EU15 plus Norway. One of them, the FreR(M) indicator, measures the average cost to reach a market area of a certain population size by lorry. The impedance term is generalised road transport cost including cost of the driver's time, cost per kilometre and a fixed cost component. The CON(T) indicator accumulates population of NUTS-2 regions of EU15 plus Norway and Switzerland reachable within a maximum travel time of three hours by any combination of car, rail and air with transfer times between modes explicitly considered. The CON(T) index was used to assess transport infrastructure scenarios with respect to competitiveness, cohesion and sustainability. The FreR(T) index is a freight accessibility indicator expressing the size of the market that can be reached in a certain travel time, e.g. the population that can be reached overnight or in 12, 36, 60 or 84 hours by the fastest connection using road, rail or combined traffic with driving time restrictions for lorry drivers observed.

Gutiérrez et al. (1996) and Gutiérrez and Urbano (1996) calculated average travel time by road and rail from about 4,000 nodes of a multimodal European transport network to 94 agglomerations with a population of more than 300,000 with and without planned infrastructure improvements. Road travel times included road and car ferry travel times modified by a link-type specific coefficient and a penalty for crossing nodes representing congested population centres. Rail travel times included timetable travel time plus road access time and penalties for changes between road and rail (60 minutes), rail and ferry (180 minutes) and change of rail gauge between Spain and France (30 minutes).

Copus (1997, 1999), in studies for the Highlands and Islands European Partnership Programme and for DG Regio of the European Commission developed peripherality indicators for NUTS-2 and NUTS-3 regions based on road-based potential measures of the Keeble type. The model takes account of different average speeds for different classes of road, realistic ferry crossing and check-in times, EU border crossing delays and statutory drivers' rest breaks. Accessibility is presented as a peripherality index derived as the inverse standardised to the interval between zero (most central) and one hundred (most peripheral).

In a report for the Study Programme on European Spatial Planning of DG REGIO, Wegener et al. (2001) proposed reference indicators describing the geographical position of European NUTS-3 regions. Besides geographical, physical and cultural indicators, three accessibility indicators were proposed. The first two measure accessibility by road and rail to population, the last one accessibility by air to economic activity (expressed by gross domestic product, or GDP). Accessibility to population was seen as an indicator for the size of market areas for suppliers of goods and services and accessibility to GDP as an indicator of the size of market areas for suppliers of high-level business services. Accessibility was presented as percent of European average accessibility.

Schürmann and Talaat (2000) produced an index of peripherality for the Third Cohesion Report of the European Commission (2001) with a geographical information system. Potential type indicators are calculated for passenger and freight transport by road using GDP or population or labour force as destination activity. Travel times for lorries were computed separately from car travel times to take account of speed limits for lorries, delays at borders and ferry ports and statutory drivers' rest periods. The indicators were calculated for NUTS-3 regions and for equivalent regions of the candidate countries and Norway and Switzerland. The indicators were aggregated to NUTS-2, NUTS-1 and NUTS-0 regions. The peripherality index was presented in two ways: either standardised on the European average (as in Wegener et al., 2001) or to an interval between zero and one hundred (as in Copus, 1997, 1999).

In 2004 a research team led by Nordregio (2004) in a project for DG Regio analysed the socio-economic situation of mountain areas in the EU and potential accession and other countries. The study analysed different accessibility indicators, among them population potential, airline distances to national capital cities and the nearest three cities with more than 100,000 inhabitants, access to airports, universities and hospitals. Two spatial levels were used: All indicators were calculated at municipal level and then aggregated to mountain areas. First all indicators were standardised at the European average, but also at the respective national averages. Access to public facilities was initially calculated as shortest travel time by car to the nearest facility and then converted to the proportion of population at more than one hour from the nearest facility.

L'Hostis developed in ESPON 1.2.1 (2005) and ESPON FOCI (2010) a variant of the daily accessibility indicator labelled 'city network contactability'. Presented primarily in map form, the indicator expresses which other MEGAs can be accessed by an origin MEGA within a time window of 5 h until 23 h and allowing for at least 6 hours of activity at the destination.

Another study by Nordregio (Gløersen et al., 2006) analysed the accessibility of peripheral, sparsely populated regions in Finland, Norway and Sweden in the European Union. Due to their extremely peripheral location, these regions rely on transport hubs such as airports and seaports; therefore the number of destinations and the frequency of services of flight and ferry connections were analysed. In addition, access to universities and hospitals was analysed as the proportion of population living within 60 minutes from these facilities.

In a study for the Directorate-General for Internal Policies of the Union of the European Parliament (European Parliament, 2007) a 2.5x2.5 km raster system for the entire European Union plus Norway and Switzerland was used to calculate a comprehensive set of road potential accessibility indicators to population, GDP and service facilities, such as airports, high-speed train stations, universities and hospitals. The results at raster level were aggregated to the NUTS-3 and NUTS-2 level, and indicators, such as number and proportion of population within 60 minutes travel time were derived and mapped.

Spiekermann and Schürmann (2007) updated the potential accessibility indicators for road and rail introduced in ESPON 1.2.1 (2005) and used in several ESPON projects and EU documents with 2006 network data. More recently, the work was extended to air and multimodal accessibility (Spiekermann, 2009; see also ESPON, 2009). Indicators were calculated for NUTS-3 regions of the ESPON space. Particular attention was given to the question how changes over time are analysed, because different ways of presenting changes, e.g. relative change, absolute change, change of the standardised index value, give different results with respect territorial cohesion.

The number of available passenger flights within a maximum travel time by road of 90 minutes was developed for the debate on territorial cohesion (Commission of the European Communities, 2008; European Commission, 2010). This indicator of the generic type of cumulative opportunities was calculated at raster cell level and for NUTS-3 region. For each area the number of flights reachable with the maximum travel time was summed up.

Dijkstra and Poelman (2008) used a travel time indicator to measure remoteness of rural NTUS-3 regions. A rural region was considered as peripheral if more than half of its population have a travel time by car of more then 45 minutes to the nearest city with more than 50,000 inhabitants. The classification of remoteness was combined with the OECD classification of regions to overcome some of its shortcomings. The derived typology of regions, which is also part of the ESPON typology of regions, has five classes of NUTS-3 regions: urban regions, intermediate regions close to a city, intermediate, remote regions, rural regions close to a city and rural remote regions.

Hamed and Krause (2010) developed an index to measure the accessibility of transport routes by mean of a route accessibility index (TRAX: TRACECA Route Accessibility indeX). This index takes into account four basic elements: transport time, transport cost, transport reliability and cargo safety. These elements were quantified for three alternative routes linking Europe to the TRACECA countries by means of interviews with the logistics operators in the TRACECA region and in western Europe and of drivers' journals for real driven routes.

Comparison

The European accessibility models reviewed above yield a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 5):

- More than half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunities indicators. A few models calculate several types of indicator.
- The origins for which accessibility indicators are calculated are usually NUTS-2 or NUTS-3 centroids, very few studies have a more detailed representation of space.

Table 5. Dimensions of European accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Keeble et al. (1982; 1988)	Potential	NUTS-1 NUTS-2	GDP in NUTS-2 and other European NUTS-0.	Road distance	-	Sea crossings, trade barriers	Freight	Road	EU9 EU12
Cederlund et al. (1991) Erlandsson and Törnqvist (1993)	Travel time, cumulated	Cities	Cities	Travel time	-	-	Travel	Fastest mode	EU12
Lutter et al. (1993)	Travel cost, cumulated	NUTS-3	194 centres, nearest 3 agglomerations, airports etc.	Travel time	-	-	Travel	Road, rail, air, intermodal	EU12
Bruinsma and Rietveld (1993)	Potential	Cities	Cities	Travel time	-	-	Travel	Air	EU27+2
Spiekermann and Wegener (1994, 1996)	Cumulated, potential	10 km raster cells	Population in 10 km raster cells	Travel time, travel cost	-	-	Travel	Rail	EU27+2
Chatelus and Ulied (1995)	Travel cost, cumulated	NUTS-2	Population of NUTS-2	Travel cost	Statutory drivers' rest breaks	-	Travel, freight	Road Rail Air, intermodal	EU15 +2
Gutierrez and Urbano (1996)	Travel cost	4,000 nodes	94 agglomerations	Travel time	Congestion in urban areas	Change of rail gauge	Travel	Road, rail	EU12
Copus (1997, 1999)	Potential	NUTS-2 NUTS-3	Population, GDP, labour in NUTS-2/3	Travel time	Statutory drivers' rest breaks	Border delays	Travel	Road	EU15+2+12
Wegener et al., (2001)	Potential	NUTS-3	Population, GDP in 10 km raster cells	Travel time, travel cost	-	Border delays	Travel	Road, rail, air	EU15
Schürmann and Talaat (2000)	Potential	NUTS-0 - NUTS-3	Population, GDP, workforce in NUTS-3	Travel time	Statutory drivers' rest breaks	Border delays	Travel, freight	Road	EU15+12
Nordregio (2004)	Cumulated	LAU-2 of mountain areas	Municipality facilities	Travel time	-	-	Travel	Road	EU27+2+5

Table 5. Dimensions of European accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
L'Hostis in ESPON 1.2.1 (2005); ESPON FOCI (2010)	Cumulated	FUAs	FUAs	Travel time	Timetable re-strictions	-	Travel	Rail, air, inter-modal	EU27+2
Gløersen et al. (2006)	Cumulated	LAU-2	Airports, seaports, universities Hospitals	Travel time	-	-	Travel	Road Air	EU27+2
European Parliament (2007)	Potential	2.5 km raster cells NUTS-3 NUTS-2	Population, GDP airports, HSR sta-tions, universities, hospitals	Travel time	-	-	Travel	Road	EU27+2
Spiekermann and Schürmann (2007); Spiekermann (2009); ESPON 1.2.1 (2005)	Potential	NUTS-3	NUTS-3 population	Travel time	-	Border delays	Travel	Road, rail, air, multimodal	EU27+2
Dijkstra and Poelman (2008)	Travel cost	LAU-2	Cities > 50,000	Travel time	Slope	-	Travel	Road	EU27+2
Commission of the European Communities (2008); European Commission (2010).	Cumulated	Raster cells, NUTS-3	Daily flights at air-ports	Travel time	-	-	Travel	Road	EU27+2

- The destination activities are usually population or GDP for potential type accessibility indicators and a pre-defined set of agglomerations for the travel cost indicators. For daily accessibility indicators both population and public facilities, such as airports, high-speed train stations, universities or hospitals are used as destinations.
- Nearly all models use travel time as impedance term, only few models apply travel costs or a combinations of both as generalised cost.
- Only few models consider constraints on the impedance term. Models that consider freight transport use statutory drivers' rest breaks as constraints.
- Only few accessibility models consider barriers, such as waiting times at national borders. Only Keeble et al. use trade barriers, such as tolls.
- Nearly all accessibility models are based on passenger travel, only few models consider freight transport.
- Half of the models consider one mode only, in most cases road. The other models have networks for different modes, however, only two use intermodal travel times.

Equity and cohesion

Table 6 summarises the main results of the accessibility models with respect to spatial disparity and its changing patterns over time.

It can be seen that all European accessibility studies expose the existing core-periphery pattern of accessibility in Europe and all indicate that over time the gap in accessibility between core and peripheral regions has increased.

A distinction can be made between potential and cumulated opportunities. Whereas potential accessibility has improved in the former cohesion countries in southern Europe and increasingly also in the new member states in central and eastern Europe, cumulated opportunities, in particular where business trips are concerned, have increased mainly in central regions with good air connections.

Another important distinction can be made between whether changes in accessibility are measured in relative or in absolute terms. Whereas in relative terms (e.g. in percent) accessibility has improved more in the peripheral regions, in absolute terms accessibility in the core regions in western Europe has continued to grow more.

Assessment

An overall assessments of European accessibility models is difficult. The general tendency is that none of the models is really able to serve all purposes:

- Most models focus on person travel and ignore freight transport although freight transport might be more relevant for peripheral regions. Spiekermann and Neubauer (2002) in their review of European accessibility studies found only two out of ten studies dealing with freight accessibility. However, empirical work has shown that road accessibility by using car and trucks are highly correlated and that car accessibility can be used as a proxy for truck accessibility.
- Most models do only have an implicit relation to certain sectors of the economy, i.e. by concentrating on person travel the models are closely related to the service sector and neglect that transport has different relations with different sectors (see Vickerman, 1999).

Table 6. Equity and dynamic statements of European accessibility models

Authors	Spatial disparities	Changing pattern through time
Keeble et al. (1982; 1988)	Core-periphery pattern	Disparities in accessibility have increased in past periods
Cederlund et al. (1991) and Erlandsson and Törnqvist (1993)	Core-periphery pattern	Disparities in accessibility have increased in past periods
Lutter et al. (1993)	Existing, but scope depends on destination activities considered	Travel time benefits for peripheral regions, cumulated opportunities increase in central regions
Bruinsma and Rietveld (1993)	Core-periphery pattern	Increasing disparities in accessibility
Spiekermann and Wegener (1994, 1996)	Clear core-periphery pattern plus clear centre-hinterland disparities in all European countries	Increasing disparities induced by TEN
Chatelus and Ulied (1995)	Clear core-periphery pattern	Decreasing disparities
Gutierrez and Urbano (1995, 1996)	Clear core-periphery pattern	Decreasing disparities induced by TEN
Copus (1997, 1999)	Clear core-periphery pattern	Dynamics not considered
Wegener et al., (2001)	Different core-periphery patterns for different transport modes	Increasing or decreasing disparities is an outcome of the indicator
Schürmann and Talaat (2000)	Clear core-periphery pattern for road transport	Improvements mainly for EU candidate countries
Nordregio (2004)	Great disadvantage in accessibility of mountainous regions	Increasing disadvantage of mountainous regions
Gløersen et al. (2006)	Great differences in accessibility between core and periphery	Increasing peripherality of remote regions
L'Hostis in ESPON 1.2.1 (2005); ESPON FOCI (2010)	Urban connectivity differs clearly between MEGAs in Europe	n.a.
European Parliament (2007)	Great differences in accessibility between core and periphery	Increasing peripherality of remote regions
Spiekermann and Schürmann (2007), Spiekermann (2009); ESPON 1.2.1 (2005)	Great differences in accessibility between core and periphery	Cohesion improving in relative terms but declining in absolute terms
Dijkstra and Poelman (2008)	One third of rural regions are remote	n.a.
Commission of the European Communities (2008); European Commission (2010).	Access of airports differs widely	n.a.

- Following that, the reality of the business environment in peripheral rural areas is hardly represented in the European accessibility models.
- Some models, those working with travel cost indicators, support the case for public investment in infrastructure by demonstrating increased cohesion. Other models, mainly of the potential type, are much more cautious or even forecast increased regional disparities as outcome of transport infrastructure investments.

To conclude, despite the vast range of models, there is currently no model presented in the literature that would match all requirements for the different dimensions. Models that are superior in a certain dimension are behind in others. There is no model available that would be able to calculate accessibility for a spatially detailed representation of pan-Europe for person travel and freight transport for all transport modes including multi- and intermodal trips for different indicator types and destination activities and that has a database that allows assessments for different points in time, i.e. past, current and future accessibility patterns.

3.3 Regional accessibility studies

The number and diversity of accessibility studies at the regional level in Europe is much larger than those of Europe-wide studies. Consequently, only a part of these studies can be included in this review. The focus of the subsequent presentation of regional accessibility studies in Europe is on studies from the last decade. First, studies will be presented in which the study area covers more than one country, i.e. trans-national accessibility studies. The second subchapter presents studies which are either for whole countries, i.e. national accessibility studies, or are dealing with only parts of a country.

3.3.1 Trans-national accessibility studies

For several trans-national areas in Europe, accessibility studies evaluated the situation from a viewpoint that is below the Europe-wide, but above the national scale.

Nordic countries

The peripherality of Nordic regions was considered within the regions but also in the European context by Spiekermann and Aalbu (2004). On the one hand, the study assessed the disadvantages of Nordic locations in terms of real travel costs from Nordic regions to attend half-day business meetings and conferences in Brussels and in Helsinki. On the other hand, the intra-Nordic and European peripherality was assessed by multimodal potential accessibility indicators for all municipalities of the Nordic countries.

A study on northern peripheral, sparsely populated regions assessed the degree of peripherality of these regions in relation to the rest of Europe (Gløersen et al., 2006). Three extensions to the concept of accessibility were introduced: (i) The indicator of population potential within 50 km at 1x1 km raster level was used to delimitate peripheral, sparsely populated areas. (ii) A ratio of potential accessibility by air with potential accessibility by road was calculated in order to identify regions with a high dependency on air transport. (iii) Access to airports was measured based on population at 1 km raster level as the percentage of municipality population living within one hour travel time to the nearest airport.

Accessibility in peripheral Finland, Sweden and Norway was mapped as travel time zones to the nearest towns of more than 10,000 inhabitants in a study by Gløersen (2009: 46). The zone delimitations range from 45 minutes representing commuting distance to 90 minutes as an acceptable distance for access to basic services.

Baltic Sea Region

In a background study for the VASAB 2010 plus Spatial Development Action Programme, Hanell et al. (2000) calculated daily accessibility by road, rail and air for 10 km raster cells for the Baltic Sea Region for the year 1996 and a future situation with the trans-European Transport Network programme implemented. Accessibility indicators were presented in three-dimensional accessibility surfaces for the current level and for scenarios of assumed changes..

In an accessibility analysis of the Baltic Sea Region (Schürmann and Spiekermann, 2006) car, lorry and rail travel times from 2 km raster cells to the nearest rail stations, commercial airports, transport terminals and large cities were calculated. Travel times between major BSR cities by road, rail and air were used to map urban connectivity in the area. A set of multimodal potential accessibility indicators at NUTS-3 level completed the analysis. Even though the focus was on passenger travel, freight transport was tackled as well by lorry travel times to transport terminals.

Transport infrastructure, mobility and accessibility patterns were identified as main drivers of spatial development and spatial integration of the countries around the Baltic Sea (Schmitt et al., 2008; Dubois and Schürmann, 2009). Regional accessibility was analysed in a 3-step approach. First the service quality of rail, air and ferry services was assessed through the frequency of rail, air and ferry services. Second, different accessibility indicators such as population potential within 50 km radius and potential accessibility by road to GDP and to population, were generated for a system of raster cells of 2.5 x 2.5 km for the entire ESPON space. Third, travel time indicators such as lorry travel times to freight terminals, car travel times to universities and to commercial airports were generated for the same raster system illustrating regional accessibility patterns throughout Europe.

North-west Europe

Potential accessibility indicators for freight rail transport were used by Smith and Gibb (1993) to forecasts the likely impacts of the Channel Tunnel on NUTS-2 regions within seven EU member states. Rail travel times for the shortest path calculations were taken from timetables. Different scenario simulations were conducted with varying speed assumptions for the tunnel section.

Potential accessibility was used in the GEMACAII project to assess the relative position of agglomerations in north-west Europe (Spiekermann et al., 2001). Accessibility indicators were calculated at municipality level for fourteen urban regions and at NUTS-3 level for regions in-between. Population in NUTS-3 regions of Europe were used as destination activities. Transport modes considered were road, rail and air.

Central and South East Europe

The accessibility model of the BBR was used in the INTERREG IIIB CADSES project PlaNet Cense to analyse the accessibility patterns for Central and South East Europe (BBR, 2006). The potential accessibility indicator was calculated for a dense grid of reference points as origins. FUAs served as destinations. Car travel time and, if a combination of car and plane was faster, the combined travel time of the two modes were used as impedance.

The INTERREG IIIB CADSES project RePUS "*Strategy for Regional Polycentric Urban System in Central-Eastern Europe Economic Integrating Zone"* used different accessibility indicators to characterise the urban systems of Austria, the Czech Republic, Hungary, Italy, Poland, and Slovenia and to identify potentials for (cross-border) co-operations of municipalities and regions (Benini, 2007). Following the approach developed in the ESPON 1.1.1 project for the delimitation of so-called PUSH and PIA areas (Schürmann, 2004), 60-minutes car travel time isochrones from regional capitals were overlaid with municipality boundaries to delimitate service areas and population potentials within these areas. The number of overlapping service areas in each municipality was used to assess the freedom of choice for the inhabitants to travel to different regional centres to reach public and private services.

Alpine Space

BAK Basel Economics (2004) calculated potential accessibility indicators for 147 regions of the Alpine Space and its nearer surroundings. Travel times for road and public transport are based on very detailed network representations. Destinations are European NUTS-2 regions and for intercontinental accessibility also airports in other continents weighted by GDP. Results are presented in map form and in histograms showing the distribution of accessibility over aggregate classes.

Accessibility indicators were also used to contribute to a new typology of the Alpine Space in Atlas format (Tappeiner, 2008a; 2008b). Road distance and travel time by car were calculated for all municipalities of the Alps. Destinations used are the nearest motorway or major road, the nearest commercial airport, regional capitals, the nearest municipality with more than 5,000 inhabitants and the nearest hospital.

Iberian Peninsula

Figueira and Viegas (1999) measured freight accessibility of Portuguese coastal regions in the Iberian context as demographic accessibility and economic accessibility. Demographic accessibility was estimated by considering population of European regions as relevant destination activity using travel times as a threshold criteria for acceptability. Economic accessibility was based on weights summarising the complementarity of the economies of the destination regions with respect to the economy of the origin regions.

Gutiérrez Gallego et al. (2010) analysed the socioeconomic realities of border regions between Portugal and Spain with accessibility measures. The indicator used was road travel time to the nearest of the 15 main economic centres in Portugal and Spain.

Comparison

The trans-national accessibility models reviewed above yield a wide range of approaches to the various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 7):

- About half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunity indicators. A few models are able to calculate more than one type of indicator.
- The origins for which accessibility indicators are calculated differ very much. The range is from NUTS-3 regions through municipalities down to a detailed representation of space in form of small raster cells.
- The destination activities are usually population for accessibility indicators of the potential type and a pre-defined set of agglomerations, cities or certain facilities, such as airports or hospitals, for the travel cost indicators. For cumulated opportunity indicators, population, cities or public facilities are used as destinations.
- Nearly all models use travel time as impedance term, only one model applies travel costs. Some models use airline or road distance.
- Only few models consider constraints on the impedance term in form of timetable restrictions for public transport.
- None of the trans-national accessibility models considers political, cultural or language barriers in the impedance term.

Table 7. Dimensions of trans-national accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Hanell et al (2000)	Cumulated	10 km raster cells in BSR	10 km raster cells in Europe	Travel time	-	-	Travel	Road, rail, air	Baltic Sea Region
Spiekermann and Aalbu (2004)	Travel cost, potential	NUTS 3, LAU-2	Brussels, Helsinki LAU-2	Travel time, travel cost	Timetable restrictions	-	Travel	Road, rail, air, multimodal	Nordic countries
Gløersen et al. (2006).	Cumulated, potential,	NUTS 3, grid cells	NUTS 3, Airports,	Travel time, distance	-	-	Travel	Road, Airports	EU27+NO+CH SE, FI periphery
Gløersen (2009)	Travel cost	Raster cells	Cities > 10.000 inhabitants	Travel time	-	-	Travel	Road	Periphery of NO, SE, FI
Schürmann and Spiekermann (2006)	Travel cost, potential	Raster cells, NUTS-3	Rail stations, airports, transport terminals, cities	Travel time	-	-	Travel Freight	Road, rail, air	Baltic Sea Region
Schmitt et al. (2008; Dubois and Schürmann, 2009).	Travel cost, potential	2.5 x 2.5 km Raster cells	Raster cells; freight villages; higher education facilities, airports	Airline distance Travel time	-	-	Travel, Freight	Road	Baltic Sea Region, EU27
Smith and Gibb (1993)	Potential	NUTS-2	NUTS-2	Travel time	-	-	Freight	Rail	UK, IE, FR, BE, NL, LU, DE
Spiekermann et al. (2001)	Potential	LAU-2 in aggl., NUTS-3	LAU-2/NUTS-3 population	Travel time	-	-	Travel	Road, rail, air	North-west Europe
BAK Basel Economics (2004)	Potential	141 regions	NUTS-2	Travel time	Timetable restrictions	-	Travel	Road, public transport	Alpine Space extended
Tappeiner (2008a; 2008b)	Travel cost	LAU-2	Motorways/major roads, airports, regional capitals, LAU-2 > 5,000, hospitals	Road distance Travel time	-	-	Travel	Road	Alpine Space
BBR (2006)	Potential	Grid points	FUAs	Travel time	-	-	Travel	Road, intermodal	Central/South-East Europe
Benini (2007)	Travel costs	LAU-2	Regional capital cities	Travel time	-	-	Travel	Road	Central/South-East Europe
Figueira and Viegas (1999)	Cumulated	Cities	Cities	Travel time	-	-	Freight	Road	Portugal and Spain
Gutiérrez Gallego et al. (2010)	Travel cost	Raster cells	15 economic centres	Travel time	-	-	Travel	Road	Portugal and Spain

- Nearly all accessibility models are based on passenger travel, only few models consider freight transport.
- Half of the models consider one mode only, in most cases road. The other models have networks for different modes, however, only one model uses intermodal travel times.

Spatial pattern

Table 8 summarises the main results of the trans-national accessibility models with respect to the spatial pattern of accessibility observed.

Nearly all trans-national accessibility studies show large differences in accessibility for different parts of their study area. Regardless the type of indicator, spatial disparities are very much pronounced in those studies.

However, it is also stated that the question of disparities in accessibility is a question of the destinations considered. That means that some trans-national areas show large disparities if Europe-wide accessibility is considered, but are much less polarised when destinations of regional interest are considered. In addition, when evaluating the access to public facilities, such as hospitals or regional centres, some of the studies conclude that the travel times are reasonable for most of the population and better than expected.

Assessment

An overall assessments of trans-national accessibility models is difficult. The general tendency is similar to that of the European accessibility models (see Chapter 3.2): that none of the models is really able to serve all purposes.

In addition, it is difficult to compare the results of the different trans-national accessibility models in more detail. The different ways of incorporating the dimensions of accessibility in the models, in particular the different destination activities considered, the different ways the impedance terms are calculated and the very large variety of spatial detail with respect to origins, destinations and network representation, do not allow to draw more detailed conclusions concerning spatial patterns in different types of regions than those stated above.

3.3.2 National and regional accessibility studies

The national and regional accessibility studies are presented on a country by country base. However, summary tables are differentiated by the spatial coverage of the studies, i.e. whether they cover a whole country or only parts of it.

Iceland

In an accessibility study for the Greater Reykjavik area 53 sub-districts and 141 plan-districts were used as trip origins, but destinations comprised only a small number of locations of specific interest: Reykjavik city centre, the University of Iceland, the national university hospital and a large shopping mall (Bjarnason, 2005). Three variants of travel-time based accessibility indicators for cars, cycling and bus were introduced. The so-called accessibility time 50% gives the duration it takes to reach half of all working places. Second, a travel-ratio gives the ratio of travel times of bikes v. cars and buses v. cars. Finally, another set of ratios gives the quotient between the shortest distances by car, bicycles and bus to airline distance.

Table 8. Accessibility pattern stated in trans-national accessibility studies

Authors	Spatial scope	Accessibility pattern
Hanell et al. (2000)	Baltic Sea Region	Hugh disparities in accessibility for all modes. Highest value for German and Polish regions as well as for St. Petersburg and for cities with international airports. The largest increases are along TEN-T corridors, the largest in Germany and Poland.
Spiekermann and Aalbu (2004)	Nordic countries	Clearly above European average travel costs of Nordic regions to Brussels. High disparities in the intra-Nordic and European degrees of accessibility with extreme low values in the far north.
Gløersen et al. (2006).	Northern periphery of SE, FI	Nordic peripherality is assessed to reveal the difficulties to access goods and services produced in European core areas.
Gløersen (2009)	Northern periphery of NO, SE, FI	Population growth is observed in areas with good accessibility, i.e. within commuting distance to cities, but not beyond.
Schürmann and Spiekermann (2006)	Baltic Sea Region	Travel time to public facilities is very different in different parts. Areas of short travel time extend along the major infrastructure arteries. Areas in the northern and eastern parts of the BSR have overall weak accessibility. Denmark, Germany and the southern parts of Poland have much higher levels of potential accessibility than the remaining parts of the Baltic Sea region.
Schmitt et al. (2008), Dubois and Schürmann (2009).	Baltic Sea Region	Travel time to public facilities is very different in different parts. Areas of short travel time extend along the major infrastructure arteries. Areas in northern and eastern parts of the BSR lack many of the analysed facilities, their overall accessibility is rather weak. The spatial reference of standardising accessibility indicators, e.g. BSR v. EU, results in different assessments of central and peripheral areas.
Smith and Gibb (1993)	UK, IE, FR, BE, NL, LU, DE	The accessibility benefits of the Channel Tunnel would be restricted to the south-east of England without any further improvements in the UK rail networks.
Spiekermann et al. (2001)	North-west Europe	The 14 agglomerations considered vary considerably in terms of road, rail and air potential accessibility to European destinations. However, also within several agglomerations, there are large differences, in particular for rail and air accessibility.
BAK Basel Economics (2004)	Alpine Space extended	Regions of southern Germany have highest accessibility values, in particular for road and rail, to European destinations followed by Zürich and Milan. There are huge disparities in accessibility, Standardised index values (EU27=100) range between 18 and 140.
Tappeiner (2008a; 2008b)	Alpine Space	Due to the topography of the Alps, accessibility in terms of distance and travel time to selected destinations is spatially very fragmented with areas of long distances and travel times. But 90 % of all municipalities are located within less than 25 min. or 20 km apart from the nearest hospital.
BBR (2006)	Central and South-East Europe	From a European viewpoint the area has a clear core-periphery pattern, from a regional viewpoint, high regional accessibility spots are spread over the area without any clear core or peripheral area.
Benini (2007)	Central and South-East Europe	Depending on the urban system and the topography, accessibility to regional cities is quite different among the CADSES countries. While 60-minute isochrones for Poland, Czech Republic and Italy overlap each other to a high degree, the situation in Slovakia, Hungary and Austria is quite different with large areas suffering from a lack of access to any regional city.
Figueira and Viegas (1999)	Portugal and Spain	Peripheral regions have lower levels of accessibility, because they are farther from their potential partners. Significant gains in accessibility are obtained when the limits of acceptable travel time are slightly extended.
Gutiérrez Gallego et al. (2010	Portugal and Spain	Travel times from the Portuguese-Spanish border regions to the nearest economic centres are highest in the Iberian peninsula.

Norway

Two studies related to accessibility in the Oslo region were carried out with survey-based data. Naess et al. (1995) studied the use of car and public transport and found that residents in local communities with a high population density and a short distance to downtown Oslo travel considerably shorter distances and use significantly less energy per capita than those living in more remote areas. Naess et al. (2001) considered the effect of increasing accessibility on modal choice in an empirical study about commuting patterns in two transport corridors in Oslo.

A recent study on the social and economic situation of the mountain areas in southern Norway included an accessibility analysis with population potential and access to services from a local and regional perspective (Arnesen et al., 2010). Accessibility indicators were calculated for a 1 km raster and aggregated to municipality level. A population potential within 50 km airline distance was calculated for 2000 and 2010, absolute and relative changes were mapped. Car travel times indicators to airports, railway stations, hospitals and universities.

Sweden

An early example of accessibility-related studies in Sweden applying the travel times database of the National Road Administration to compute accessibility potentials at the municipal level was carried out by Forslund and Johansson (1995). Alternative national road investment projects and programmes were evaluated by comparing project costs with benefits in terms of time savings and reduced accident rates. Three types of accessibility were analysed in association with the capacity of international ports, labour supply and population size in municipalities.

Johansson et al. (2002) investigated the relationship of municipal time distances and local and regional labor markets in a case study of southern Sweden. Accessibility was measured in terms of number of jobs, labour supply and supply of service functions. The data on time distances for accessibility potentials were obtained from the Swedish National Road Administration database.

Andersson and Ejermo (2005) applied potential accessibility indicators for explaining the competitiveness of regions and enterprises with the case of 130 Swedish corporations during 1993–1994. The number of patents was related to accessibility to internal and external knowledge sources measured as travel time-based potentials.

The Swedish National Rural Development Agency (NRDA) regularly monitors access of rural population to important public and private services, such as administration, education, health care, or airports. For this, the NRDA calculated travel time by road to the nearest airport (Dahlgren, 2005). Spatial representation of the origins is very detailed by using 250 m grid cells including information on the number of inhabitants per cell. Results were presented as isochrone maps showing which populated grid cells of Sweden have what travel time to the nearest airport.

Johansson and Karlsson (2007) analysed the intra- and inter-regional export diversity with regard to the accessibility to research and development. The focus was on spatial knowledge spillovers, external economies of scale in research and development activities and the innovative capacity of regions. Accessibility is defined as potentials by applying an origin-destination travel time matrix for road and time sensitivity parameters in local, intra-regional and inter-regional interactions.

Andersson and Karlsson (2007) analysed the role of knowledge in regional economic growth by focusing on knowledge accessibility of Swedish municipalities. Accessibility was measured as travel time-based potentials.

Finland

A pioneering Finnish accessibility study by Tykkyläinen (1981) applied three accessibility indicators: relative, mean and integral accessibility for the entire country. Calculations were done at the municipal centre level.

Meriläinen (1996) considered rural accessibility situations in Finland using the example of six villages in the commuting area of Hämeenlinna. Accessibility of villages was calculated as mean accessibility to all municipalities and as a travel time to job concentrations and municipal centres. The calculations were based on estimated average annual speeds. Alternative road improvement plans were assessed with these indicators.

Accessibility in the context of environmental efficiency was analysed by Määttä-Juntunen et al. (2010) for the Oulu region in Finland. The study focused on the possibilities of reducing transport based CO_2 emissions of trips to shopping centers. The analyses in the study was implemented at a 1 km grid cell level.

Kotavaara et al. (2010) measured Finnish potential accessibility by road and accessibility to railway stations at municipal and built-up area levels for the period 1970–2007. In the study it was found that population change was statistically related to accessibility.

Denmark

Freight accessibility in Denmark was studied by Möller and Nielsen (2007) for the case of the cost efficiency of the domestic wood chip supply chain. As transport is a major contributor to the delivered costs of wood chips, a continuous raster-based cost surface was applied for mapping the national wood chip resources in relation to selected bioenergy plants.

Baltic States

There are relatively few accessibility studies in the Baltic States. Most of the studies focused on urban public transport including relationships between accessibility and intelligent transport systems in Vilnius (Jakubauskas 2008) or between accessibility and residential land value in Riga (Pavlyuk 2008). Jakimavicius and Macerinskiene (2006) estimated potential accessibility in residential areas based on travel time from the centers of Lithuanian administrative regions.

Russia

Bougromenko (1997) analysed living standards taking into account indices like road network level and integral transportation accessibility, i.e. average travel time required to reach any point of an area from any other point. This was done for 87 regions of Russia. The accessibility by metro and bus services for elderly and disabled people in St Petersburg was analysed by Sergeyeva (1998).

Poland

Before 2000 the accessibility considerations in Poland were mainly theoretical. Emphasis was put mainly on topological issues (Domański 1979, Mackiewicz and Ratajczak 1996).

However, in the last decade there were some empirical studies concerning accessibility at the local level (Guzik and Kołoś, 2003; Taylor 2003; Niedzielski and Śleszyński, 2008, Gadziński and Beim, 2010), at the regional level (Guzik, 2003) and at the national level (Komornicki and Śleszyński, 2009; Komornicki et al., 2010). The studies differed with respect to travel purpose and destination attractiveness, e.g. access to shopping and health care facilities by rural dwellers

(Taylor, 2003), easiness to reach holiday resorts by tourists (Guzik and Kołoś, 2003), access to post-elementary educational services by pupils (Guzik, 2003), accessibility to jobs and workers (Niedzielski and Śleszyński, 2008) and accessibility to possible locations of regional airports (Komornicki and Śleszyński, 2009). At the local level Niedzielski and Śleszyński (2008) used gravity-model-based indicators differentiated by commuting mode.

At the national level potential accessibility indicators were employed by the study of Komornicki et al. (2010). Impedance was generally computed as travel time in all studies, however, Taylor (2003), Gadziński and Beim (2010) and Guzik and Kołoś (2003) used public transport timetables while Komornicki et al. (2010) adopted a speed model for road network and design speeds for railway network.

UK

The impact of the construction of the M25 London orbital motorway on economic activities for 179 zones in England, Wales and Scotland were studies by Linneker and Spence (1992) by applying a potential accessibility measure with total employment as mass variable. Travel times between all pairs of regions were calculated separately for private cars and heavy goods vehicles. A later study by Frost and Spence (1995) applied the same model in a spatially more disaggregated way to a total of 322 travel to work areas (TTWA) for the whole of Great Britain.

In the beginning of the 1990s a number of studies analysed the accessibility situation in the Highlands and Islands of Scotland (Copus, 1992; 1994). Even though potential accessibility indicators for roads were calculated, the resulting index was called 'economic potential index'. First, calculation was based on local districts; in a follow-up study, the Highlands and Islands were subdivided into 19 areas, which were adopted from the former HIDB statistical areas.

A number of accessibility studies in the UK in the late 1990s and the beginning of the 21st century were concerned with the assessment of access to rural health care centres (Martin et al., 2001 for the south west of England; Lovett et al., 2001 for East Anglia; White, 2001 for Gwynedd, Wales), in particular from the point of view of elderly people. Selected destinations in these studies included general practice surgeries and minor hospitals, and focus was given to public transport (e.g. Lovett et al., 2000), but car or walking was also assessed (Higgs and White, 2000). In most cases simple travel distance or travel time indicators were selected as the measure of accessibility, sometimes even straight line distance measures (National Assembly for Wales, 2000) were used. Alternative accessibility measures include indicators on the number of population within a certain distance to bus routes, or raster based approaches of calculating least cost paths from each resident cell to each health care facility cell. Some sophisticated approaches were also developed incorporating opening hours of the facilities, specialist clinics, or by analyzing impacts for different social groups. Kelly et al. (2001) introduced travel time indicators to health care and other public services to improve the *Standard Spending Assessment* (SSA) formula, which is the base on which funds for services are being allocated in the UK which did so far not account for the travel time or travel distance to reach such facilities from residences.

In local, urban and regional transport planning in the UK two accessibility measures have received increasing attention during the last decade (Cooper et al., 2009):

- The *Public Transport Accessibility Level* (PTAL) score measures the access to public transport networks from any point in space. The PTAL score combines walk time from home based on an agreed speed of 4.8 km/h to the public transport networks with waiting times at bus stops of 8 minutes and at rail/underground services of 12 minutes. As origins are usually represented by small-scale raster cells results are illustrated as contour maps that differentiate areas with poor access to public transport from those with good and excellent access. However, this score measures only the access to public transport, it does not take into account the speed or frequency of the services as such, the quality of the services, the ease of interchange and the destinations to reach (TfL, 2010; Nettleton et al, n.a.).

- The *Access to Opportunities and Services* (ATOS) indicator measures the access to essential services and employment by public transport and walking. Essential services include employment (defined as work places with more than 500 employees), education, health services, quality food shopping facilities and open space.

These indicators were first developed by Transport for London (TfL) and were tested with samples of local authorities in London as part of the development of Local Transport Plans. The PTAL scores were calculated based upon a grid of points at 100 m intervals (approx. 150,000 points), while ATOS was calculated based upon approx. 24,000 Census Output Areas for Greater London. In addition, a composite score was introduced that sums up all average travel times for each origin and ranks the derived overall travel time into five accessibility classes.

The UK Department for Transport (DfT) declared the PTAL and ATOS scores as core national accessibility indicators for local authorities (DfT, 2009a; 2009b). Employment, primary schools, secondary schools, colleges, general practice surgeries, hospitals and high-quality food stores were defined as important public service facilities to be included in such studies. The indicators should be calculated on the basis of road networks, public transport networks and walking and cycling networks. The analysis framework developed by the DfT assisting the local and regional authorities in accessibility analyses provided thresholds for maximum accepted travel times and distances as well as default link speeds by road class for cars, cycling and walking to be used in the models. Recommendations on calculation methods and parameters have also been developed. Emphasis was given on calculating so-called ‘catchment indicators’ defined as the absolute population and percentage of population within each travel time threshold to services, which in fact represent a further processing of the isochrones approach. The catchment indicators can also be further differentiated by relevant age groups or social groups depending on the type of destination.

The ATOS travel time approach was also used in a study calculating the Scottish public transport accessibility index as part of the *Scottish Index of Multiple Deprivation* (SIMD) (DHC, 2006). A slightly different set of destinations was chosen honouring specific Scottish conditions, i.e. covering primary and secondary schools, petrol stations, general practice surgeries, post offices and retail centres. Origins were represented again by the census output areas (COAs), but results were also aggregated to higher levels. As a specific constraint the different opening hours were taken into account when calculating public transport access.

In many rural parts of the UK and also often in small and medium-sized towns accessibility has often been discussed from the point of view of social exclusion of disadvantaged, handicapped and elderly people, and the role of public transport in alleviating these obstacles (Commission for Rural Communities, 2009). The classical travel time/isochrones approach was amended by new elements. For instance, access to certain types of specialised hospitals was not only computed by road and public transport, but in the case of the Worcestershire case study differentiations were made between times of the day (peak hours, off-peak hours) and types of public transport (conventional bus services and additional bus services through specialised operators).

Ireland

Murphy and Killen (2007) applied accessibility indicators to find the optimal location of a new pediatric hospital in Ireland. Accessibility by road and by public transport was considered as the key issue for the location decision. Travel times by car and public transport to different potential hospital locations were calculated from each municipality. Interestingly, travel time calculations were divided into peak and off-peak scenarios. The resulting isochrones were further processed to assess the percentages of total population, of children and of females aged 15-35 years located near the potential hospital sites.

Netherlands

The Netherlands were the subject of a vast number of accessibility studies addressing different topics and indicator concepts. In many studies specific attention was given to job accessibility. For example, Geurs and Ritsema van Eck (2001) used different accessibility indicators including cumulative opportunities and potential accessibility to assess the current situation and future situations due to land-use and transport changes in the country. Modes considered were road and public transport, origins working population of municipalities and destination activities jobs in municipalities.

Muhammad et al. (2008) introduced the issue of telecommuting into an accessibility model. Potential accessibility was calculated for about 1,300 transport zones of the Netherlands in which different frequencies of telecommuting per month were represented by different distance decay functions. Modes considered were road and public transport in combination with walking and cycling.

Germany

The accessibility model of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) has developed into a comprehensive tool capable of adressing different issues at different spatial scales and resolutions with different sets of accessibility indicators (e.g. Spangenberg and Pütz, 2002; BBR, 2005; BBSR, 2011). Detailed representations of road, rail and air networks as well as different sets of destination activities allow the calculation of differently defined accessibility indicators of all generic types. However, in political documents, very often travel time to selected destinations was used. Accessibility indicators were also used to define new typologies of regions in Germany.

The accessibility of services of general interest in the state of Bavaria was the topic of a study by Schürmann and Spiekermann (2010). Services of general interest considered included those for basic needs (primary and lower secondary schools, physicians, dentists, pharmacies, banks, post and police, and those for higher needs (higher secondary schools, tax authorities, employment centres, hospitals). The accessibility of these facilities by car and by public transport for different population groups was evaluated by calculating travel times from the places of residence of the population in 100 m raster cells to the nearest facility of each type. The study was based on a full coverage of the Bavarian road network and a complete timetable for public transport.

Schürmann and Spiekermann (2011) developed applications of small-scale accessibility models for four urban agglomerations in Germany. The objective was to demonstrate the intra-regional change of the accessibility patterns over a historical period of two decades and to relate these changes to the development of land values, settlement development, population and jobs and commuting patterns. Accessibility indicators calculated were travel time to the core of the agglomeration and potential accessibility to population. The indicators were calculated for road and public transport for raster cells of 100 m size.

Switzerland

The long-term historical development of accessibility by road and public transport in Switzerland was compared with the development of the population (e.g. Fröhlich et al., 2006; Axhausen et al., 2010). Potential accessibility indicators were calculated for 150 districts for the period 1850-2000 and for the 2,900 Swiss municipalities for the period since 1950 using population as destination activity. Accessibility pattern were presented among others also in three-dimensional surfaces.

BAK Basel Economics (2007) calculated potential accessibility indicators for Swiss municipalities. Travel times for road and public transport were based on very detailed network representations. Results were presented in map form and in histograms showing the aggregate distribution of accessibility over accessibility classes. For the non-alpine northern parts of Switzerland additional indicators such as travel times by road and rail to Basel and Zürich and to the main airports as well as accessible GDP within different amounts of travel time were calculated.

Austria

In a study for the Austrian National Transport Plan, Bökemann and Kramar (1999) assessed the impacts of different transport infrastructure options on the competitive position of Austrian regions by using accessibility indicators. For all municipalities potential accessibility by road and rail were calculated. In addition to the traditional potential accessibility indicator, an alternative indicator for rail was developed. Rail stations were used as destinations. Their accessibility was measured as the number of trains serving the station each weighted by its type (intercity, regional, local etc.). Road access time to the stations weighted by a negative exponential function was used as impedance. Statistical measures such as rank-size rule and GINI coefficients with Lorenz curves were used to analyse the spatial disparities in accessibility.

The accessibility situation in Austria was assessed in a study by ÖROK (2007) by using travel time to the nearest regional and the nearest supra-regional centre as indicator. Calculation were done for a 250 m raster cell system for Austria for road and public transport. Road travel time took the traffic conditions on the network into account. Public transport travel times were based on timetables and include waiting and transfer times.

Czechia

The issue of changes in accessibility and its cartographic visualisation is a traditional research topic of Czech transport geographers. A map of Prague's time-based accessibility from the territory of Bohemia by rail was constructed already 1904 by Nový using an isochrone method. Blahník (2009) analysed historic-geographical accessibility of Prague by railway in 1918-2020. He reconstructed the railway network for selected years in a GIS and demonstrated the reduction of travel time from each place of Czechia during the century by isochrone maps. Analogously, the historic development of accessibility of Prague by road transport in 1918-2020 was modelled. Petr (2008) modelled time accessibility maps for petrol stations generally and for each company separately. Another time accessibility example was presented for Southern Bohemia by Kraft (2008). He compared the speed of public transport connection of municipalities to the regional capital České Budějovice.

Another approach is to analyse spatial accessibility, not only time accessibility, and include differences in transport costs (Hanes, 2010). The main sources were the Czech railways timetable 2009. Several maps presenting various types of accessibility were done.

The aim of Návratil (2010) was to compare methods of accessibility analysis in Czech sociogeographic regions. The result of the analysis covered only the region itself and not the neighbouring regions. A detailed description of the functions and the approaches in the models and scripts is a core of the study.

Travel time based accessibility to regional capitals from their administrative regions was modelled by Hudeček and Marada for the Atlas of Landscape of the Czech Republic (Hrnčiarová et al. 2009). Rajman (2009) analysed the accessibility of Prague by road by using real travel times for different points in time during the day and the week. Results for the Czech territory were demonstrated for periods with very low traffic volume and for peak hours.

The social situation in transport is evident for example in the level of car ownership in rural areas (Marada and Hudecek 2006). Květoň (2006) analysed the relationship between demographic structure and accessibility using the Jesenik peripheral region as case study. Boruta and Ivan (2010) analysed also for the Jesenik region representative travel times between two municipalities, of which the fastest of all connections with arrival at 8 a.m. was used. Subsequently, through aggregation into three time intervals the municipalities were allocated to below-average, average and above-average time groups.

Slovakia

Horňák (2005) evaluated 68 regional districts of Slovakia with respect to the access to motorways. Two indicators were used: road distance to the nearest motorway exit of any motorway section longer than 20 km and road distance to the nearest motorway exit of the main arterial Slovak motorway in the western part of the country. Similarly, Michniak (2006) analysed the accessibility of municipalities to the nearest passenger railway stations.

Pšenka and Horňák (2009) analysed the accessibility of Slovak regional centres by trains and buses. Michniak (2002) evaluated the allocation of Slovak municipalities to regional centres by distance-based indicators and compared the results with the current administrative boundaries.

Hungary

Tóth (2006) calculated daily and potential accessibility by road for all Hungarian municipalities. To assess the relation between accessibility and economic development, accessibility indicators were related to income levels.

At a regional scale Györffy (2006) analysed the density and quality of the road system in northern Hungary and calculated public transport travel times from municipalities to regional centres.

Greece

Katsios et. al. (2006) developed a raster-based accessibility model for Greece by which also the transport networks were transformed into a raster representation. Travel time by road, rail, maritime shipping and air to reach all ports, airports and centres of Funcitonal Urban Areas (FUAs) were calculated. Results were presented as raster maps and as aggregate indicators for travel times.

France

The accessibility of the French urban system was the topic of several studies of the last decades. Chapelon, L'Hostis and Mathis (1994a; 1994b) studied the impact of several transport projects with accessibility analyses, among them the impact on regional accessibilities of the TGV in France and the A10 motorway from Paris to Bordeaux. Chapelon (1998; 2000; 2003) further analysed the possibilities of accessibility indicators in the late 1990s and performed evaluations of the French motorway network, of accessibility of riparian cities of the Atlantic and rail accessibility of French cities.

Cattan and Grasland (1997/1998, Grasland, 2000) analysed the inequalities in accessibility of towns by road distances compared with euclidean distances and by road, rail and multimodal travel time based indicators. Travel times between cities were transformed into average airline speeds between cities of different size. Hilal (2003) modelled the potential accessibility to jobs in the French municipalities and concluded that periurban regions had substantially lower potential accessibility to jobs than both urban or rural areas. Chapelon and Leclerc (2007) assessed accessibility by rail of French cities and analysed disparities. The study continued with analysing the rail accessibility for early 2010s and 2020 when construction plans for further high-speed rail and projects to improve the existing network will be implemented. Finally, the persistent inequalities in 2020 were highlighted and the recommendations to address them proposed. Angrand, Robin, Sarrazin and Vincent (Angrand et. al., 2007) studied indicators to measure the volume of jobs accessible from municipalities considering travel distances equal to the average distance travelled by at least 75% of the economically active persons in the urban area where they belonged, and applied these indicators 10 different cases in France.

In 2008, SÉTRA (Service d'études techniques des routes et autoroutes) published a dossier on *Territorial accessibility and services: notions and representation*, a technical paper on accessibility analysis for decision taking processes in the field of transport infrastructure including ten case studies portraying various dimensions accessibility.

The work of DRE Aquitaine (2008) on its region is an example for a regional accessibility study in France. The study focused on travel and analysed mainly in cartographic ways the regional coverage by different modes of transport, road railways and air and which zones of Aquitaine are inadequately served. For this, road travel times to motorway exits, main railway stations and airports were calculated for raster cells for today and a future situation. Raux, Mercier and Ovtracht (2007) discussed gravity accessibility measures and applied them to the agglomeration of Strasbourg to determine accessibility to jobs.

The inter- and intraregional accessibility situation of a regional capital in France was analysed in several studies taking Lille in Nord Pas de Calais as example. L'Hostis et al. (2004) used specially designed accessibility indicators of the quality of services supplied to different segments of the population. Real travel time information including transfer time were compiled for the analysis. The methodology was applied to Nord Pas de Calais and used to assess the accessibility of its regional capital, Lille. Bozzani and L'Hostis (2006) measured the accessibility benefits that accrue from the combination of high-speed rail and air transport, as opposed to the mere juxtaposition of the two fast modes. The study used real timetable data for air travel and TGV and combined the two modes to intermodal trip chains to determine the cities in Europe that are accessible from Lille during a day. The question answered was to what extent a TGV ride to CDG Airport in Paris increases the number of cities accessible.

Mathis (2003) provided a compilation of articles related to graph theory in which theoretically oriented paper presented different approaches in analysing space and networks. In this volume, Decoupigny (2003) analysed the effects of different alternatives for the impedance term to be used on route choice and resulting emissions from transport using French examples.

Spain

At the national level, the assessment of accessibility changes of the transport infrastructure investments of 5,000 km additional high-capacity roads and 6,000 km high-performance rail foreseen in the Spanish transport plan 2005-2020 got specific attention (López Suárez et al., 2006; 2008; 2009). A network efficiency indicator computed as the destination-weighted ratio of real travel time and an ideal, straight-line high-speed travel time were calculated for all municipalities to compare the different options. In addition, a destination-weighted generalised cost indicator was computed describing the average effort to go from one place to all others in Spain to consider accessibility benefits in each region due to investments undertaken in all other regions. Results were further processed in a multicriteria analysis; assessment criteria, based on the 'sustainable transport' paradigm, are structured into efficiency, cohesion and environmental criteria (López Suárez, 2007).

Ajenjo et al. (2004) and Alberich González (2004) evaluated the evolution of accessibility in Catalonia from 1985 to 2000 at municipality level and related it to changes in the demographic characteristics of these municipalities during the same period. A set of accessibility indicators was used, namely absolute travel time and distance between municipalities, a ratio of travel time or distance to ideal travel time or distance on a straight line, and access time to motorways. It was concluded that classic travel time indicators are not suitable to study accessibility as an intermediate variable of different aspects related to population in a territory with highly concentrated population in one single area such as Catalonia. Cumulated opportunity indicators considering only accessibility to places within a maximal distance range are much more suitable. It was also demonstrated that indicators incorporating ratios between actual and ideal travel time seem not to properly reflect reality as they provide highest accessibility levels to most peripheral areas.

García Palomares (2000) analysed the accessibility effects of a new orbital motorway in the metropolitan area of Madrid. Indicators used were mean travel time to employment weighted by the volume of activities reachable at destination, and accessibility potential to jobs.

Nogales Galán et al. (2002) studied accessibility in the Extremadura region by using average absolute and relative travel time indicators. A variable of wealth was incorporated in the analysis by using the level of rents available at the destination municipality as weights.

Hernández (2002) analysed the current accessibility conditions of the seven Canary Islands by means of sea transport for both passengers and vehicles. The accessibility indicator introduced to the specific geographic situation is of the cumulative opportunity type. Based on the travel time between the island capital cities by available ferry services, the time available at the destination island was measured by assuming a return trip in the evening. Using the constraints of service hours, the available time to be spent in public administration or commercial activities at the capital cities of La Gomera and Tenerifa islands was estimated.

Portugal

Figueira de Sousa, Fernandes and Galiau (2009) analysed the changes in accessibility in Portugal resulting from the large road infrastructure programme engaged since the accession of the country to the EU. They analysed travel time accessibility to major cities (Lisbon and Porto), to border points, to ports and to airports for 1985, 1988, 1992 and 2000.

Silva and Pinho (2010) analysed local accessibility conditions and the resulting potential for sustainable mobility patterns for the Greater Oporto area in northern Portugal by applying the so-called Structural Accessibility Layer (SAL) – a design support tool for integrated land use and transport policies based on a concept of structural accessibility. The accessibility indicator used is of the cumulative opportunity type. For three different modes, non-motorised transport, public transport and road, the percentage of locations of 18 different activities (e.g. employment, schools, leisure, shopping, health care) that can be reached within a mode-specific maximum time was calculated for census tracks. Evaluation of accessibility was done by classifying the results for each mode into three classes resulting in an evaluation cube with 27 sub-cubes. The geographical representations of comparative accessibility levels were found to provide a new insight in local mobility conditions and constraints for sustainability.

Viegas et al. analysed in the framework of demand studies for the a new airport in Lisbon the potential of attracting traffic of this facility using potential accessibility indicators considering the competition of already existing airports. In this analysis, three different scenarios were drawn, considering only the road network in the first one, the high-speed rail network in the second and a combined analysis in the third one. Travel time was the impedance variable.

Comparison

The national and regional accessibility models reviewed above yield a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 9 for the national and Table 10 for the regional accessibility models):

- Only one third of the national models and only every sixth of the regional model use potential type indicators, very few are calculating cumulative opportunities. The majority of the models use travel cost indicators mainly in the form of travel time to pre-selected destinations. A few models calculate more than one type of indicator.
- The origins for which accessibility indicators are calculated are in most accessibility models the centroids of municipalities. A few studies, mainly at the national scale, are less detailed in space. However, the main tendency of the last decade was a movement towards spatially more disaggregate accessibility models. This is done by using a raster representation of space in which the cell size ranges from a few kilometres down to 100 m only in some regional applications.
- The destination activities are much more diverse than in the European or trans-national accessibility models. The potential type models work usually with population as destination activitiy, however, also accessibility to jobs is the subject of several studies. Many studies, in particular those working with travel cost type indicators, use urban and regional centres, network nodes and services of general interest as destination activity.
- With a few exceptions, all models use travel time as impedance term, the remaining models work with travel distance. None of the models at these scales use travel costs.
- Some of the models consider constraints on the impedance term. This is usually done when public transport is considered and represented with real timetable based travel times..
- None of the accessibility models considers barriers.
- Nearly all accessibility models are based on passenger travel, only two models at the national scale and none at the regional scale consider freight transport.
- Many of the models consider road transport only, in particular models at the national scale. Other models have networks for rail or for all means of public transport, a few include also walking and cycling. Intermodal travel times is a rare exception of the accessibility models at these scales.

Spatial pattern

The main results of the accessibility models with respect to spatial patterns are summarised in Table 11 for the national accessibility models and in Table 12 for the regional accessibility models.

It can be seen that most of the national and regional accessibility studies point to the existence of large disparities of accessibility in the areas considered. This is regardless the type of indicator used. On the other hand, when evaluating the access to public facilities such as hospitals or regional centres, some of the studies conclude that the travel times are reasonable for most of the population and better than expected.

Table 9. Dimensions of national accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Dahlgren (2005)	Travel cost	250 m raster cells	Airports	Travel time	-	-	Travel	Road	Sweden
Forslund and Johans-son (1995).	Potential	LAU-2	LAU-2 (worker/population), International ports	Travel time	Capacities of seaports	-	Travel, freight	Road	Sweden
Johansson et al. (2002)	Potential	LAU-2	Jobs, household and business services, labour	Travel time	-	-	Travel	Road, rail	Sweden
Andersson and Ejermo (2005)	Potential	Local labour market area	R&D resources	Travel time	-	-	Travel	Road	Sweden
Johansson and Karls-son (2007)	Potential	LAU-2	Company and university R&D	Travel time	-	-	Travel	Road	Sweden
Andersson and Karls-son (2007)	Potential	LAU-2	Business and university R&D	Travel time	-	-	Travel	Road	Sweden
Tykkyläinen (1981)	Travel cost	Municipal centres	Municipal centres	Travel dis-tance	-	-	Travel	Road	Finland
Kotavaara et al. (2010	Travel cost, potential	LAU-2, built-up area centroids	LAU-2 centres Built-up area centroids	Travel time	-	-	Travel	Road, rail	Finland
Möller and Nielsen (2007)	Travel cost		Bioenergy plants	Travel cost	-	-	Freight	Road	Denmark
Jakimavicius and Macerinskiene (2006)	Travel cost		Regional centres	Travel time	-	-	Travel	Road	Lithuania
Bougromenko (1997)	Travel cost	87 regions	87 regions	Travel time	-	-	Travel	Road	Russia
Komornicki et al. (2010)	Potential	NUTS 4	NUTS-4 Population and 12 socio-economic variables	Travel time	-	-	Travel	Road, rail, multi-modal	Poland
Linneker and Spence (1992), Frost and Spence (1995)	Potential	179 zones 322 travel to work areas	179 zones, 322 travel to work areas	Travel time	-	-	Travel, freight	Road	Great Britain
Murphy and Killen (2007)	Travel cost	LAU-2	Potential paediatric hospital locations	Travel time	Peak hours	-	Travel	Road, public transport	Ireland

Table 9. Dimensions of national accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Geurs and Ritsema van Eck (2001)	Cumulative Potential	LAU-2	Jobs in LAU-2	Travel time	-	-	Travel	Road, public transport	The Nether-lands
Muhammad et al. (2008)	Potential	Transport zones	Jobs in transport zones	Travel time	Telecommut-ing (reduced constraint)	-	Travel	Road, public transport	The Nether-lands
Spangenberg and Pütz (2002); BBR (2005); BBSR (2011)	Travel cost potential	Raster cells LAU-2	LAU-2, MEGAs, regional cen-tres, motorways, rail stations, airports, hospitals etc.	Travel time	-	-	Travel	Road, rail, air	Germany / Europe
Fröhlich et al. (2006); Axhausen et al. (2010)	Potential	LAU-2	LAU-2	Travel time	Slope, time-table restric-tions	-	Travel	Road, public transport	Switzerland
BAK Basel Economics (2007)	Potential	LAU-2	LAU-2	Travel time	Timetable restrictions	-	Travel	Road, public transport	Switzerland
Bökemann and Kramar (1999)	Potential	LAU-2	GDP in LAU-2 Rail stations	Travel time	-	-	Travel	Road Rail	Austria
ÖROK (2007)	Travel cost	250 m raster cells	Regional and supra-regional centres	Travel time	Congestion, timetable restrictions	-	Travel	Road, public transport	Austria
Blahník (2009)	Travel cost	Rail stations	Prague	Travel time	-	-	Travel	Rail	Czechia
Petr (2008)	Travel cost	Local dis-tricts	Petrol stations	Travel time	-	-	Travel	Road	Czechia
Hrnčiarová et al. (2009)	Travel cost		Regional centres	Travel time	-	-	Travel	Road	Czechia
Rajman (2009)	Travel cost	Local dis-tricts	Prague	Travel time	Peak hours	-	Travel	Road	Czechia
Horňák (2005)	Travel cost	68 districts	Motorway exits	Travel dis-tance	-	-	Travel	Road	Slovakia
Michniak (2006)	Travel cost	LAU-2	Railway stations	Travel dis-tance	-	-	Travel	Road	Slovakia
Pšenka and Horňák (2009)		LAU-2	Regional centres	Travel time	-	-	Travel	Public transport	Slovakia

Table 9. Dimensions of national accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Michniak (2002)	Travel cost	LAU-2	Regional centres	Travel dis-tance	-	-	Travel	Road	Slovakia
Tóth (2006)	Cumulative, potential	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Hungary
Katsios et. al. (2006)	Travel cost	300 m raster cells	Ports, airports, FUAs	Travel time	Topography	-	Travel	Road, rail	Greek
Cattan and Grasland (1997/1998); Grasland, 2000)	Travel cost	Municipali-ties > 20,000	Municipalities > 20,000	Travel time, travel speed	-	-	Travel	Road, rail, multi-modal	France
Halal (2003)	Potential	LAU-2	LAU-2	Travel time	-	-	Travel	Car	France
Angrand et. al. (2007)	Cumulated	LAU-2	LAU-2	Travel dis-tance	-	-	Travel	Road	France
López Suárez et al. (2006; 2008; 2009); López Suárez (2007)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road, rail	Spain
Figueira de Sousa, Fernandes and Galiau (2009)	Travel cost	LAU-2	Lisbon and Porto; border points; ports; airports	Travel time	-	-	Travel	Road	Portugal

Table 10. Dimensions of regional accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Bjarnason (2005)	Travel cost	53/141 zones	City centre, university, national university hospital, shopping mall	Travel time	-	-	Travel	Road, public transport, cycling	Greater Reykjavik area (IS)
Naess et al. (1995, 2001)	Travel cost	Home location	Workplaces, different level centres	Travel time	-	-	Travel	Road, public transport	Oslo region (NO)
Arnesen et al. (2010)	Travel cost, potential	1 km raster cells LAU-2	Population Airports, railway stations, hospitals and universities.	Travel time	-	-	Travel	Road	Mountain areas, southern Norway (NO)
Meriläinen (1996)	Travel cost	Villages	Municipalities, job concentrations, urban centres	Travel time	-	-	Travel	Road	Hämeenlinna region (FI)
Määttä-Juntunen et al. (2010)	Travel cost	1 km raster cells	Shopping centres	Travel time	-	-	Travel	Road	Oulu region (FI)
Komornicki and Śleszyński (2009)	Travel cost		Regional airports	Travel time	Peak hours	-	Travel	Road, rail	Mazowieckie (PL)
Guzik and Kołoś (2003)	Travel cost	Regional cities	Holiday resorts	Travel time	Direct service existence	-	Travel	Public transport	Carpathian spa resorts (PL)
Taylor (2003)	Travel cost, cumulative	Villages	Shopping, health care facilities	Travel time	Time table restrictions	Opening hours	Travel	Public transport, walk	Three rural communes (PL)
Guzik (2003)	Travel cost	Cities and villages	Secondary schools	Travel time	-	-	Travel	Public transport	Małopolskie (PL)
Niedzielski and Śleszyński (2008)	Potential	Transportation zones	Jobs, workers	Travel time	-	-	Travel	Road, public transport	Warsaw (PL)
Gadziński and Beim, (2010)	Travel cost	Public transport stops	Main travellers' destinations	Travel time	-	-	Travel	Public transport	Poznań (PL)
Copus (1992; 1994)	Potential	Local districts; HIDB statistical areas	Local districts; HIDB statistical areas	Travel time	-	-	Travel	Road	Highlands and Islands of Scotland (UK)

Table 10. Dimensions of regional accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Martin et al. (2001); Lovett et al. (2000; 2001); White (2001); Higgs and White (2000); National Assembly for Wales (2000), Kelly et al. (2001)	Travel cost	Buildings, blocks, wards	GP surgeries, (minor) hospitals, specialist clinics	Airline and travel distance, travel time	Timetable restrictions, social groups	Opening hours of services	Travel	Road, public transport, walk,	Different UK regions incl. South West of England; East Anglia
Cooper et al. (2009)	Travel cost	100 m grid Census output areas	Public transport stops Employment centres, education, health services, quality food shopping facilities and open space	Travel time	Waiting times	-	Travel	Public transport, walk, cycling	Greater London (UK)
DfT (2009a; 2009b)	Travel cost, cumulative	Census output areas	Employment, primary schools, secondary schools, colleges, general practice surgeries, hospitals and high-quality food stores	Travel time	Timetable restrictions, age and social groups	Opening hours of services	Travel	Road, public transport, walk, cycling	Local authorities (UK)
DHC (2006)	Travel cost	Census output areas	Different schools, petrol stations, general practice surgeries, post offices, retail centres.	Travel time	Timetable restrictions	Opening hours of services	Travel	Public transport	Scotland (UK)
Commission for Rural Communities (2009)	Travel cost	Census output areas	Different types of specialised hospitals	Travel time	Peak/off-peak hours	Opening hours	Travel	Road, public transport	Worcestershire (UK)
Schürmann and Spiekermann (2010)	Travel cost	100 m raster cells	Services of general interest (schools, health care facilities, pos and banks offices etc.)	Travel time	Timetable restrictions	-	Travel	Road, public transport	Bavaria (DE)
Schürmann and Spiekermann (2011)	Travel cost, potential	100 m raster cells	Agglomeration centre, population	Travel time	-	-	Travel	Road, public transport	Munich, Karlsruhe, Hannover, Hamburg regions (DE)
BAK Basel Economics (2007)	Travel cost, Cumulated, potential	LAU-2	LAU-2 (population, GDP), Basel and Zürich, airports	Travel time	Timetable restrictions	-	Travel	Road, public transport	Northern parts of Switzerland

Table 10. Dimensions of regional accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Kraft (2008)	Travel cost	NUTS-3	České Budějovice (regional capital)	Travel speed	-	-	Travel	Public transport	Southern Bohemia (CZ)
Květoň (2006); Boruta and Ivan (2010)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Public transport	Jeseníky region (CZ)
Györffy (2006)	Travel cost	LAU-2	Regional centres	Travel time	Interchange times	-	Travel	Public transport	Northern Hungary (HU)
EUPOLIS (2007)	Travel cost	Turin	28 European cities, 120 international airports	Travel time	-	-	Travel	Air, multimodal	Turin (IT), Europe
DRE Aquitaine (2008)	Travel cost	Raster cells	Motorway exits, main railway stations airports	Travel time	-	-	Travel	Road	Aquitaine (FR)
L'Hostis et al. (2004)	Potential	Regional cities	Lille	Travel time	Time table restrictions	-	Travel	Rail	Nord-Pas de Calais (FR)
Raux et al (2007)	Travel cost	Regional cities	Strasbourg	Travel cost	-	-	Travel	Road, rail and bus	Nord-Pas de Calais (FR)
Bozzani and L'Hostis (2006)	Cumulative	Lille	Major European cities	Travel time	Time table restrictions	-	Travel	Rail, aAir	Lille (FR)
Ajenjo et al. (2004); Alberich González (2004)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Catalonia (ES)
García Palomares (2000)	Travel cost, potential			Travel time	-	-	Travel	Road	Madrid region (ES)
Nogales Galán et al. (2002)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Extremadura (ES)
Hernández (2002)	Travel cost, cumulative	Island capitals	Island capitals	Travel time	Time table restrictions; opening hours	-	Travel	Road, fFerry	Canary Islands (ES)
Silva and Pinho (2010)	Cumulative	Census tracks	Location of 18 different activities	Travel time	-	-	Travel	Road, public transport, non-motorised	Oporto region (PT)

Table 11. Accessibility patterns stated in national accessibility studies

Authors	Spatial scope	Accessibility pattern
Dahlgren (2005)	Sweden	Accessibility of airports is generally good with areas of low travel time reaching far into the airport hinterland along major road arteries. However, most of these areas are uninhabited areas, so that the population potential of an airport in its service area is often low.
Forslund and Johansson (1995).	Sweden	Evaluation of national road investment projects shows how changes in accessibility properties can influence the production potential of individual regions.
Johansson et al. (2002)	Sweden	Increase of accessibility by reduced road travel time increases the spatial size of labour markets.
Andersson and Ejermo (2005)	Sweden	Accessibility to university researchers have a positive effect on performance of enterprises and regions. But intraregional accessibility to research units of other corporations or accessibility to the corporation's own research units did not have a significant effect.
Andersson and Karlsson (2007)	Sweden	Differences in growth of value added per employee across regions can be explained by intra-municipal and intra-regional knowledge accessibility, but not by inter-regional knowledge accessibility.
Tykkyläinen (1981)	Finland	Accessibility in northern Finland proved to be poor. Locations of provincial capitals were considered to be optimal.
Kotavaara et al. (2010	Finland	Strong relationship between potential accessibility by road and population change, while the role of railways proved to be rather marginal.
Möller and Nielsen (2007)	Denmark	The geographical distribution and high transportation costs of biomass fuels underpin the use of wood chips as local fuels.
Komornicki et al. (2010)	Poland	Regions in the central south of Poland (Śląskie, Małopolskie and Opolskie Voivodship) and in central Poland (Łódzkie) have the highest potential accessibility, regions in the north and west (Lubuskie, Warmińsko-Mazurskie,Pomorskie and Podlaskie) have the lowest.
Linneker and Spence (1992), Frost and Spence (1995)	Great Britain	The overall derived pattern of economic potential showed peaks in all major centres and low values in remoter rural areas of Scotland, Wales and the South-West of England.
Murphy and Killen (2007)	Ireland	Optimal location of a specialised hospital differs depending on the main objective: if the hospital is to serve the Greater Dublin area only, a city-centre location in Dublin is best; if the hospital is to serve the Irish population, a hospital location further west is preferable.
Geurs and Ritsema van Eck (2001)	The Netherlands	Accessibility to jobs by road differs by three main levels: the Randstad with highest, the area east of the Randstad with modest accessibility and peripheral areas in north-eastern, southern and southwestern parts of the country. Highest accessibility to jobs by public transport results in a much more scattered pattern in which the Randstad is less dominant and more regional centres across the country are visible as peaks.
Muhammad et al. (2008	The Netherlands	Overall pattern of job accessibility as in Geurs and Ritsema van Eck (2001). With the introduction of telecommuting a much more regionalised pattern appears with high values for job accessibility around small and medium-sized cities.
Spangenberg and Pütz (2002); BBR (2005); BBSR (2011)	Germany	There are clear spatial disparities in accessibility in Germany, e.g. accessibility to agglomeration centres or to airports is very low in border regions, but also for some regions in the centre of Germany. On the other hand, 98 % of the population can reach the nearest hospital within 20 minutes road travel time.
Fröhlich et al. (2006); Axhausen et al. (2010)	Switzerland	Road accessibility became superior to rail accessibility in the 1930s. Only in the large urban centres, accessibility by rail is better than accessibility by road. The relative advantage of the large cities decreased through population suburbanisation since the 1950s, but large cities are still dominant.

Table 11. Accessibility patterns stated in national accessibility studies (continued)

Authors	Spatial scope	Accessibility pattern
BAKBASEL (2007	Switzerland	Great disparities in accessibility exist between mountain regions and other regions and between larger cities and smaller municipalities. Both disparities are much more pronounced for public transport, however, which provides lower accessibility values than road.
Bökemann and Kramar (1999)	Austria	Highest accessibility is concentrated in the Vienna region and in northern and western Austria having strong economies and good links to southern Germany. Accessibility by road is higher than by rail, however, the spatial patterns of high and low accessibility are rather similar. Infrastructure investments would benefit the lagging regions, but the overall pattern cannot be reversed.
ÖROK (2007)	Austria	The accessibility to regional centres is fairly good, about 98 % of the population reach the nearest regional centre within 30 minutes by road, 95 % by public transport. Topography and related distribution of regional centres have a large impact on accessibility..
Blahník (2009)	Czechia	The development of accessibility by rail of Prague 1918-2020 shows high regional disparities between connected and disconnected cities.
Petr (2008)	Czechia	Distribution of petrol stations is relatively balanced, however. areas at national roads have advantages.
Hrnčiarová et al. (2009)	Czechia	The worst accessibility of regional centres can be found in so-called inner peripheries on the western, southern and eastern border of the Central-Bohemian region and at the Bohemian-Moravian border, and in some outer peripheral zones.
Rajman (2009)	Czechia	Prague's accessibility is changing with time of day and week and related traffic volumes. In some areas the travel time to Prague gets worse during peak hours by more than 100%.
Horňák (2005)	Slovakia	Lagging accessibility of eastern Slovakia to motorway network.
Michniak (2006)	Slovakia	About 25 percent of the Slovak population lives more 5 km away from the nearest railway station
Pšenka and Horňák (2009)	Slovakia	They conclude that the spatial division of the country in the north, serviced mostly by long-distance trains, and the south, based on better bus time accessibility has increased in between 1989 and 2009.
Michniak (2002)	Slovakia	More than 200 municipalities have a low accessibility towards their regional centre and should be allocated to other districts, or several new districts might be established.
Tóth (2006)	Hungary	Budapest and its surroundings are the centre of accessibility in Hungary. A couple of regional centres are classified as central as well. The largest number of peripherally located settlements can be found on the Hungarian Great Plain and in Southern Transdanubia. There exists a moderately strong linear relationship between accessibility of population and economic development.
Katsios et. al. (2006)	Greece	Half of the Greek territory is inadequately served by any transport infrastructure. For two third of Greek's territory the travel time to the nearest FUA is longer than 30 minutes, however, this concerns only about 20 percent of the population.
Cattan and Grasland (1997/1998); Grasland, 2000)	France	Airline speed between cities in France is a function of the distance between and the size of the cities.
Hilal (2009)	France	Accessibility to jobs appears to be substantially lower for peri-urban areas than for urban or rural areas.
López Suárez et al. (2006; 2008; 2009); López Suárez (2007)	Spain	Impacts of the Spanish transport plan PEIT appear to benefit most depressed regions in Spain. Spillover effects are important and need to be assessed for different regions in the process of the impact assessment of the national infrastructure plans. Infrastructures built in certain regions may have important impacts in neighbouring regions.

Table 12. Accessibility pattern stated in regional accessibility studies

Authors	Spatial scope	Accessibility pattern
Bjarnason (2005)	Greater Reykjavik area (IS)	In general, accessibility by road is much higher than by public transport: However, there are also several areas where public transport accessibility is higher, mostly these areas are in close distance to bus stops. Areas of better public transport accessibility are much more fragmented than those with high accessibility by road.
Naess et al. (1995, 2001)	Oslo region (NO)	The relative speeds of car and public transport in commuting and every day activities exert an important influence on the modal choices of the journey to work. Hence, expansion of road capacity leading to a travel time reduction cause a shift from public transport to car as well as long distances to central areas.
Arnesen et al. (2010)	Mountain areas, southern Norway (NO)	Most municipalities of mountainous Norway suffer from access to public services; only selected municipalities at the fjords or within the valleys show sufficient high access to all facilities.
Meriläinen (1996)	Hämeenlinna region (FI)	Accessibility of villages can be increased by road infrastructure, but even major improvements seem not to have significant impacts on the vitality of those villages.
Määttä-Juntunen et al. (2010)	Oulu region (FI)	A careful, accessibility based selection of the locations of shopping centers might reduce CO_2 emissions.
Komornicki and Śleszyński (2009)	Mazowieckie (PL)	Warsaw is a barrier to the accessibility of the regional airports. It will continue to play this role even after the extension of the road network.
Guzik and Kołoś (2003)	Carpathian spa resorts (PL)	The three best accessible spa resorts in the Polish Carpathian Mountains (Rabka, Ustron, Krynica) have numerous services with relatively short travel time. The non-spa resort of Zakopane is by far the most accessible town of all resorts reviewed.
Taylor (2003)	Three rural communes (PL)	The best accessibility is enjoyed by inhabitants of larger villages and medium-sized places favourably located on stage bus routes.
Niedzielski and Śleszyński (2008)	Warsaw (PL)	Residential and employment accessibility for both road and public transport exhibits a concentric though irregular pattern declining in intensity with increasing distance from Warsaw's CBD.
Gadziński and Beim, (2010)	Poznań (PL)	The isochronal analysis shows that there is a big lack of radial tram lines establishing rapid connection between Poznań districts (especially in the northern part of the city) and to new settlements and the most important destinations of the daily trips.
Guzik (2003)	Małopolskie (PL)	For 60 percent of the municipalities, travel time to the nearest secondary school before 8 am is longer than the standard of 45 min.
Copus (1992; 1994	Highlands and Islands of Scotland (UK)	Significant differences between the mainland and islands, but also a gradual decline in mainland potential with increasing distance from Central Belt and major centres.
Martin et al. (2001); Lovett et al. (2000; 2001); White (2001); Higgs and White (2000); Naude et al. (1999); National Assembly for Wales (2000), Kelly et al. (2001)	Different UK regions incl. South West of England; East Anglia	Accessibility to public service facilities is very different and depending on the mode used. Accessibility significantly varies for different social and age groups. Taking account of opening hours of the facilities results in quite different accessibility patterns, since often opening hours and time schedules of public transport as preferred mode of elderly people are not compatible.
Cooper et al. (2009)	Greater London (UK)	Local access to public transport may be extremely different depending on the home base, since every single trip from home to public transport stops may include detours and may be subject to the small-scale distribution of underground access ramps.

Table 12. Accessibility pattern stated in regional accessibility studies (continued)

Authors	Spatial scope	Accessibility pattern
DfT (2009a; 2009b)	Local authorities (UK)	Various local applications show that the accessibility patterns vary significantly subject to the considered destination, time of day, and the mode used. Consequently, the impact of accessibility on daily behaviour very much differs for different age or social groups.
DHC (2006)	Scotland (UK)	Accessibility patterns are subject to a variety of local conditions: (i) specific spatial configurations of different types of services, (ii) specific public transport and road infrastructure provisions, (iii) operating hours of transport as well as opening hours of facilities. Altogether the resulting accessibility patterns are different for different social and age groups, and may also differ even for neighbouring areas.
Commission for Rural Communities (2009)	Worcestershire (UK)	Accessibility for public transport is very different, with areas of high accessibility close to public transport stops, and low accessibility in areas in greater distance to the stops. Accessibility is subject to the type of public transport service and the type of destination to reach, resulting in different accessibility patterns for different age groups and trip purposes.
Schürmann and Spiekermann (2010)	Bavaria (DE)	In general, there is in Bavaria good access with reasonable travel times to basic services of general interest. However, very different access to higher level services make rural areas disadvantaged. Accessibility by public transport in rural regions is much worse than accessibility by road.
Schürmann and Spiekermann (2011)	Munich, Karlsruhe, Hannover, Hamburg regions (DE)	Suburban locations along radial corridors of newly opened motorways or railway lines have improved their accessibility within the agglomerations. The consequences were rising land values, settlement activities, population increase and extended commuting distances.
BAK Basel Economics (2007	Northern Switzerland (CH)	Accessibility of Zürich and Basel is much better than that of suburban and rural municipalities. Disparities are much higher for public transport than for road.
Kraft (2008)	Southern Bohemia (CZ)	Clear differences of regional centers according to their position in the transport system, particularly for public transport.
Květoň (2006)	Jeseníky region (CZ)	Highest rates of elderly people correlate with the worst travel time accessibility of villages.
Györffy (2006)	Northern Hungary (HU)	The main accessibility problem of rural areas is the inadequate quality and density of the road network. Public transport access to regional centres is above one hour for two thirds of the rural population, mainly because of transfer times.
EUPOLIS (2007)	Turin (IT)	The accessibility of Turin to other European cities is slightly below the average of the other cities considered, whereas its accessibility to international airports is above the average.
DRE Aquitaine (2008)	Aquitaine region (FR)	Travel times to network nodes is a function of network design.
L'Hostis et al. (2004)	Nord-Pas de Calais (FR)	The study proposes ways that the objective to reach the regional capital Lille within one hour from regional cities would become feasible which it is currently not the case.
Bozzani and L'Hostis (2006	Lille (FR)	There is a clear spatial extension of the accessibility of Lille as a result of the combination of high-speed rail and air transport.
Nogales Galán et al. (2002, 2003)	Extremadura (ES)	The road network in Extremadura follows a national logic rather than a regional one. Areas far from national axes and the border points with Portugal have the worst accessibility.
Hernández (2002)	Canary Islands (ES)	About 70 % of commercial working hours and between 80 and 90 % of public administration working time at the main islands can be utilised in a day trip travelling from the main islands, values are lower for travelling from smaller islands to the main islands.
Silva and Pinho (2010)	Oporto region (PT)	Whereas accessibility by car to activities of interest is very good, about half of the study region with 15 percent of the population has poor access by public transport.

Assessment

An overall assessment of national and regional accessibility models is difficult. The general tendency is that none of the models is really able to serve all purposes. In national and regional studies of accessibility other origins and destinations become relevant than in European studies. If a balanced polycentric urban system is a goal of national spatial planning, accessibility of cities at the second or third level of the urban systems is of interest. Accessibility on the labour market is important from both viewpoints, i.e. from the firms' and from the workers'. More and more, the provision of minimum standards of services of general interest in urban, periurban or rural areas is becoming a problem of high political importance. This makes the analysis of accessibility of public facilities such as schools, food shops, doctors and pharmacies, important.

Nearly all national and regional studies have highlighted the sometimes large differences in accessibility in their study areas. However, the review has also shown that due to the great variety of the dimensions of accessibility, more detailed statements on overall regional patterns of accessibility by type of regions cannot derived from the literature. The conclusion is to develop a systematic and consistent set of accessibility indicators at the regional scale to be applied in TRACC to elaborate an accessibility typology for different types of regions.

3.4 Accessibility impacts

Accessibility is not a goal by itself but a derived demand. Accessibility is important because it provides access to opportunities at distant locations or makes it possible to receive goods and services or visitors from distant locations. For policy making, the maximisation of accessibility is therefore an objective only as far as it helps to improve the quality of life by facilitating access to opportunities, goods and services and so participation in social and cultural life.

This section reviews the state of the art of measuring, explaining and forecasting the impacts of accessibility. It first identifies the types of impacts of interest of accessibility of political interest. It then summarises the theoretical concepts explaining the relationships between accessibility and the impacts of interest. Guided by this theoretical background it reviews available empirical evidence about these relationships and existing mathematical models to forecast them. The section closes by proposing hypotheses about the likely effects of transport policies on the most relevant accessibility impacts.

3.4.1 Types of impacts

The impacts of accessibility of political interest are scale-dependent. At the European or national level, the relevant impacts are *economic*, i.e. impacts on regional economic development and territorial cohesion. At the intraregional level, the most important impacts are *social*, i.e. effects on social inclusion or exclusion by access to services of general interest and participation in social and cultural life. *Environmental* impacts of accessibility are relevant at all levels, but they are indirect and inversely related to accessibility, as good accessibility gives rise to more movements of goods and persons over longer distances, and these movements generate negative environmental impacts, such as more energy consumption and greenhouse gas emissions.

Economic, social and environmental impacts of accessibility differ in how they are measured and forecast. Social impacts can be measured and forecast directly by appropriate accessibility indicators, such as travel time to the nearest urban centre, education facilities or health services. Economic impacts of accessibility can be measured directly, e.g. in terms of GDP per capita, but to forecast the economic impacts of accessibility requires a theory or model about the way changes in accessibility affect regional economic development. The calculation of environmental impacts of changes in accessibility requires a transport model forecasting the flows of trains, cars and lorries likely to result from transport infrastructure investments.

3.4.2 Theoretical background

According to the above classification, economic and environmental impacts of accessibility cannot be directly measured but require a theory or model of their relationship with accessibility. The theoretical concepts developed for this are discussed in this subsection.

Economic impacts

The important role of transport infrastructure and quality of service for regional economic development is one of the fundamental principles of spatial 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.

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.

Historically, theories about the spatial economy start with von Thünen's (1826) isolated state in which economic location is a function of market access. Marshall (1890) added synergies between complementary industries as a location factor, Weber (1909) access to suppliers and labour. Christaller's (1933) central place theory introduced economies of scale to explain the multilevel polycentric system of cities as a function of service areas of different size, and Lösch (1940) did the same for centres of production as a function of market areas. At the height of neoclassical theory, Ohlin (1933) proposed that under conditions of perfect competition and factor mobility and constant returns to scale interregional flows of capital, labour and trade will lead to equal prices of production factors and goods in all regions. The opposite position was taken by Perroux (1955) and Myrdal (1957) who proposed that because there *are* barriers to mobility and economies of scale, the presence of advanced industries will, in a process of "cumulative circular causation", lead to spatial polarisation between prospering and lagging regions.

A synthesis between the two opposing views was offered by the new economic geography (Krugman, 1991; Krugman and Venables, 1995; Fujita et al., 1999). The new economic geography explains regional economic development as the result of the interplay between agglomeration forces (economies of scale) and spatial interaction costs as illustrated by the vertical and horizontal dimensions of the diagram in Figure 2. The theory suggests that the prevailing historical trend of increasing economies of scale and decreasing transport costs has led from isolated dispersed settlements to an ever more polarised spatial structure with a small number of dominant agglomerations (the white arrows in the diagram). If a more balanced polycentric spatial structure is a political objective, either the trend towards increasing economies of scale or the trend towards ever lower transport costs needs to be stopped or even reversed (the solid arrows in the diagram). One important conclusion of this is that not only vertical linkages are important but also horizontal linkages between cities with complementary economic specialisation. The new economic geography has also overcome unrealistic assumptions of neoclassical theory, such as the assumption of perfect competition, by adopting the concept of imperfect (monopolistic) competition.

Other contributions to the theory of regional economic development include institutional economics, which address the importance of property rights and transactions (Coase, 1960; Williamson, 1966), evolutionary economics linked to theories of synergy, self-organisation and complexity in the spirit of Forrester (1968), and more recently theories about the role of global cities (Sassen, 1991), spatial clusters of complementary industries (Porter, 1990) and the growing importance of information technologies (Castells, 1989) and creative industries (Florida, 2004). However, only few of these newer theoretical approaches have been used for applied quantitative models of regional economic development to date.

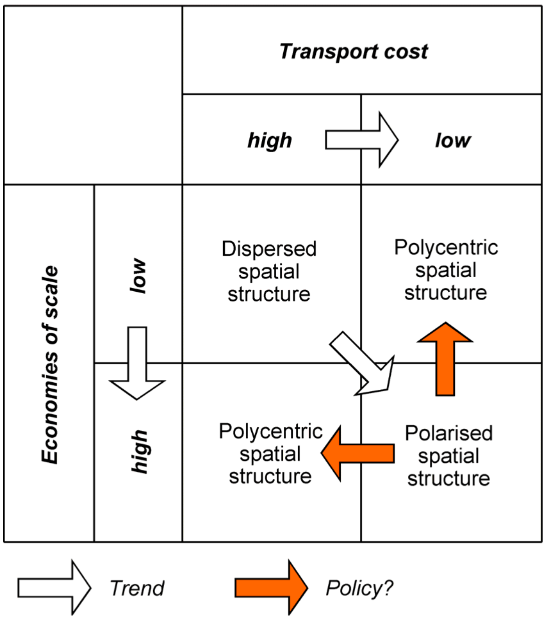


Figure 2. Economies of scale and transport cost

Another set of theories addresses not the location of economic activity (the demand side of regional labour markets) but interregional migration (the supply side of regional labour markets). Following migration theory (Ravenstein, 1985; Zipf, 1949), migration flows between regions are primarily job-oriented, i.e. people move from regions with high unemployment and low wages to regions with many job opportunities and higher wages. However, international migration of labour is inhibited educational, language and cultural barriers and, legal immigration constraints, as the history of labour migration in the EU since the two recent EU enlargements has demonstrated.

Environmental impacts

Environmental impacts of accessibility are indirect as they result from the flows of goods, services and persons occurring on the transport networks. The pattern of movements reflects the response of firms and households to network travel time and travel costs, i.e. is a function of the same variables used to calculate accessibility indicators.

There exists a broad range of testable theories about human travel behaviour. The most straightforward one is the model of rational behaviour under uncertainty underlying travel demand or goods transport models: Firms and households choose that combination of transport mode and transport route which minimises their travel time and/or transport cost to reach a destination (in the case of travellers) or to obtain goods from an origin (in the case of firms). Following this model, changes in transport supply, i.e. travel time and travel cost, result in shifts in the choice of origin, destination, mode and route. If transport becomes faster and less expensive, people will make more and longer trips and firms will order goods from more distant locations. If transport becomes slower and more expensive, people will make less and shorter trips and firms prefer regional products from suppliers nearby. These response mechanisms are largely responsible for the vast expansion of spatial mobility and the resulting spatial dispersal of human activities during the last century.

Things are getting more complex if also the feedback between network use and network capacity leading to congestion on the most heavily used network links is taken into account. Another complication arises if origins and destinations, e.g. firms and households, are not taken as fixed but are themselves influenced by changes in accessibility as discussed in the previous subsection.

It follows that it is not possible to calculate the environmental impacts of accessibility directly. Instead it is necessary to apply a travel and goods transport model to generate the flows of people and goods on the transport networks that are used to calculate the accessibility indicators subject to the distribution of origins and destinations at the time of analysis or forecast. To take account of feedbacks between transport and location, the transport model needs to be linked to the model of firm relocations and migrations discussed above.

If the flows of people and goods on the networks by mode resulting from a change in accessibility are made, the environmental impacts of these flows in terms of energy consumption and greenhouse gas emissions can be calculated subject to assumptions about fleet composition and fuel efficiency of vehicle types.

It is important to note that it cannot be assumed that any improvement of accessibility will also result in a corresponding improvement of sustainability. It is simple to see that a major motorway extension will attract more lorries and cars and generate more energy consumption and greenhouse gas emission. Things are getting more difficult with a major rail investment. On first sight the new line will attract more travellers and goods and so reduce vehicle-km, energy consumption and greenhouse gas emission on roads. However, if fewer lorries and cars are on the road, congestion and hence travel times will go down. This will make road transport again attractive with the effect that more and longer road trips are made. The net effect for energy consumption and greenhouse gas emissions is hard to predict; it may well be that a well-intended policy to improve sustainability is detrimental for the environment.

3.4.3 Empirical evidence

Despite the highly developed theoretical background of the likely economic and environmental impacts of transport infrastructure investments, the empirical evidence in this field is rudimentary and in many respects ambiguous.

Economic impacts

While there is broad agreement that more accessible regions are more competitive and economically successful, the empirical relationship between transport and economic development is more complex (Vickerman et al., 1999). 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 Nordic countries. To make things even more difficult, some of the economically fastest growing regions are among the most peripheral ones, such as some regions in the new EU member states in Eastern Europe (see Figure 3).

So it is not surprising that it has been difficult to empirically verify the impact of transport infrastructure on regional development (Vickerman, 1994). There is 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 still 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 (Bröcker et al., 2004). 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).

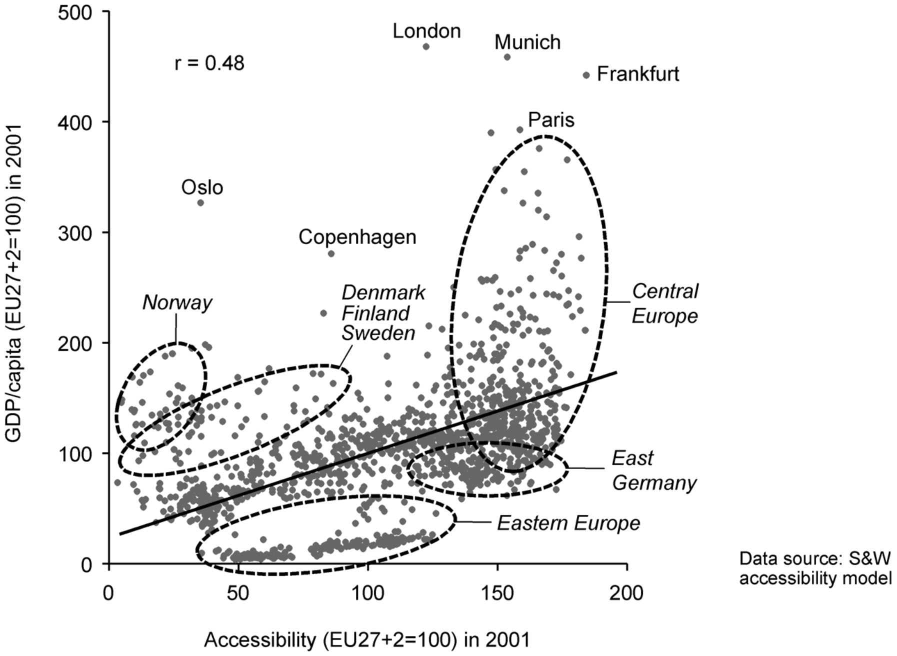


Figure 3. Accessibility and GDP per capita of NUTS-3 regions

There is even disagreement on the direction of the impact and thus whether transport infrastructure contributes to regional polarisation or decentralisation (Vickerman, 1994). Some analysts argue that regional development policies based on the creation of infrastructure have not succeeded in reducing regional disparities, 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 makes it easier for producers in the peripheral region to market their products in the large cities, but may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies (Vickerman et al., 1999; Quinet and Vickerman, 2004).

Figure 4 visualises this dilemma for one peripheral region (A) and two central regions (B and C): Peripheral region A is disadvantaged by its location and by its poor transport connections to the central regions B and C. An improvement of the transport link between A and B enables Region A to market its products in B and C, but also opens it up to the products of B and C. In the real world, however, primarily the transport connections between the central regions are improved.

Environmental impacts

The empirical situation in the field of travel and goods transport is more clear-cut but there remain ambiguities, too. There are detailed records of the evolution of transport networks and level of service on these networks in EU countries and regions. There is, too, a huge amount of data on transport activities in terms of tonnes-km by category of goods, vehicle-km by vehicle type as well as on energy consumption of transport and greenhouse gas emissions of transport. However, these data are in general collected separately and are not brought together in a policy-relevant way at a policy-relevant spatial scale below the national level.

This makes it difficult to assess the environmental impacts of transport infrastructure investments from empirical evidence. Instead the preferred method in practice is to apply a combined travel demand and goods transport model and to calculate the energy consumption and greenhouse gas emissions generated by it.

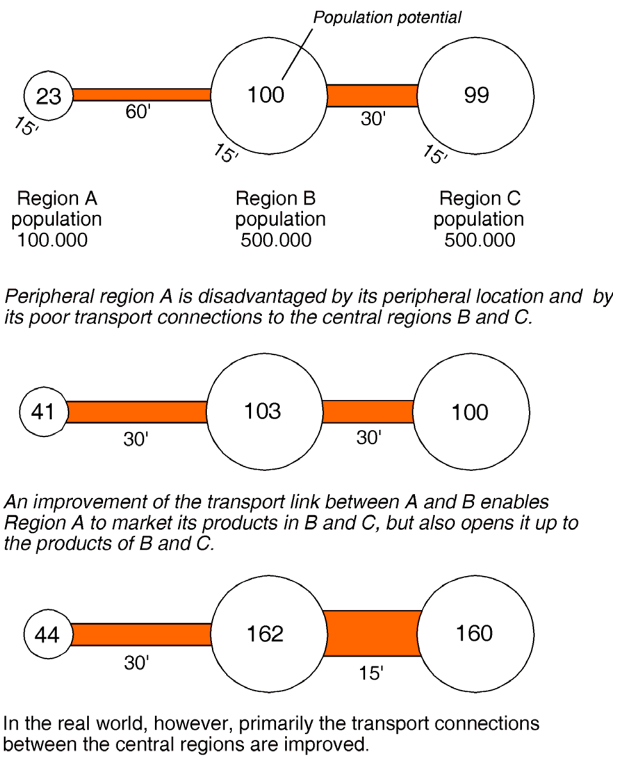


Figure 4. Who gains: core or periphery?

3.4.4 Regional economic models

There are three types of regional economic development models: regional production function models, multiregional input-output models and spatial computable general equilibrium models. The principles of these three types of models are summarised and the most important operational models of regional economic development applied in Europe are briefly presented here.

Regional production function models

Production function approaches model 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, among other location factors, infrastructure is added as a public input used by firms within the region (Aschauer, 1989; 1993; Jochimsen, 1966; Buhr, 1975). The assumption behind the 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. The main problem 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 transport infrastructure endowment. In addition the latter suffer from the fact that they disregard the network quality of transport infrastructure, i.e. value a kilometre of motorway or railway the same everywhere, irrespective of where they lead to.

More recent production function approaches attempt to respond to the latter criticism by replacing the simple infrastructure endowment indicators in the regional production function by more complex accessibility indicators. Accessibility indicators in most cases are some form of population or economic potential based on the assumption 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 hybrid approaches where accessibility is but one of several explanatory factors of regional economic growth, including soft location factors. Also the accessibility indicators used have become much more diversified by type, industry and mode (see Schürmann et al., 1997). The SASI, ASTRA and MASST models are models of this type incorporating accessibility among other explanatory variables.

- SASI. The SASI model developed at the Vienna University of Technology and the University of Dortmund is a recursive simulation model of socio-economic development of regions in Europe (Wegener and Bökemann, 1998; Wegener, 2008). Subject to exogenous assumptions about the economic and demographic development of the European Union as a whole, the model predicts the impacts of transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks. It differs from other regional economic models by modelling not only production (the demand side of regional labour markets) but also population and migration (the supply side of regional labour markets). The sectoral production functions of SASI include production factors (some of them delayed) representing regional capital, labour market potential, economic structure, sector-specific accessibility indicators and soft location factors, such as research and development and quality of life. The SASI model has been applied in several EU projects, such as IASON, ESPON 1.1.3 and 2.1.1 and AlpenCorS and STEPs and projects for national and regional authorities.
- ASTRA. The ASTRA model developed at the University of Karlsruhe is a recursive-dynamic model of the system-dynamics type designed to assess the likely impacts of transport policies on the regional economy and environment (Schade, 2005). Its macroeconomic submodel determines regional supply and demand and inter-industry linkages using national input-output tables. Regional supply is forecast by a Cobb-Douglas production function calculating potential output as a function of production factors labour supply, capital stock, natural resources and technical progress in the form of total factor productivity depending on sectoral investment, freight transport time savings and labour productivity. The ASTRA model also contains submodels of passenger travel and freight transport, the size and composition of the vehicle fleet and environmental impacts of transport, such as emissions, noise, accidents and congestion. ASTRA works at the European level and provides results at country level. It has been applied in several EU projects, such as STEPs and iTREN-2030. National versions of the model have been realised and applied for Germany and Italy at a more detailed geographical level. The Italian version of the model is based on a different macroeconomic submodel where production factors (capital and labour) are complementary rather than substitutable.
- MASST. The MASST (MAcroeconomic Sectoral, Social, Territorial) model was developed at the Politecnico di Milano to assess long-term scenarios of spatial development in Europe in the ESPON programme (ESPON 3.2, 2006, Vol. 4, 11–53; Cappello, 2007; Capello et al., 2008). MASST models national and regional GDP growth, population and migration based on alternative assumptions about macroeconomic tendencies and policy assumptions, such as interest, savings, exchange and inflation rates, public expenditures, geographical reorientation, foreign direct investment, trends in public debts, energy prices, migration policies as well as new institutional arrangements, such as further integration of the European Union and European policies, such as structural and agricultural funds and transport infrastructure priorities. Accessibility of a region is calculated as its economic potential, i.e. as the sum of the difference between the per-capita income of all other regions and that of the region divided by their distance to it.

Multiregional input-output models

Multiregional input-output models represent interregional and inter-industry linkages using the Leontief (1966) multiregional input-output framework. These models estimate inter-industry and interregional trade flows as a function of technical inter-industry input-output coefficients and transport costs (Echenique, 2004). Final demand in each region is exogenous, regional supply, however, is elastic, so that the models can be used to forecast regional economic development in response to changes in transport costs. If transport costs rise, industries and households tend to order more products from suppliers in near-by regions so that the exports of these regions grow and those of far-away regions decline. Examples of operational multiregional input-output models are MEPLAN, TRANUS and DELTA.

- MEPLAN. The MEPLAN model was developed by Marcial Echenique at the University of Cambridge (Echenique et al., 1969; 1990). It models regional economic development and transport flows based on national input-output tables expanded by households of different types as consumers of goods and services and producers of labour. Interregional trade flows, i.e. regional imports and exports, are predicted as a function of regional supply and demand by commodity type and production prices plus transport costs. The trade flows are converted to freight flows and passenger trips and assigned to a multimodal transport network. The flows in the network generate congestion which affects transport costs. The revised transport costs are fed back to the economic model until equilibrium is achieved. The model is made quasi-dynamic by computing an equilibrium for a series of time steps. The MEPLAN model has been applied to many regions, countries and Europe as a whole, e.g. in the Channel Tunnel study to assess the likely economic impacts of the fixed link between the European continent and the United Kingdom (Rohr and Williams, 1994).
- TRANUS. The TRANUS model developed by Tomás de la Barra et al. at Modelistica in Venezuela is based on a random utility derivation of the spatial input-output model (de la Barra, 1979, 1989). Like MEPLAN the model simulates the location of production and consumption at the level of regions as a function of production prices and transport costs thus generating flows of commodities and services which are then converted to freight and passenger trips. TRANUS interacts with its own transport model based on a multimodal logit assignment procedure particularly suited for multimodal transport networks with multiple choices and low levels of congestion. Log-sum transport disutilities are fed back to the spatial input-output model and influence the flows of commodities and services there. The TRANUS model was applied to the State of Oregon, to Spain, to Venezuela and several other Latin American regions, and more recently to a highly detailed model of Chile.
- DELTA. The land-use/economic modelling package developed by David Simmonds and colleagues (Simmonds, 1999; Simmonds and Skinner, 2003) works at two spatial levels, though not in all applications. The higher spatial level incorporates a spatial input-output model in which trade flows are influenced by transport costs linked with a model of investment and a migration model. The higher-level version has been applied to Scotland and several areas in England and to the whole of Great Britain.

Spatial computable general equilibrium models

Following the ideas of the new economic geography, more recent input-output based models of trade flows include economies of scale and imperfect (monopolistic) competition. Such multiregional input-output models are today called spatial computable general equilibrium (SCGE) models, although the term CGE originally had a broader meaning (Bröcker, 2004). The distinction between SCGE models and multiregional input-output models is becoming more and more blurred as also the latter determine a general equilibrium between transport and location. Examples of SCGE models are CGEurope, RAEM and recent versions of the REMI model.

- CGEurope. The CGEurope model developed at the University of Kiel is a multiregional spatial computable general equilibrium model in which transport costs are expenditures of firms for transport and business travel (Bröcker, 1998; Bröcker et al., 2004; 2010). It assumes imperfect (monopolistic) competition of the Dixit-Stiglitz (1977) type in each region for the markets of tradable goods and perfect competition for local goods and factor markets. Prices and quantities respond to changes in transport times and transport costs resulting in changes in income and welfare in each region. The CGEurope model predicts the spatial distribution of production factors in a target year in a comparative static equilibrium analysis, i.e. by comparing cases with and without implementation of the policies leaving everything else unchanged. The main output of the model is the so-called Hick's measure of variation, i.e. the monetary equivalent of the change of welfare of households. CGEurope has been applied in several EU projects, such as IASON, ESPON 2.1.1 and TEN-CONNECT.
- RAEM. The RAEM model developed at the University of Groningen and TNO Delft is an SCGE model of regional capital investment and stock and flow relationships of households and firms (Oosterhaven et al., 1998; Ivanova, 2007). Households maximise their utility of consumption of goods and services under budget constraints, and industries minimise their costs of labour, capital and inputs under technology constraints. Each sector consists of identical firms each producing a unique specification of a particular commodity, which gives them monopolistic power over their consumers. Households and domestic sectors consume transport services in their consumption and production activities. The latest version RAEM 3.0 includes international trade and interregional migration. The model determines equilibrium of supply and demand and interregional trade flows in each time period. RAEM was developed for the Netherlands and has been applied in a simplified version (RAEM-Light) in Hungary, Japan and South Korea.
- REMI PI+. The REMI model developed at the University of Massachusetts (Treyz, 1980; Treyz et al., 1992) originally was a multi-regional input-output model with endogenous final demand. Its latest version, PI+ (Policy Insight), is a new economic geography extension of the original REMI framework with endogenous real estate prices, labour mobility and inter-industry purchases (Fan et al., 2000). It relaxes some of the restrictive assumptions of new economic geography in that workers are mobile between sectors and regions, real estate prices are explicit in consumption and production, and differentiated inputs are used in production. Agglomeration forces in the model are consumers' and producers' prices and wages, the centrifugal force in the model is the limited supply of land. Evolutionary equilibrium is determined taking account of different speeds of adjustment of different subsystems over time. Previous generations of the REMI model have been applied for policy analyses in over a hundred regional and state agencies in North America and Europe.

Comparison

The three types of model, regional production function models, multiregional input-output models and spatial computable general equilibrium models, have much in common with respect to underlying theory (see Table 13). All three are aggregate models at the meso scale of regions. All consider transport a production factor of great importance for regional economic development. There are no neoclassical models assuming perfect factor mobility in the set of models discussed here, as all of them model spatial impedance in the form of transport costs and other forms of barriers, though with different detail. Markets with imperfect competition, increasing returns to scale and bounded rationality under uncertainty by economic agents are addressed in models of all three groups, either by the nonlinear specification of production factors in the extended production functions or by logit type utility functions in the multiregional input-output models or by the Dixit-Stiglitz model of monopolistic competition in the SCGE models.

Table 13. Comparison of multiregional economic models

Model type	Model	Trade flows	Imperfect competition	Networks	Demography	Migration	Dynamics
Regional production function	SASI	no	implicit	yes	yes	yes	yes
	ASTRA	output	implicit	no	yes	yes	yes
	MASST	no	implicit	no	yes	yes	yes
Multiregional input-output	MEPLAN	yes	no	yes	no	no	no
	TRANUS	yes	no	yes	no	no	no
	DELTA	yes	implicit	external	no	yes	yes
Spatial computable general equilibrium	CGEurope	yes	yes	external	no	no	no
	RAEM	yes	yes	external	no	yes	no
	REMI PI+	yes	yes	no	yes	yes	yes

However, there are also major differences. Multiregional input-output models and SCGE models explicitly model trade flows between regions based on product prices and transport costs and determine regional growth of industrial sectors from these flows. Production function models aggregate trade and travel flows into one complex variable, accessibility. Needless to say that the explicit modelling of purchases of firms from other regions based on comparison of product price, diversity and transport cost is superior to the econometric estimation of the aggregate impact of accessibility on regional economic development, in particular if not only trade volumes but also prices are endogenous as in SCGE and some multiregional input-output models.

More problematic are obvious omissions in some of the models. If in the ASTRA model accessibility is expressed only as freight transport time for distance bands or in the MASST model only by interregional distance or km of roads in a region, these models are likely to underestimate the impact of network improvements, in particular of rail investments. The CGEurope model assumes that regional labour is constant and immobile and so fails to take account of the impacts of demographic change and interregional migration on regional labour markets. The SASI model presently treats regional sector productivity as exogenous instead of modelling improvement in productivity through better accessibility. However, all these deficiencies can be easily overcome by relatively minor model modifications.

Another relevant difference between the models is their treatment of dynamics. Multiregional input-output models and SCGE models assume that markets are in equilibrium, at the start and target year (CGEurope), at the end of each period (MEPLAN, TRANUS, DELTA, RAEM) or after a number of periods (REMI PI+). The production function models, however, are all recursively dynamic with different types of adjustment delays.

In particular the latter difference, between equilibrium and dynamics, seems to affect the sensitivity of the models to transport cost changes. This is suggested by a comparison of the results of the CGEurope and SASI models. In the EU projects IASON (Bröcker et al., 2004) and ESPON 2.1.1 (Bröcker et al., 2005) the two models were applied to the same study area, the same regional and network data and the same policy scenarios. It turned out that the two models agreed with respect to the direction and spatial distribution of the effects of the policies and whether the policies contribute to greater cohesion or polarisation between the regions in Europe, but differed with respect to the magnitude of the responses by a factor of up to ten, with the SASI model showing the stronger responses. Possible reasons for this divergence included differences in the specification of transport costs, in particular with respect to border impediments, the neglect of mobile capital in SASI and the neglect of mobile labour in CGEurope. Another hypothesis was that CGEurope as an equilibrium model primarily predicts short-term responses, whereas the quasi-dynamic SASI model shows self-reinforcing cumulative effects over time (Bröcker et al., 2004, 168-175). Further research will be necessary to test the two hypotheses.

3.4.5 Hypotheses

The combined results of empirical and modelling studies suggest that the present European transport policy may widen rather than narrow differences in accessibility between central and peripheral regions. Although the biggest absolute changes in accessibility are gained in some peripheral regions which start with very poor levels of provision, the relative gap between the best and the worst of the main centres increases.

This does not imply that the relative gains in accessibility of peripheral regions may not be beneficial to their economic development, however it must be pointed out that these gains will always be overshadowed by the much larger gains in accessibility of the regions in the European core. It is therefore not possible to refer to transport network improvements unambiguously as instruments to promote the cohesion between the regions in Europe and the reduction of interregional economic and social disparities. A European transport policy truly committed to that goal would have to shift significantly the focus of the trans-European networks investment programme to transport links within and between the peripheral regions, not in addition to, but at the expense of, transport investment in the European core.

Similarly, the results of the empirical and modelling studies suggest that transport policies that aim at improving accessibility do not automatically also improve sustainability. Even transport policies explicitly aimed at shifting transport to environmentally more sustainable models are not certain to achieve that goal due to the inherent nonlinear dynamics of transport and location.

4 TRACC accessibility and impact indicators

Based on the review of accessibility and impact indicators in the previous chapter, this chapter presents the TRACC set of accessibility and impact indicators to be implemented in the subsequent phases of the project.

4.1 Accessibility indicators

The review of accessibility studies ranging from a few studies addressing global accessibility down to a vast number of studies dealing with regional accessibility has shown the variety of indicators and approaches. Most frequently used are accessibility indicators of the basic type travel cost, particularly in studies at the regional or national scale. However, also the two other generic types of accessibility indicators, cumulated opportunities and potential accessibility, are used in several studies, the latter in particular in studies at the European scale and only rarely at the regional scale. The activities of interest at the destination are very often population, but also GDP, jobs, labour force, cities of different functions, different public and private services or institutions or freight terminals are used. The spatial resolution differs much. Whereas some European studies consider only a few points in space or are working at the NUTS-2 level, many studies work at the NUTS-3 level or are even based on a raster representation of Europe. Most studies at the regional scale work at the LAU-2 level, however, with the availability of high-resolution grid data, there is a tendency towards calculating accessibility at the regional scale for small raster cells. The level of network detail differs accordingly. Whereas a few studies use no network at all but airline distances, the other end of the spectrum is marked by studies working with full road networks and public transport timetables including real transfer times. Most accessibility studies deal with passenger travel, only very few are concerned with freight transport.

The review has shown that there is no single standard accessibility indicator serving all purposes. The conclusion for TRACC is therefore to develop a systematic and consistent set of accessibility indicators which is derived from the conceptual framework as laid down in Chapter 1 and which matches the following requirements:

- As different types of accessibility indicators provide answers to different questions, the three generic types of accessibility indicators, i.e. travel cost, cumulated opportunities (daily accessibility) and potential accessibility should be used at all levels considered.
- The TRACC project is expected to analyse accessibility at very different spatial levels ranging from the global through the European to the regional level.
- The spatial coverage should be at least the ESPON space. Candidate countries and other countries of the Western Balkan should be included if possible. Regional case studies should cover different types of the regional typologies developed by ESPON.
- The spatial resolution should be appropriate. This is NUTS-3 for the Europe-wide indicators and LAU-2 for the regional case studies. In addition, raster representations of space should be explored to analyse to what extent a finer spatial resolution influences results.
- All relevant transport modes should be addressed, i.e. road, rail and public transport, air and water as well as combinations of modes in form of multimodal aggregation and intermodal trip chains.
- Traditional accessibility indicators should be amended by newer forms of accessibility. The traditional indicators should guarantee continuity with previous ESPON studies; in particular the potential accessibility indicator should be updated to a recent year.
- There should be accessibility indicators dealing with passenger travel and indicators dealing with freight transport.

Table 14 presents the resulting proposal for the TRACC set of accessibility indicators. The indicator set is differentiated by the three main spatial contexts to be taken into account (global, European, regional), and at each level further differentiated by travel and freight. For the European level, accessibility indicators for travel are further divided into traditional and newer ones. For the regional level, the indicators are differentiated into those regional indicators for both travel and freight that can be calculated for the whole of Europe and those that will be calculated in the regional case studies. For the latter, a distinction is made between traditional indicators and indicators looking at the accessibility to selected services of general interest to reflect current policy debates on the subject of services of general interest. For all levels, each generic indicator type is represented by one indicator.

The proposed thresholds, e.g. maximum travel time or minimum city size, or the proposed destinations for global accessibility will be subject to some exploration and might be changed during the analytical work.

Global accessibility

The task of the global accessibility indicators is to describe the linkages of the regions to the world. As demonstrated in Chapter 3.1, previous analyses of global accessibility were in most cases restricted to travel time indicators for selected points in Europe, usually airports. The TRACC set of global accessibility indicators provides progress in three directions: (i) Besides travel also freight accessibility is included. (ii) Not only travel cost indicators are included but also accessibility indicators of the types cumulated opportunity and potential: (iii) The indicators are not restricted to preselected rare points in Europe, but will be calculated for all NUTS-3 regions of the ESPON space.

There are three global accessibility indicators defined for travel, i.e. each generic type of accessibility indicators is represented:

- *Access to global cities*. What are the travel times from the European regions to selected global cities? New York and Tokyo serve as examples for non-European global cities. For each NUTS-3 region the shortest total travel time will be calculated including intermodal trips by road, rail and/or air to airports with intercontinental flights plus the flight time to the two cities.
- *Global travel connectivity*. How many intercontinental flights can be reached from the European regions within a maximum travel time of three hours? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services will be calculated. If an airport is within the maximum travel time, the intercontinental destinations served from that airport will be added to the regional global connectivity value.
- *Global potential accessibility travel.* What is the relative position of the European regions towards global destinations? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services will be calculated. The intercontinental flights weighted by flight frequency and/or population/GDP of the final destination will be used as attraction, i.e. the mass term in the calculation of the potential accessibility.

Accordingly, there are three global accessibility indicators for freight transport following a similar approach as the indicators for travel:

- *Access to global freight hubs*. What are generalised travel costs for specific commodity groups from the European regions to selected global freight hubs? Detroit and Shanghai serve as examples for non-European global freight hubs. For each NUTS-3 region the lowest total generalised costs will be calculated including intermodal trips by road, rail, water and/or air to seaports and airports with intercontinental services plus the generalised costs from there to the two freight hubs.

Table 14. TRACC set of accessibility indicators

Spatial context	***Basic characteristics***	***Generic type of accessibility indicator***		
		Travel cost	***Cumulated opportunities***	***Potential***
Global	***Travel***	***Access to global cities*** Travel time (intermodal) to global city (New York, Tokyo)	***Global travel connectivity*** Number of flights from European airports to intercontinental destinations reachable within three hours	***Global potential accessibility travel*** Intermodal accessibility to intercontinental flights of European airports weighted by destinations as mass
	Freight	***Access to global freight hubs*** Travel time/cost (intermodal) to major intercontinental terminals (Shanghai, Detroit)	***Global freight connectivity*** Intercontinental container throughput of European sea ports reachable within 24 h travel time	***Global potential accessibility freight*** By road and rail to container throughput of European sea ports
Europe	***Travel (traditional)***	***Access to top ten MEGAs*** Average fastest travel time to top ten MEGAs	***European daily accessibility travel*** Daily accessibility to population by road, rail, air	***European potential accessibility travel*** To population by road, rail, air, multimodal
	Travel (new)	***Travel speed*** Average travel speed by road and rail	***Urban connectivity*** Urban connectivity by road, rail, intermodal	***European potential acc. intermodal travel*** To population intermodal (all modes)
	Freight	***Access to nearest maritime ports*** Average generalised cost to nearest three maritime ports	***European daily accessibility freight*** GDP accessible within allowed lorry driving time	***European potential accessibility freight*** Accessibility potential to GDP by different modes
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** ICON based access time to motorway exits, rail stations, airports	***Availability of urban functions*** Cities > 50.000 within 60 minutes by road and rail	***National potential accessibility travel*** To national population by road and rail
	Freight (Europe-wide)	***Access to freight terminals*** ICON based access time to freight terminals	***Availability of freight terminals*** Freight terminals within 2 h by lorry	***National potential accessibility freight*** To national GDP by lorries and rail freight
	Travel (case studies, traditional)	***Access to regional centres*** Travel time to nearest regional centre by road and public transport/rail	***Daily accessibility of jobs*** Jobs accessible within 60 minutes by road and public transport/rail	***Regional potential accessibility*** To population by road and public transport/rail
	Travel (case studies, to services of general interest)	***Access to health care facilities*** Travel time to nearest hospital	***Availability of secondary schools*** Number of secondary schools within 30 minutes of road travel time	***Potential accessibility to basic health care*** Potential accessibility to general practice surgeries

- *Global freight connectivity*. What amount of intercontinental container throughput of ports can be reached from the European regions within a maximum freight transport time of 24 hours? For each NUTS-3 region the shortest total intermodal travel times by road, rail, water and/or air to seaports with intercontinental container services will be calculated. If a seaport is within the maximum travel time, the intercontinental container throughput of that port will be added to the regional global connectivity value for freight.
- *Global potential accessibility freight.* What is the relative position of the European regions towards global destinations with respect to freight transport? For each NUTS-3 region the shortest total intermodal travel cost by road, rail, water and/or air to ports with intercontinental container services will be calculated. The intercontinental container throughput of the ports will be used as attraction, i.e. the mass term in the calculation of the global freight potential accessibility.

European accessibility

The task of the European accessibility indicators is to provide assessments of the attractivity and competitiveness of European regions in the European context based on their location and their integration in the transport networks. As shown in Chapter 3.2, there is already a wide collection of previous studies including ESPON work on European accessibility available. The TRACC set of European accessibility brings value-added in three directions: (i) Traditional accessibility indicators such as the accessibility potential will be updated to a current point in time thus allowing an up-to-date assessment and also the analysis of trends over time. (ii) The additional inclusion of new types of accessibility indicators and in particular of indicators addressing freight transport will enable new insights into European accessibility conditions. (iii) The explorative analysis of raster-based indicators will enable methodological conclusions on the appropriate spatial resolutions of accessibility indicators.

For each of the three generic types of accessibility indicators, first a traditional indicator for accessibility travel is defined:

- *Access to top ten MEGAs*. What is the average travel time from the regions to the upper level subset of the European MEGAs? For each NUTS-3 region the fastest travel time of road, rail and air transport to reach the top ten MEGAs will be calculated, and an average value will be determined.
- *European daily accessibility travel*. How many people can I reach within a day's round trip? How many people can visit my region within a day's round trip? For each NUTS-3 region the number of persons that can be reached within a one way travel time of five hours by road, rail, air and fastest mode will be summed up. Five hours per way will be used to allow for at least five hours of activities at the destination.
- *European potential accessibility travel.* What is the relative competitive position of European regions towards European destinations? For each NUTS-3 region the population in destination regions will be weighted by the travel time to go there. The weighted population will be summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator will be calculated for road, rail, air and as an multimodal aggregate. The indicator will be calculated with the same specification and network detail for the year 2011 as the potential accessibility indicators of ESPON 2006 and the Accessibility Updates. That means that the development of potential accessibility by road, rail, air and multimodal can be analysed over a time period of ten years in total. In an exploratory part of the project, the NUTS-3 regions used as origins and destinations will be replaced by small raster cells to investigate whether a more detailed representation of space would lead to better results.

There is a second set of European accessibility travel indicators that goes somewhat beyond the traditional indicators described before. These indicators include relatively new aspects and are more complex in terms of data requirements and calculation methods:

- *Travel speed*. What is the average travel speed to serve regional transport demand? The rationale of this indicator is based on the assumption that transport policy cannot provide the same degree of accessibility everywhere in Europe, but might provide the same quality of the infrastructure by delivering comparable speeds to the regional transport demand. First, regional transport demand will be calculated by a negative exponential model in which the number of trips from the region to all other regions is estimated. Then, the travel time to the destination regions will be converted to airline speeds. Finally, the average travel speed of a region will be calculated as the trip-weighted average speed to all other regions. This will be done for rail and road modes.
- *Urban connectivity*. What opportunities or restrictions for urban connectivity does transport infrastructure provide? For each city of more than 50,000 inhabitants the travel time to other cities of that minimum size will be calculated for road, rail and air travel. Urban connectivity is there if two cities are less than three or alternatively five hours of centre-to-centre travel time apart from each other. The indicator will be mainly presented in map form, but could also be numerically defined by using concepts of graph theory.
- *European potential accessibility intermodal travel.* What is the relative competitive position of European regions towards European destinations by using the best combination of all transport modes in intermodal trip chains? For each NUTS-3 region the population in destination regions will be weighted by the intermodal travel time to go there. The weighted population will be summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator will be calculated by using shortest intermodal travel times between regions.

A third group of European accessibility indicators is concerned with freight transport. The indicators developed follow the logic of the more traditional accessibility indicators for travel:

- *Access to nearest maritime ports*. What are the costs to reach the nearest maritime ports? For each NUTS-3 region the average generalised travel cost for different commodities to reach the nearest three maritime ports will be estimated. Modes considered will be road, road and rail and road and inland waterway.
- *European daily accessibility freight*. What market area can be served by lorries from a region? For each NUTS-3 region the amount of GDP that can be reached within the maximum allowed driving time of a lorry driver will be calculated.
- *European potential accessibility freight.* What is the relative competitive position of European regions towards European destinations with respect to freight transport? For each NUTS-3 region the GDP in destination regions will be weighted by the generalised travel time to go there. The weighted GDP will be summed up to give the value of the potential accessibility freight for the origin region. Freight handling categories considered will be unitised goods, bulk and general cargo thus reflecting different conditions with respect to impedance, e.g. different times and costs for loading and unloading. Modes included will be road, rail, inland waterways, short sea shipping and air. For those modes that are generally used in combination with other modes, e.g. short-sea shipping needs feeder service by an inland mode to connect non-coastal regions, travel times and costs will be calculated based on intermodal trip chains.

Regional accessibility

The task of the regional accessibility indicators is to provide the base for an analysis of the restrictions and opportunities for daily life provided by the transport infrastructure in the regions to the population and economic actors. The review of regional accessibility studies provided in Chapter 3.3 has shown that there is a huge variety of approaches at this scale. In most of them travel cost type indicators in the form of travel time to a few selected destinations and the trend towards high spatial resolution dominate. The TRACC set of regional accessibility indicators provides progress in three directions: (i) A Europe-wide modelling of accessibility to regional destinations allows a comparison of regional accessibility for all NUTS-3 regions. (ii) The systematic integration of freight accessibility provides insights in the local restrictions and opportunities for economic actors. (iii) A harmonised set of accessibility indicators to be implemented in different regional case studies allows a unique Europe-wide comparison of local and regional conditions of daily life in very different types of European regions.

There are two basic groups of regional accessibility indicators. In the first group accessibility for travel and freight to destinations of regional importance are calculated for the whole ESPON space and the Western Balkan. The indicators of the second group will be calculated in the seven TRACC case studies only.

The regional accessibility travel indicators to be calculated for the whole of Europe cover again all three generic types of accessibility indicators:

- *Access to high-level transport infrastructure*. What is the access time to reach the nearest entrance nodes of higher-level transport infrastructure? Access time to the nearest transport nodes (motorway exits, main rail stations and airport) will be calculated for raster cells for road and rail. Following the ICON approach access times will be aggregated by including the relative importance and utility of the different networks for the regional population. Aggregation from raster cells to NUTS-3 will allow comparison with other accessibility indicators.
- *Availability of urban functions*. What amount of urban functions can be reached in reasonable travel time? By looking at road and rail transport, it will be assessed which functions of cities with more than 50,000 inhabitants can be reached within a travel time of 60 minutes maximum. Calculation will be made for raster cells and will be aggregated to NUTS-3 regions.
- *National potential accessibility travel.* What is the relative competitive position of regions towards national destinations? This indicator is similar to the potential accessibility at the European level. For each NUTS-3 region the population in destination regions will be weighted by the travel time to go there. and the weighted population will be summed up to give the value of the accessibility potential for the origin region. However, the destinations will be restricted to regions in the same country as the origin region. That means that in practice national accessibility calculations will be done separately for each country of the ESPON space and the Western Balkan. The potential accessibility indicator will be calculated for road and rail.

The regional accessibility indicators for freight transport to be calculated Europe-wide follow a similar logic as those for travel:

- *Access to freight terminals*. What is the access time to reach the nearest freight terminals? Access time to nearest transport nodes (cargo transport centres, seaports, inland ports, airports with cargo handling) will be calculated for raster cells for road and rail. Following the ICON approach access times will be aggregated by including the relative importance and utility of the different networks for the regional economic actors. Aggregation from raster cells to NUTS-3 will allow comparison with other accessibility indicators.
- *Availability of freight terminals*. What amount of options have regions with respect to freight logistic centres? By looking at road transport, it will be assessed which number of freight terminals can be reached within a lorry travel time of two hours maximum. The indicators will be calculated for raster cells and will be aggregated to NUTS-3 regions.
- *National potential accessibility freight.* What is the relative competitive position of regions towards national destinations with respect to freight transport? This indicator is similar to the po-

tential accessibility for freight at the European level. For each NUTS-3 region the GDP in destination regions is weighted by the generalised travel time to go there and the weighted GDP will be summed up to give the value of the accessibility potential for the origin region. However, the destinations are restricted to regions in the same country as the origin region. That means that in practice national accessibility calculations for freight will be done separately for each country of the ESPON space and the Western Balkan. The potential accessibility indicator will be calculated for road and rail.

In the regional case studies, the first set of indicators to be calculated is for travel and follows the traditional set of accessibility indicators calculated at the European level. All indicators will be calculated for municipalities, i.e. at the LAU-2 level. However, in same case studies the calculation will be done first for smaller raster cells and then also aggregated to LAU-2:

- *Access to regional centres*. How distant or how far is the nearest regional centre? Proximity to an urban centre has often been used as a proxy for accessibility to jobs and different services such as higher education, health care, commerce etc. For each municipality or raster cell of the case study region, the minimum travel times by road and public transport to the nearest urban centre will be calculated.
- *Daily accessibility of jobs*. How many jobs can I reach from my place of residence? This indicator approaches the opportunities of the regional labour market from the point of view of the population. For each municipality or raster cell the amount of jobs reachable within a maximum commuting distance of 60 minutes by car and by public transport will be estimated.
- *Regional potential accessibility.* What is the regional population potential of a municipality? In order to evaluate the different locations within a region from the viewpoint of economic actors, e.g. firms assessing the regional labour market, or retail industries assessing the market area, the population potential of each municipality or raster cell within the case study region will be calculated. As for the other spatial levels the population potential will be calculated as the sum of people in destination areas weighted by the travel times to go there. Modes considered will be road and public transport.

The second set of indicators to be calculated in the regional case studies is also for travel and considers destinations of specific relevance for daily life, i.e. services of general interest:

- *Access to health care facilities*. What is my travel time to go to the nearest hospital? Travel times for each municipality or raster cells by road and by public transport will show the spatial diversity in access to important health care facilities.
- *Availability of secondary schools*. Do I have access to secondary schools in reasonable travel time and do I have a freedom of choice to select between different options? For each municipality or raster cells travel time contours of 30 minutes travel time by road and by public transport will be calculated, and it will be checked how many secondary schools will be reachable within this travel time.
- *Potential accessibility to basic health care.* What is my locational quality with respect to basic health care? Using general practice surgeries as destination activity in a potential accessibility indicator allows to assess the relative distribution of health care provision of different areas within the case study region. For each municipality or raster cell, the potential value is calculated as sum of general practice surgeries located in the case study region weighted by travel times by road and public transport. Depending on the data situation in the individual case studies, primary schools or secondary schools might be used instead of general practice surgeries.

In Table 15 a synopsis of the TRACC set of accessibility indicators is given with respect to the main dimensions of accessibility (see Table 1). The accessibility indicators are classified according to the origins, the destinations, the type of impedance and the form of the impedance function and the transport modes.

Table 15. Main dimensions of TRACC set of accessibility indicators

Spatial context	*Basic characteristics*	*Generic type of accessibility indicator*		
		Travel cost IF linear	***Cumulated opportunities*** IF rectangular	***Potential*** IF non-linear
Global	***Travel***	***Access to global cities*** O NUTS-3 regions D New York, Tokyo I Travel time M Intermodal	***Global travel connectivity*** O NUTS-3 regions D Flights from European airports to intercontinental destinations I Travel time within 3 hours M Intermodal	***Global potential accessibility travel*** O NUTS-3 regions D Flights from European airports to intercontinental destinations (weighted by destination population) I Travel time M Intermodal
	Freight	***Access to global freight hubs*** O NUTS-3 regions D Shanghai, Detroit I Travel time/cost M Intermodal	***Global freight connectivity*** O NUTS-3 regions D Intercontinental container throughput of European seaports I Travel time within 24 h M Road, rail	***Global potential accessibility freight*** O NUTS-3 regions D Container throughput of European seaports I Generalised time M Road, rail
Europe	***Travel (traditional)***	***Access to top ten MEGAs*** O NUTS-3 regions D Top ten MEGAs I Travel time (average) M Fastest of road, rail, air	***European daily accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions I Travel time within 5 h M Road, rail, air, fastest	***European potential accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions I Travel time M Road, rail, air, multimodal
	Travel (new)	***Travel speed*** O NUTS-3 regions D NUTS-3 regions weighted by transport demand of origins I Travel time M Road, rail	***Urban connectivity*** O Cities > 50.000 D Cities > 50.000 I Travel time within 3 or 5 h M Road, rail, air	***European potential acc. intermodal travel*** O NUTS-3 regions D Population of NUTS_3 regions I Travel time M Intermodal (all modes)
	Freight	***Access to nearest maritime ports*** O NUTS-3 regions D Nearest three maritime ports I Generalised cost M Road, rail, inland waterway	***European daily accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions I Travel time (maximum allowed for lorry drivers) M Road	***European potential accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions I Generalised time M Road, rail, inland waterways, short-sea shipping, air, intermodal

O Origins D Destinations I Impedance IF Impedance function M Modes

Table 15. Main dimensions of TRACC set of accessibility indicators (continued)

Spatial context	***Basic characteristics***	***Generic type of accessibility indicator***		
		Travel cost IF linear	***Cumulated opportunities*** IF rectangular	***Potential*** IF non-linear
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** O NUTS-3 regions / raster cells D Motorway exits, rail stations, airports I Weighted travel time (ICON) M Road, rail	***Availability of urban functions*** O NUTS-3 regions / raster cells D Cities > 50.000 I Travel time within 60 minutes M Road, rail	***National potential accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions of origin country I Travel time M Road, rail
	Freight (Europe-wide)	***Access to freight terminals*** O NUTS-3 regions / raster cells D Freight terminals I Weighted travel time (ICON) M Road, rail	***Availability of freight terminals*** O NUTS-3 regions / raster cells D Freight terminals I Travel time within 2 h M Road	***National potential accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions of origin country I Generalised costs M Road, rail
	Travel (case studies, traditional)	***Access to regional centres*** O LAU-2 regions / raster cells D Regional centre (next) I Travel time M Road, public transport	***Daily accessibility of jobs*** O LAU-2 regions / raster cells D Jobs of LAU-2 I Travel time within 60 minutes M Road, public transport	***Regional potential accessibility*** O LAU-2 regions / raster cells D Population of LAU-2 I Travel time M Road, public transport
	Travel (case studies, to services of general interest)	***Access to health care facilities*** O LAU-2 regions / raster cells D Hospital (nearest) at LAU-2 or exact location I Travel time M Road, public transport	***Availability of secondary schools*** O LAU-2 regions / raster cells D Secondary schools at LAU-2 or exact location I Travel time within 30 minutes M Road, public transport	***Potential accessibility to basic health care*** O LAU-2 regions / raster cells D General practice surgeries at LAU-2 or exact location I Travel time M Road, public transport

O Origins D Destinations I Impedance IF Impedance function M Modes

There are two different spatial reference systems for which accessibility indicators will be calculated. All global and all European accessibility indicators as well as Europe-wide regional travel and freight indicators will be calculated for NUTS-3 regions or partly for raster cells of the ESPON space and the Western Balkan. Turkey will not be included as internal zone in the accessibility models nor in the SASI model because this would raise some fundamental methodological and data issues.: If Turkey would be an internal zone, countries in the Caucasus, countries in the Arab world (Near East and Middle East), and also Russian regions in central Asia would have to become 'external zones', as they have direct boundaries with Turkey or because important transport routes are directly linked to Turkey. In consequence, this would require to include these countries as external zones into the models, and to collect all required network and socio-economic data for them as well. As this is not feasible in the TRACC framework the Turkish regions will be included as external zones only with higher spatial detail than done so far.

It has to be noted that the destinations in the accessibility models are not confined to the ESPON space and the Western Balkan. In particular for the indicators of the type cumulated opportunities and potential it is important to include destinations in Eastern Europe and North Africa to avoid edge effects. The second spatial reference system is that of the case study region for which the last two groups of accessibility indicators will be calculated.

The results of the different accessibility indicators will be presented in map form and analysed with respect to their spatial pattern. In addition, a post-processing of the indicators will be done to compare different accessibility indicators with each other. In particular a comparative analysis of European and regional accessibility is foreseen. In addition, it is planned to analyse accessibility through aggregation of indicators to relate it to the ESPON regional typologies, to calculate population shares that are living in locations with certain qualities of accessibility and to calculate different indices of territorial cohesion with respect to accessibility

The TRACC set of accessibility indicators yields a major innovation compared to other accessibility studies, because it addresses different aspects of accessibility of municipalities and regions in Europe in a systematic way, something that has not been done by any previous accessibility study. Once all the accessibility indicators will be available, each place in Europe can be classified according to different accessibility aspects ranging from its relative location in the global competition or within Europe down to the daily accessibility requirements of the local population.

4.2 Accessibility impact indicators

As indicated in Section 3.4, the relevant impacts of accessibility at the European or national level are *economic* and *environmental* impacts. At the intraregional level, the most important impacts are *social* impacts.

The indicators of *economic* impacts of accessibility will be produced by the SASI model: impacts on regional economic development expressed as gross domestic product (GDP) per capita and impacts on territorial cohesion expressed by several cohesion indicators. Cohesion indicators are either relative or absolute. Relative cohesion indicators measure relative convergence or divergence in terms of percent of GDP per capita. Absolute cohesion indicators measure absolute convergence or divergence in terms of GDP per capita in Euro. The difference between relative and absolute cohesion is important because relative convergence can be associated with absolute divergence. For instance, regions in the new EU member states may benefit from a certain transport infrastructure investment more than regions in the old member states in relative terms (in percent), but in absolute terms (in Euro) the regions in the old member states may benefit more. Relative cohesion indicators are the Gini coefficient, the coefficient of variation and the correlation between GDP per capita and the relative change in GDP per capita. Absolute cohesion indicators are the correlation between GDP per capita and the absolute change in GDP per capita.

Social impacts of accessibility, i.e. effects on social inclusion or exclusion by differences in access to services of general interest, will be measured by a number of accessibility indicators, such as travel time to the nearest urban centre, travel time to education facilities and travel time to health services.

Environmental impacts of accessibility will be measured as energy consumption and greenhouse gas emissions by transport calculated with a travel and goods transport model attached to the SASI model.

5 Selection of regional case studies

Global and European accessibility are important location factors for firms and working and leisure travel of people. However, for the daily life of citizens, regional/local accessibility to jobs, services and public facilities may be more important than global or European accessibility. One part of the TRACC project is therefore concerned with regional accessibility in a set of regional/local case studies in order to gain systematic knowledge on accessibility patterns in different types of regions throughout Europe.

One of the technical objectives for the regional case studies is that the methodologies to be implemented should be as similar as possible in order to allow a comparison of the resulting accessibility patterns, i.e. should not be disturbed by artefacts induced by methodological differences. In each case study, the set of regional accessibility indicators as defined in Chapter 4 will be calculated and analysed to arrive at comparable results as possible.

The TRACC project intends an exploratory analysis of regional accessibility patterns around Europe. For this, three considerations have guided the selection of the regional case studies.

- The case study areas to be selected for regional accessibility modelling in TRACC should cover a wide range of different types of regions in different parts of Europe. This asks for a relative large number of regions to be included.
- The comparison of regional/local accessibility patterns in different parts of Europe would be difficult if the case study regions would be limited to one or very few NUTS-3 regions that would be analysed in an isolated manner without having information on regional accessibility in the surrounding regions. Therefore, larger areas should form the spatial reference base of the case study regions.
- There are data constraints which are mainly related to network data. It is currently impossible to set up a harmonised network database for Europe, in particular for public transport, with the level of detail from which subsets could be extracted for regional case studies. Consequently, regional case studies have to be developed from existing regional network databases.

Based on these considerations the TRACC project has developed a specific concept for the case study regions. Each regional case study in TRACC consists of two integrated spatial layers, a macro region and a set of zoom-in areas.

- The macro region of a regional case study is usually defined at NUTS-0 or NUTS-1 level, i.e. contains a large number of NUTS-3 regions of different types.
- A number of zoom-in areas within each macro region usually to be defined at NUTS-3 level should represent different types of regions within each macro region.

The regional accessibility models of the case studies will be set up in a way that they calculate the accessibility indicators at least for LAU-2 regions, if possible for smaller raster cells. This allows on the one hand to analyse accessibility pattern for the wider area of the macro region with different types of regions and on the other hand more in-depth analyses for specific types of regions by looking into the zoom-in areas.

In order to be able to implement this spatial concept for the regional case studies, a pragmatic component had to be part of the selection process. Only those areas could be selected as macro regions for which project partners had already a fairly good database for accessibility modelling. As each project partner is responsible for one macro region, this results in seven macro regions in total for the regional accessibility analysis in TRACC. Figure 5 shows the seven TRACC macro regions selected: EURAM in Spain and France, Northern Italy, Bavaria in Germany, the Czech Republic, Poland, the Baltic Republics and Finland. Together, they form an arc stretching from the Mediterranean Sea in south-western Europe up to the far north of the Nordic countries. A portrait of each case study region is given in Annex A2.

Case study regions

Figure 5. TRACC regional case studies

The selection of macro regions in a continuous arc shape offers, in opposition to a scattered selection pattern, the possibility of an additional contrast of results along neighbouring macro regions. Transitions from one macro region to the next are to be expected relatively smooth because of the role of common geographies and socio-cultural and historical linkages. Such cross-section of Europe will allow a continuous analysis from south to north.

- The EURAM region and seaside Northern Italy are coastal corridor regions fringed by mountainous back areas in the Mediterranean framework.
- Northern Italy and Bavaria are densely populated regions located in flatlands topped by major mountain ranges, in this case the Alps.

- Bavaria, Czech Republic and Poland are part of the Central European plain, characterised by polycentric city structures.
- Czech Republic, Poland and the Baltic States, like many other new EU member states, have infrastructure deficits under way of amendment.
- Poland, the Baltic States and Finland form the south-eastern fringe of the Baltic Sea region.
- The Baltic States and Finland are peripheral regions with low density figures and conditioned by rigorous climates.

The case study regions cover a wide range of different types of regions in different parts of Europe. They cover both core and peripheral areas, inland, coastal and insular territories, urban and rural territories, densely populated and sparsely populated areas, flat and mountainous territories, territories located both in EU15 countries and in the new EU member states. Contrasting the case study regions with the nine standard ESPON territorial typologies, urban-rural, metropolitan regions, border regions, island regions, sparsely populated regions, outermost regions, mountainous regions, coastal regions, regions and regions in industrial transition, yields that the 275 NUTS-3 regions of the macro regions have almost for each regional typology the same share of regions of each type of region as the whole ESPON space (Table 16):

- In the case studies, there are slightly more rural regions and a little less urban regions than in the ESPON average. Northern Italy and Poland are those case study regions with the highest share of urbanised regions; EURAM, Northern Italy, Bavaria and Czechia have above-average shares of intermediate regions close to a city.
- The classification of the case study NUTS-3 regions in terms of metropolitanisation is very close to the overall ESPON average. Twelve percent of the NUTS-3 regions are small metropolitan, six percent are medium size metropolitan and 20 percent are big metropolitan regions.
- Also with respect to border regions, the case study regions with half of the regions classified as border regions closely follow the ESPON average.
- The share of island regions is slightly lower for the case studies than for the ESPON average. The EURAM and Finland case study have islands included.
- With the inclusion of Finland as case study, the share of sparsely populated regions of the case studies is almost two percent and such equals the ESPON space average.
- The share of mountainous regions is slightly lower for the case study regions than for the ESPON space. Northern Italy and Poland have the highest shares of regions falling in one of the mountainous categories.
- The share of coastal regions is slightly higher for the case study regions. Highest shares are in the EURAM region, the Baltic States and Finland, whereas Bavaria and Czechia do not have coastal regions at all.
- The share of regions in industrial transition is slightly higher for the case study regions than for the ESPON average. This is particular true for regions with industrial branches losing importance, in particular in Northern Italy, Bavaria and Czechia, but also for those with gaining importance with highest shares in Poland.

Within each macro region, between three and six zoom-in areas have been selected. The selection results in a good distribution of in total 30 zoom-in areas over different types of regions ensuring the in-depth study of different kinds of territorial typologies with different accessibility patterns associated. Table 17 gives an overview on the macro regions and zoom-in areas. Annex 3 contains for each case study a detailed portrait focussing on the territorial structure, the socio-economic situation and transport aspects with two maps for each case study showing the macro region and the zoom-in areas and presenting the spatial structure with a population density map.

Table 16. Case study regions and ESPON regional typologies

ESPON Typology of region	EURAM	Northern Italy	Bavaria	Czechia	Poland	Baltic States	Finland	**All case studies**	**ESPON Space**
NUTS-3 regions (total number)	11*	46	96	14	66	22	20	**275**	**1351**
Urban-rural regions *(% of NUTS-3 regions)*									
1 Predominantly urban	18,2	23,9	9,4	14,3	24,2	13,6	5,0	**16,0**	**23,2**
21 Intermediate, close to a city	54,5	45,7	43,8	42,9	33,3	22,7	20,0	**38,5**	**36,7**
22 Intermediate, remote	9,1	4,3	0,0	0,0	0,0	4,5	10,0	**2,2**	**1,6**
31 Predominantly rural, close to a city	9,1	23,9	44,8	42,9	37,9	31,8	30,0	**36,0**	**26,1**
32 Predominantly rural, remote	9,1	2,2	2,1	0,0	4,5	27,3	35,0	**7,3**	**12,4**
Metropolitan regions *(% of NUTS-3 regions)*									
1 Small metropolitan	18,2	10,9	10,4	7,1	16,7	9,1	10,0	**12,0**	**12,4**
2 Medium size metropolitan	0,0	10,9	3,1	7,1	7,6	9,1	0,0	**5,8**	**7,6**
3 Big metropolitan	18,2	19,6	20,8	21,4	28,8	9,1	10,0	**20,7**	**17,4**
0 Not a metropolitan region	63,6	58,7	65,6	64,3	47,0	72,7	80,0	**61,5**	**62,6**
Border regions *(% of NUTS-3 regions)*									
1 In eligible border program	27,3	58,7	27,1	92,9	65,2	86,4	50,0	**51,3**	**42,7**
0 Not in eligible border program	72,7	41,3	72,9	7,1	34,8	13,6	50,0	**48,7**	**57,3**
Island regions *(% of NUTS-3 regions)*									
1 Major island < 50 000 inhabitants	0,0	0,0	0,0	0,0	0,0	0,0	5,0	**0,4**	**0,9**
2 Major island between 50 000 – 100 000	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**0,4**
3 Major island between 100 000 – 250 000	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**0,5**
4 Island with 250 000 – 1 mill inhabs	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**1,2**
5 Island with >= 1 mill	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**	**2,2**
0 Not an island region	72,7	100,0	100,0	100,0	100,0	100,0	95,0	**98,5**	**94,7**
Sparsely populated regions *(% of NUTS-3 regions)*									
1 Sparsely populated	0,0	0,0	0,0	0,0	0,0	0,0	25,0	**1,8**	**2,0**
0 Not sparsely populated	100,0	100,0	100,0	100,0	100,0	100,0	75,0	**98,2**	**98,0**
Mountainous regions *(% of NUTS-3 regions)*									
1 Predominantly mountainous, remote	0,0	6,5	2,1	0,0	0,0	0,0	0,0	**1,8**	**6,5**
2 Predom. mountainous under urban influence	9,1	23,9	9,4	21,4	4,5	0,0	0,0	**9,8**	**13,7**
3 Moderately mountainous, remote	27,3	0,0	0,0	0,0	1,5	0,0	0,0	**1,5**	**1,9**
4 Moderat. mountainous under urban influence	0,0	10,9	10,4	21,4	1,5	0,0	0,0	**6,9**	**8,6**
0 Areas not covered by classification	63,6	58,7	78,1	57,1	92,4	100,0	100,0	**80,0**	**69,3**
Coastal regions *(% of NUTS-3 regions)*									
1 Coastal with low share of coastal population	0,0	10,9	0,0	0,0	3,0	9,1	10,0	**4,0**	**4,2**
2 Coastal with medium share of coastal pop.	9,1	4,3	0,0	0,0	3,0	9,1	0,0	**2,5**	**4,2**
3 Coastal with high share of coastal population	36,4	4,3	0,0	0,0	3,0	4,5	25,0	**5,1**	**6,5**
4 Coastal with very high share of coastal pop.	45,5	13,0	0,0	0,0	3,0	18,2	20,0	**7,6**	**15,2**
0 Areas not covered by classification	9,1	67,4	100,0	100,0	87,9	59,1	45,0	**80,7**	**69,9**
Regions in industrial transition *(% of NUTS-3 regions)*									
1 With industrial branches losing importance	36,4	73,9	69,8	57,1	25,8	31,8	40,0	**52,7**	**47,0**
2 With industrial branches gaining importance	0,0	4,3	3,1	0,0	28,8	9,1	5,0	**9,8**	**3,7**
3 With internal industrial structural change	27,3	4,3	8,3	35,7	9,1	18,2	10,0	**10,9**	**12,1**
0 Area not covered by typology	36,4	17,4	18,8	7,1	36,4	40,9	45,0	**26,5**	**37,2**

* Andorra not included in ESPON typologies

Table 17. Selected case studies - macro regions and zoom-in areas

Macro region	Zoom-in areas	Characteristics
EURAM Mediterranean Arc Euroregion	Andorra	Andorra is a small independent mountain country enclave with complex topography but important accessibility requirements due to primary tourist industry targeted to Spanish and French visitors.
	Pyrénées-Orientales / Girona	Pyrénées Orientales / Girona is selected to study accessibility at a transborder region between France and Spain.
	Barcelona	Barcelona is selected as being representative of major European metropolitan regions.
	Alacant	Alacant is selected as primary tourist region in Europe located on a coastal area.
	Menorca	Menorca is selected as a sparsely populated island with an important floating population in summertime. Being a biosphere reserve, Menorca needs to make compatible accessibility with environment preserving.
Northern Italy	Milan urban area	Milan has been chosen as being representative of major European metropolitan regions
	Piacenza province	Piacenza case study will measure accessibility in a province structured by radial lines centred in the capital and crossed by major corridors at trans-regional level.
	La Spezia province	La Spezia case study is interesting to analyse accessibility in a dense costal area with difficult mountainous characteristics, with intense port activity and growing tourism industry.
	Belluno province	Belluno case study is chosen as a mountain area attracting important amounts of tourists, especially in the winter season.
Bavaria	Munich region	The Munich region will give insights into accessibility patterns in a large urban area with a monocentric spatial structure.
	Nuremberg region	The Nuremberg region will provide knowledge about accessibility patterns in a medium-sized urban area with a polycentric spatial structure.
	Allgäu region	The Allgäu region in the south-western parts of Bavaria includes parts of the Alps and its foothills will depict accessibility patterns of rural and mountainous areas.
	Donau-Wald region	The Donau-Wald region in the eastern parts of Bavaria will provide findings concerning the accessibility situation of rural areas.
Czech Republic	Prague region	Prague metropolitan area as a key economic and service node of Czechia is characterized by intensive commuting processes, suburbanization, increasing concentration of inhabitants and economic wealth.
	Ústí region	Ústí in nord-west Bohemia at the border with Saxony represents the problems of the coal basin area. On the other hand, the region has a good position at the developmental axes connecting Dresden and Prague.
	Vysočina region	Vysočina region is a representative of mostly rural regions with low population density with settlement system of small munici-palities and a net of regional towns without a dominating centre.
	Olomouc region	Olomouc region shows a high inner contrast between the Olomouc regional capital agglomeration in the south and the rural and mountainous Jeseníky district in the north, one of the most peripheral areas in Czechia.

Table 17. Selected case studies - macro regions and zoom-in areas (continued)

Poland	Warsaw region	Warsaw is developing very fast while its road accessibility is poor; it will change in the next decade after the realization of the A2 motorway section to Warsaw and other express roads including southern Warsaw bypass.
	Dolnośląskie	Dolnośląskie is chosen due to the bad road and railway connection to Warsaw and good accessibility to European core areas.
	Zachodniopomorskie	Zachodniopomorskie will be studied due to the existence of port, regional airport, fragmented motorway and expressroad sections and foreseen accessibility changes in the next decade.
	Przemyski/Krosnienski subregions	Przemyski and Krosnienski subregions are selected due to 236 km of eastern Schengen zone border with Ukraine, unexplored Bieszczady mountains and very poor accessibility.
Baltic States	Tallinn (Estonia)	Tallinn region is selected as state capital and major seaport of Estonia having the highest concentration of services and infrastructure.
	Vöru (Estonia)	Vöru is a small town in a rural area of Estonia, but located at the crossroads of important east-west and north-south transport axes.
	Riga (Latvia)	Riga region is selected as state capital and major seaport of Latvia having the highest concentration of services and infrastructure.
	Rezekne (Latvia)	Rezekne is a medium-sized town in the eastern, rural part of Latvia towards the Russian border, where the economic performance is extremely poor compared to the EU27 average.
	Klaipeda (Lithuania)	Klaipeda is the main port of Lithuania, connecting the country to Western Europe and Scandinavia via several ferry services.
	Kaunas (Lithuania)	Kaunas is located in the central part of Lithuania at the crossroads of all north-south and east-west transport arteries, being a region with relatively high population densities in the context of the Baltic States.
Finland	Lapland	Lapland is chosen as a representative case of extreme periphery in the European context, substantially different to other rural regions in the rest of Europe.
	Oulu region	Oulu region is chosen as representative of a competitive growth centre located high up in the north, showing the contrast between different kinds of regional types, i.e. relatively developed urban and scarcely populated peripheral areas.
	Helsinki region	Helsinki is an illustrative example of high and good quality accessibility in spite of the physical remoteness in relation to the rest of Europe.

6 Database

The calculation of global, European and regional accessibility indicators requires comprehensive input data. Network data and socio-economic data for describing origin and destination features are needed at different spatial scales. Since TRACC covers the ESPON space and the Western Balkan as well as global destinations, data are also needed for countries beyond the ESPON space.

While this chapter focuses on the selected data to be used in TRACC, Annex A3 presents a detailed data assessment including potential data sources that eventually have not been selected.

6.1 European network and socio-economic data

Network data

A set of criteria has been applied to select the most suitable transport network database for TRACC. Selection criteria include (see Table A1 in Annex A3) available modes (road, rail, air, waterways, ferries, seaports, inland ports, freight villages), spatial coverage (ESPON space, EU candidate countries, countries of Western Balkan), network density (networks need to connect all NUTS-3 region centroids properly with each other), network topology (networks shall include built-in correct node-link topology), sufficient updates (2008-2011), temporal dimension (back-casting period, inclusion of future outline plans), relevant attributes (link types, lengths, speeds limits, travel times, frequencies), data formats (GIS formats), price and legal restrictions, continuity (preferable same data sets as used in previous ESPON projects), and general data availability.

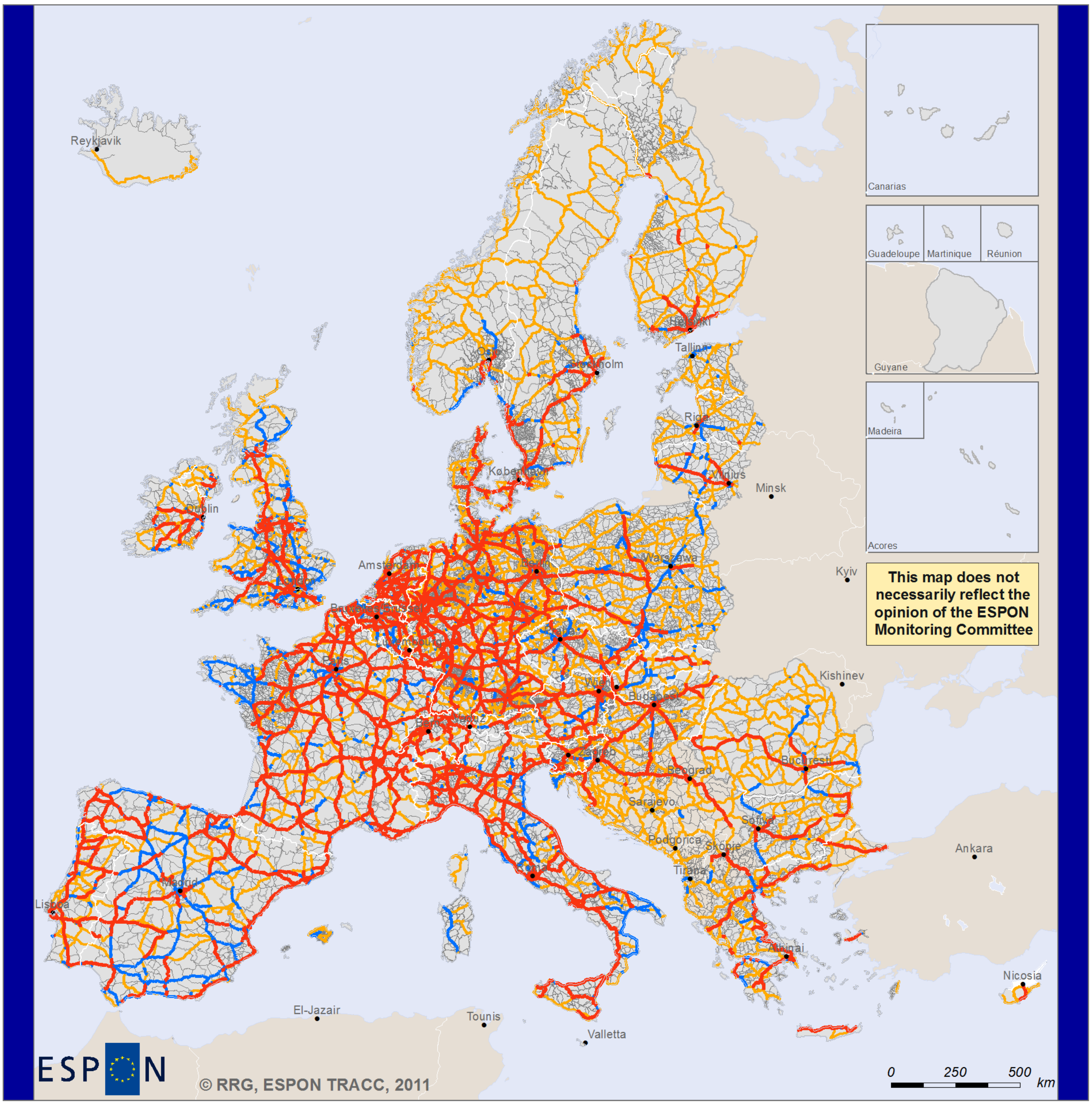
Eventually two network datasets have been selected: the TRANS-TOOLS networks will be used for the calculation of freight accessibility indicators, while the RRG GIS Database (RRG, 2011) will be used for the calculation of passenger travel accessibility indicators at the European level. RRG will complement the TRANS-TOOLS database with missing information (i.e. location of freight villages).

The selected datasets include all required modes with sufficient density (i.e. connectivity of centroids is ensured) for the most recent year, with network topologies already built in, and with all relevant attributes that are needed for accessibility modelling. Both data sets have been widely used in previous EU and ESPON projects, by that ensuring continuity of the TRACC results with previous indicator calculations. The TRANS-TOOLS and RRG networks are already available at the project partners free of charge in the required GIS formats, so that no additional data collection or data harmonisation are needed.

The necessary connector links, i.e. links connecting NUTS-3 region centroids to the networks and connecting different modal networks with each other, need to be generated automatically by scripts within the GIS.

In addition to the geographical network data, information on heavy-goods vehicle waiting times at border crossings will be retrieved from the IRU website to be used for the Europe-wide freight modelling.

Figure 6 illustrates the TEN-T road and rail networks, as well as airports and freight villages in Europe, derived from the RRG GIS Database (RRG, 2011), which have been selected for use in the Europe-wide passenger travel and to enrich the TRANS-TOOLS network database for freight modelling.



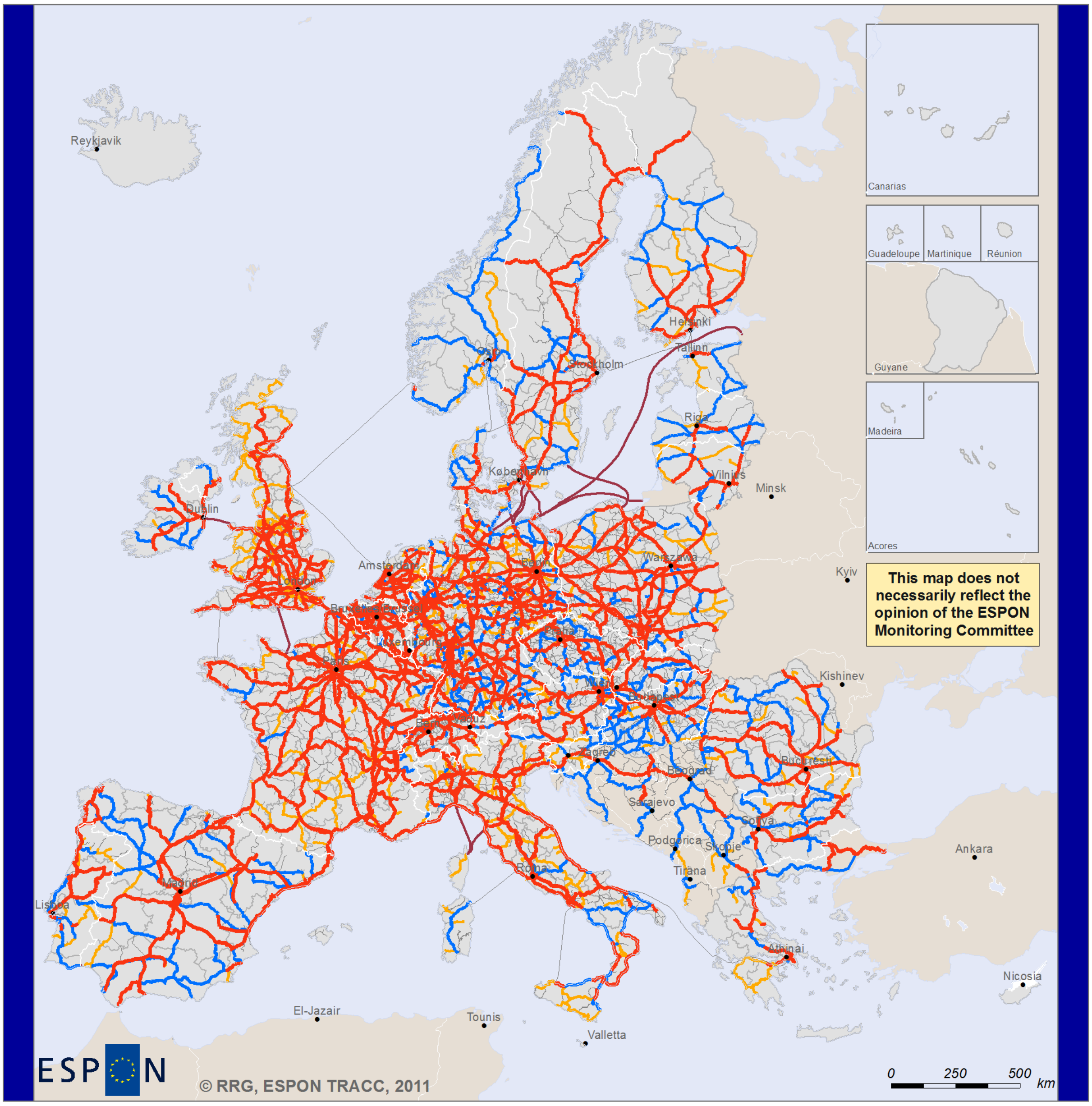
EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

RRG GIS Database, RRG 2011
© EuroGeographics Association for administrative boundaries

European-wide road network
(for European accessibility analyses)

- Motorway
- Express roads
- Trunk roads
- Other roads (non-modelling network)

Figure 6. Road network database



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

RRG GIS Database, RRG 2011
© EuroGeographics Association for administrative boundaries

European-wide rail network
(for European accessibility analyses)

- Main line, multiple tracks
- Main line, single tracks
- Secondary line
- Rail ferry
- Other rail lines (non-modelling network)

Figure 7. Rail network database

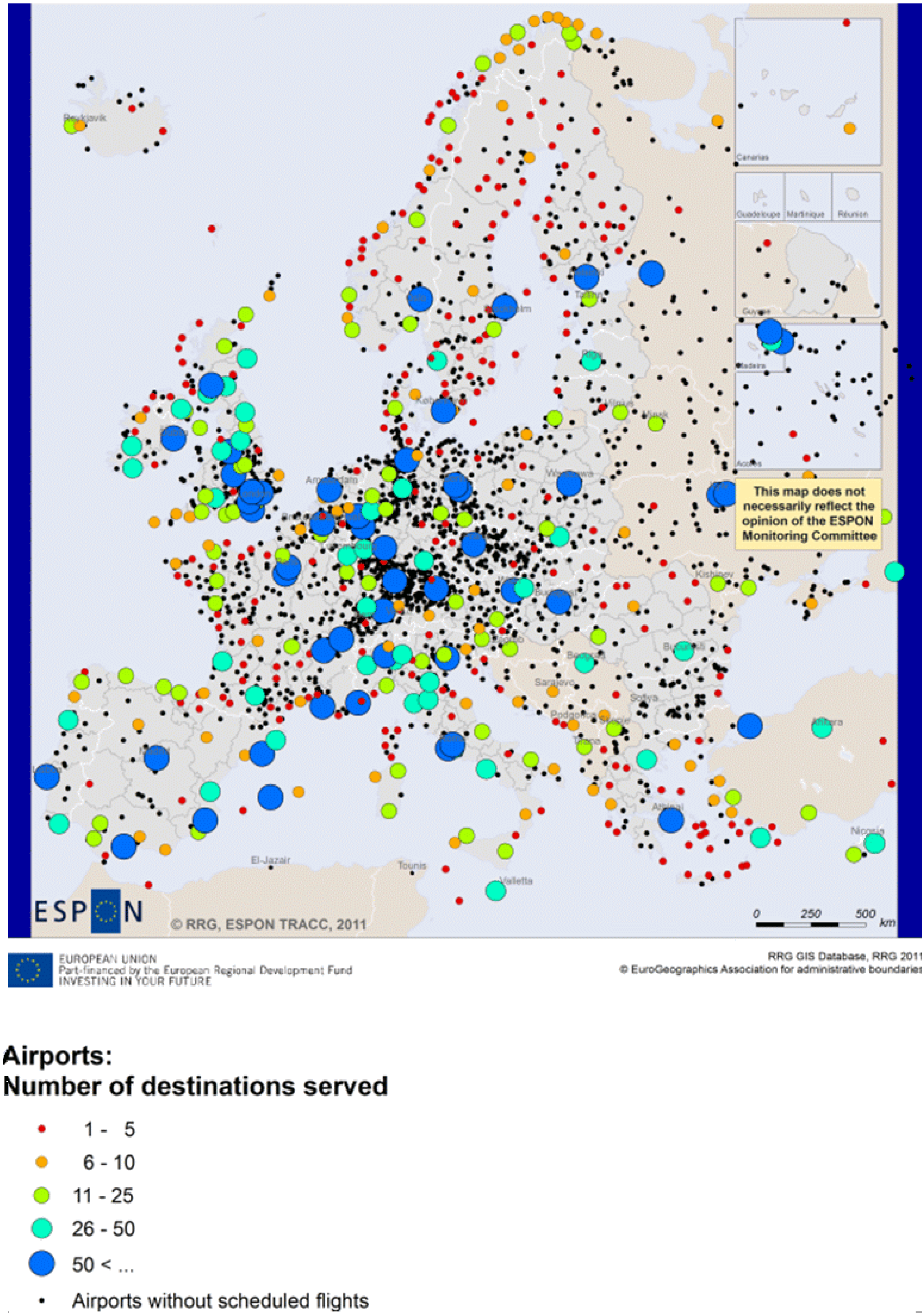


Figure 8. Airport database

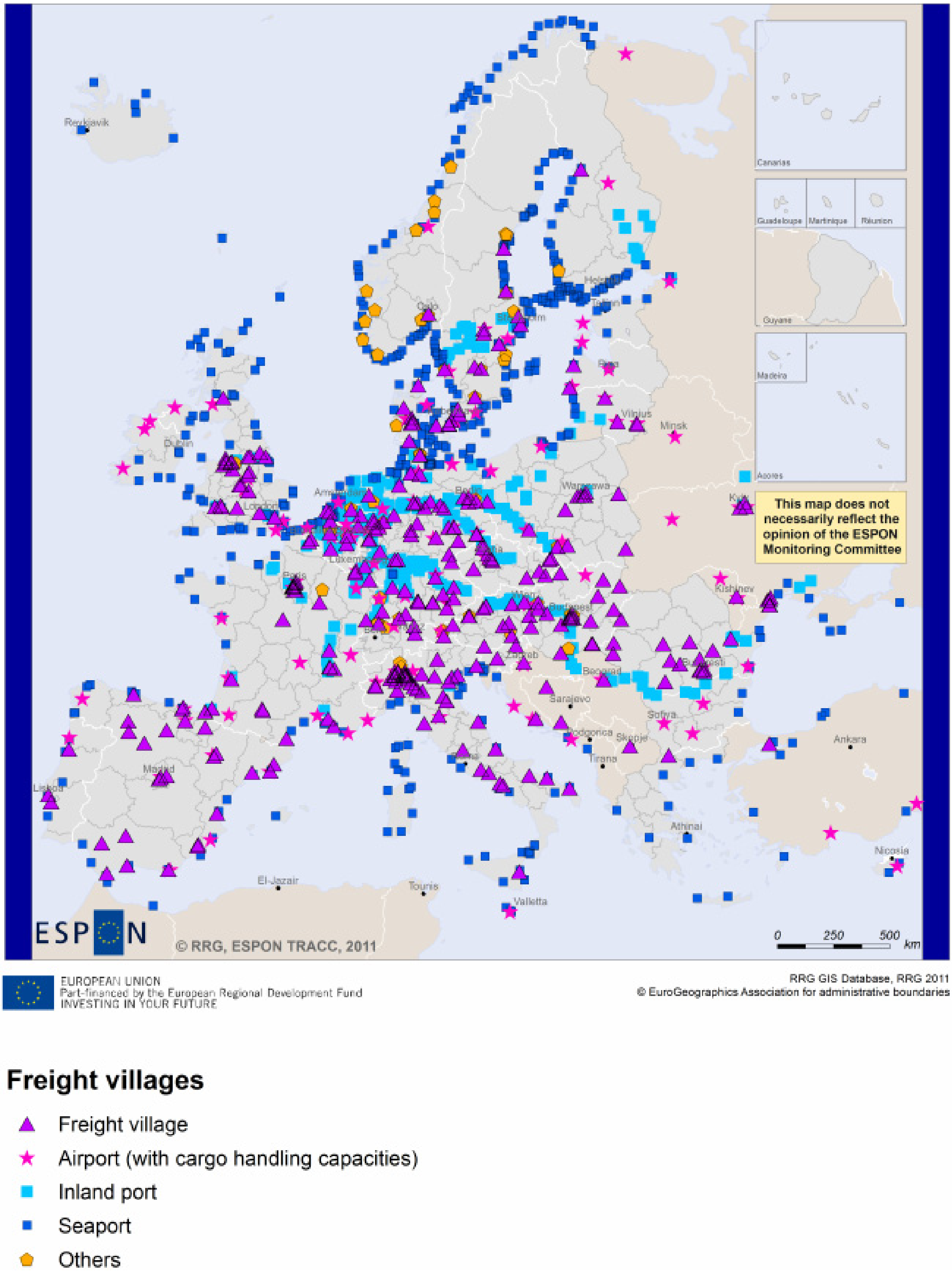


Figure 9. Freight village database

Socio-economic data

Different socio-economic data are needed, mainly for representing origin and destination activities in the accessibility formula, but also as input to the SASI model. Both, the travel and freight accessibility models as well as the SASI model cover the ESPON space, i.e. EU27 plus Norway and Switzerland, as internal zones. The regions of the Western Balkan are included as internal zones as well. Other European countries of Eastern Europe are treated as external zones. In addition, the freight model considers countries in North Africa as external zones.

Main data groups to be collected for the European and global accessibility models include population data (total population and population by age groups and sex), employment (total employment and employment by sector), GDP (absolute, per capita), and number of productive units and number of workplaces. The statistical data for the accessibility models are to be collected at NUTS-3 level according to the latest 2006 NUTS classification (Eurostat, 2007) for the internal and external zones of the accessibility models for the latest year available.

In addition, the SASI model requires simulation data, which can be grouped into base-year data and time-series data (see Annex A.2.6):

- Base-year data describe the state of the regions in the base year of the simulation (1981). Regional base-year data provide base values for the regional GDP submodel and the regional population submodel as well as base values for exogenous forecasts of changes in regional educational attainment and regional labour force participation. Required base year data include
    - 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 quality-of-life indicators in 1981
- Time-series data describe exogenous developments or policies 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 are defined for each simulation period, which are five year intervals from 1981 onwards. All GDP data are converted to Euro of 2006. Some of these data are required at the European level, some at the national level and some at regional (NUTS-3) level, as follows:
    - *European data*
        - Total European GDP by industrial sector, 1981-2031
        - Total European net migration, 1981-2031
    - *National data (34 countries)*
        - National GDP per worker by industrial sector, 1981-2031
        - National fertility rates by five-year age group and sex, 1981-2031
        - National mortality rates by five-year age group and sex, 1981-2031
        - National educational attainment, 1981-2031
        - National labour force participation by sex, 1981-2031
    - *Regional data (1,330 NUTS-3 regions)*
        - Regional endowment factors, 1981-2031
        - Regional transfers, 1981-2031

The SASI model works with network data in intervals of five years starting in 1981, i.e. socio-economic data for this period are required as well. Most of the historical data are already available with the project partners from previous model applications, but need to be converted to the latest 2006 NUTS classification.

Sources for socio-economic data

Existing data from the ESPON database will be used for most of the required data. If the ESPON database does not contain certain data, the online Eurostat Regio database and then the national statistical offices will be approached. Data from the Urban Audit and other data already available for the TRACC project partners may complement the data collection.

The socio-economic data for the different models and analyses will be harmonised as much as possible in order to avoid situations where different results are caused by different input data. Harmonisation will be done with respect to the following aspects: main data groups, spatial level, spatial coverage, reference year(s) and temporal dimension.

For the calculation of some accessibility indicators at raster level, a raster representation of population is required. For this, the project will use the latest version with 2006 data of the population grid produced by JRC and disseminated by the European Environmental Agency (EEA)..

EU Candidate countries and countries of Western Balkan

An assessment of the data situation in the EU candidate countries and other countries of Western Balkan revealed positive results (see Annex A3.3 for details): The data situation with respect to administrative boundaries and basic socio-economic data can be considered as generally good enough to include equivalent NUTS-3 regions of these countries as internal zones into the accessibility models and the SASI model, even though for some data groups data processing and data estimations will have to be done. The two network datasets (TRANS-TOOLS and RRG) already cover these countries with sufficient spatial detail. Region boundaries of administrative units that correspond to the NUTS-3 level have already been compiled by the ESPON Database project, and the necessary socio-economic data can be compiled either from Eurostat or from the national statistical offices.

6.2 Regional network and socio-economic data

Whereas for the Europe-wide accessibility and impact modelling NUTS-3 has been identified as the appropriate spatial resolution, the regional case studies will work at finer spatial resolutions (LAU-2, raster cells). Thus small scale regional data need to be collected. Because of the different scope, extent and character of the individual case studies, no overall regional case study database will be developed, but individual databases for each macro region will be set up in the responsibility of the project partner in charge of the case study. There will be between three and six zoom-in regions per macro region. There will be one case study database developed per partner, covering data for all zoom-in regions along with the data for the entire macro region.

Most of the required data are already available with the project partners, and can be used in TRACC. Unlike the database for the European accessibility modelling, the data sources used for the regional case studies differ from case study to case study. However, the necessary data groups (network data, socio-economic data, destination data) are harmonised. Table 18 lists the available data and data sources for the individual case studies.

Concerning the network data, apart from some necessary updates, in general network data for all required modes are already available in GIS format at sufficient detail with the project partners. Concerning the statistical data, the data for most case studies are already available with high resolution (i.e. municipality level, raster level). However, for some case studies some data are missing or are available at higher spatial levels only. The project partners will be responsible for collecting and updating the data necessary for their regional case studies at the required spatial resolution.

Table 18. Available data for regional case studies

Macro region	Network data	Statistical data
EURAM trans-border region (Spain, France, Andorra)	*Contents:* Networks for 2010 for road, rail, ferries, airports and seaports. Foreseen infra-structure networks with 2026 time horizon. *Source:* TRANS-TOOLS database, updated with interconnecting links. *Data format:* ArcGIS shapefile, Bridges	*Contents:* - Population, NUTS-3, 2010, LAU-2, 2006, 2010 - Number of workplaces, NUTS-3, 2006 - GDP (Mio EUR), NUTS-3, 2006 - Forced mobility (daily trips), LAU-2, 2001 - Air passenger by main airports, 2010 - Sea passenger transport by main ports, 2009 - Modal split, travel, NUTS-0, 2007 *Sources:* INE, Eurostat, Aena, Puertos del Estado, ESPON Database Project *Data format:* Dbase, Excel
Northern Italy	*Contents:* Road and rail network data consistent with LAU-2 zoning system. *Sources:* RRG GIS Database (rail), OpenStreetMap (road) *Data format:* ArcGIS shapefile, geodatabase *Remarks:* Original networks to be translated in for-mat usable by the MEPLAN model. Times in the rail network are based on actual schedules and not on track maximum allowable speed.	*Contents:* - Population by age and sex, LAU-2, 2010 - Population, LAU-2, 2006 - Workplaces, LAU-2 (2001). NUTS-3 (2009) *Source:* Italian Statistical Office (ISTAT), ESPON Database Project *Data format:* ASCII, Excel *Remarks:* Additional available data concern major transport infrastructure projects in the macro-region.
Bavaria (Germany)	*Contents:* Full road, rail and public transport net-works (busses, trams, subway) for Bava-ria for 2009. *Sources:* ATKIS, Public transport timetables with additions through S&W. *Data format:* ArcGIS shapefile, ASCII *Remarks:* Network data comprise a complete repre-sentation of road and public transport networks for Bavaria, i.e. all roads that can be used by cars are included and the public transport network is based on a complete public transport timetable.	*Contents:* - Population, LAU-2, 2008, also disaggregated to 100x100 m raster cells - Population, LAU-2, 2006 - Services of general interest (education, health care, public administration), exact locations, 2008 *Source:* Miscellaneous *Data format:* Excel, ASCII, ArcGIS shapefile

Table 18. Available data for regional case studies (continued)

Macro region	Network data	Statistical data
Czech Republic	*Contents:* Two network datasets available (1:500 000 and 1:150 000) for road, rail and air for 2006 for the whole of the Czech Republic. Road and rail attributes include, inter alias road number, length and category. *Sources:* ArcČR500 (1:500,000), CEDA 150 (1:150,000), Road and Motorway Directorate of the Czech Republic. *Data format:* ArcGIS shapefile, geodatabase, coverage *Remarks:* Data not fully updated, several errors in network topology.	*Contents:* - Population, LAU-2, 2006 - Public transport supply, NUTS-3, 2001-2008 - Number of cars, NUTS-3, 2001-2008 - GDP, NUTS-2/3, 2001-2008 - Active population, NUTS-2/3, 2005-2008 - Unemployment, NUTS-3, 3002-2008 - Net domestic/foreign migration, NUTS-3, 2001-2008 - Urban/rural population, NUTS-3, 2001-2008 - Foreign direct investments by sector, NUTS-3, 2007 - Production by sector, NUTS-3, 2008 - GVA, NUTS-3, 2008 - Public investments, NUTS-3, 2008 - Land use data by class, NUTS-3, 2001-2008 - Number of operating firms, NUTS-3, 2008 - Household consumption of goods/services, NUTS-3, 2008 - Regional budgets, NUTS-3, 2008 - Compensation of employees, NUTS-3, 2008 - Commuting flows between NUTS-3, 2008 - Group of environmental data, NUTS-3, 2008 *Source:* Czech Statistical Office, Ministry of Finance, Ministry of Internal Affairs, Ministry of Transportation, ESPON Database Project *Data format:* Excel, dbase
Poland	*Contents:* Network data for 2010 available for the whole of Poland for roads, railways, inland waterways incl. ports and seaports, and air; network density optimised for voivodships. Road attributes include road number, length, category, number of lanes, width, condition and congestion. Rail attributes include technical speeds and lengths, and also train timetable for 2010 as NUTS-3 matrix. *Sources:* IGSO PAS, General Directorate for National Roads and Motorways of Poland, Voivodship Road Administrations, PKP Polish Railway Lines JSC *Data format:* MapInfo *Remarks:* Rail speeds not precise and for 2008 only.	*Contents:* - GDP/GVA, NUTS-2/3, 1999-2008 - Population (total, by age and sex), LAU-2, 1995-2009 - Population, LAU-2, 2006 - Employment, NUTS-2, 2000-2009 - Employment persons in main workplace, LAU-2, 1995-2009 - Land use data, NUTS-3, 2000-2006 - Other data, LAU-2 *Sources:* IGSO PAS, Central Statistical Office of Poland, ESPON Database Project *Data format:* Excel, dbase

Table 18. Available data for regional case studies (continued)

Macro region	Network data	Statistical data
Baltic States (Estonia, Latvia, Lithuania)	*Contents:* Entire road and railway network incl. all stations (2010/2011). Tram networks for Tallinn, Riga and Vilnius (2010/2011). Ferry networks, inland waterway networks incl. all ports and seaports, airports and flight networks (2010/2011). *Sources:* RRG, OpenStreetMap *Data format:* ArcGIS shapefile, geodatabase	*Contents:* - Population, 2.5x2.5 km grid, 2000/2010 - Population, LAU-2, 2006/2008 - Population (total, by age group and sex), NUTS-3, 2000-2010 - GDP (total, PPS, per capita), NUTS-3, 2000-2010 - Built-up areas, 2.5x2.5 km grid, 2000/2010 - Employment (total, by sector), NUTS-3, 2000-2010 - Ports, exact location, container capacities and turnover, 2010 - Airports, exact location, cargo capacities and turnover, passenger capacities and turnover, 2010 - Major hospitals, exact location, 2010 - Universities, exact location, 2010 - Railway stations, exact location, 2010 - Tram and subway stations, exact location, 2010 *Sources:* RRG, European Environmental Agency (EEA), ESPON Database Project, Eurostat *Data format:* Dbase, Excel, ArcGIS Geodatabase
Finland	*Contents:* Network data for entire Finland for roads (2008), railways (2010/2011), inland waterways, seaports (2010 / 2011), airports (2010), domestic ferry routes, and border crossing points (2009). *Sources:* Finnish Transport Agency (Digiroad), Finnish Port Association, Finavia, Finnish Customs, RRG GIS Database (rail, airports, ports). *Data format:* ArcGIS shapefile, geodatabase. *Remarks:* Times in the rail network are based on actual schedules and not on track speeds; RRG data to complement with average track speeds.	*Contents:* - Population, 1x1 km grid, 1970, 1980/1990/2000/2005-2009; municipalities 1951-2007 with 2007 boundaries ; municipalities 2008-2009 ; 2010 expected to be available. - Population by age group and sex, 1x1 km grid, 2003/2007 - Population, LAU-2, 2006 - Education, 1x1 km grid, 2002/2006 - Income, 1x1 km grid, 2002/2006 - Households, 1x1 km grid, 2002/2006 - Sources of livelihood by 17 sectors, 1x1 km grid, 2002/2006 - Employment, 1x1 km grid, 2001/2005 - Built-up areas, 1x1 km grid, 1970/1980/1990/2000/2005 - Airports (cargo capacities and turnover, passenger capacities and turnover) - Ports (container capacities and turnover) *Source:* Statistics Finland, ESPON Database Project, RRG *Data format:* ArcGIS shapefile

6.3 Global data

Global data are required for modelling global travel and global freight accessibility indicators, such as access to global cities and freight hubs, global travel and freight connectivity, and global potential accessibility for travel and freight (see Chapter 4.1).

Following the chosen approach to model global accessibility the assembling of full road, rail, flight and waterway networks for all continents world-wide are not required for TRACC, as only a limited set of data are needed: First, only a very limited set of destinations is considered for the travel cost indicators, which are New York and Tokyo for passenger travel, and Shanghai and Detroit as major freight hubs. Second, global connectivity is measured by the number of flights of European airports to intercontinental destinations (travel), and by intercontinental container throughput of European seaports (freight). Third, for the potential accessibility indicator the intercontinental flights may be weighted by the destination mass, in other words, the global masses (such as population or GDP) of the intercontinental hubs are 'moved' to the European counterpart airports.

The chosen methodology requires only modest data collection while allowing the generation of meaningful global accessibility indicators. Table 19 summarizes the required global data along with potential data sources. It shows that most of these data are not yet available with the project partners and need to be gathered from the indicated sources.

Table 19. Data groups and data sources for global accessibility modelling

Data group	**Remarks**	**Data sources**	**Availability**
Travel cost indicators			
Global cities and hubs (New York, Tokyo, Shanghai, Detroit)	Location	RRG	Already available
Flight network	Network of direct flights between European airports and airports of selected global hubs	S&W	Partly available, but update necessary
Shipping network	Network of container ships between European container seaports and the seaports of selected global hubs	University of Oldenburg, Germany (Kaluza et al., 2010)	Not yet available, need to be collected
Cumulated opportunities			
European airports with intercontinental flights	Location of airports Intercontinental flights	RRG S&W	Already available Partly available, but update necessary
European container seaports	Location of seaports Intercontinental container throughput	RRG Port authorities, Eurostat (data on quarterly container traffic)	Already available Not yet available, need to be collected
Potential			
European airports with intercontinental flights	Destination weights (population/ GDP) for intercontinental destinations	OECD, World Bank	Not yet available, need to be collected

7 Towards policy conclusions

The final objective of the TRACC project is to create awareness and provide guidance for rational tradeoffs between the conflicting goals of competitiveness, territorial cohesion and environmental sustainability in the European transport policy (Figure 10). The project will evaluate the policy instruments available to the European Union to maintain and improve regional accessibility in order to support and thrust regional development while minimising negative implications for territorial cohesion and the environment. It will also formulate policy conclusions which can stimulate and enlighten the ongoing political discourse on transport and accessibility policy for decision makers, experts and the wider public.

It will be discussed to what extent the accessibility patterns in the European territory can contribute to generate development opportunities and how policy options take into account of the cohesion and environment policy orientations. At the end of the TRACC project, the findings of the project on accessibility patterns will be summarised in relation to the goals of the European Union in terms of competitiveness, territorial cohesion and environmental sustainability, and it will be discussed to what extent the European transport policy documents currently under revision, mostly the White Paper on Transport and the TEN-T programme, can contribute to the above mentioned objectives in the field of accessibility.

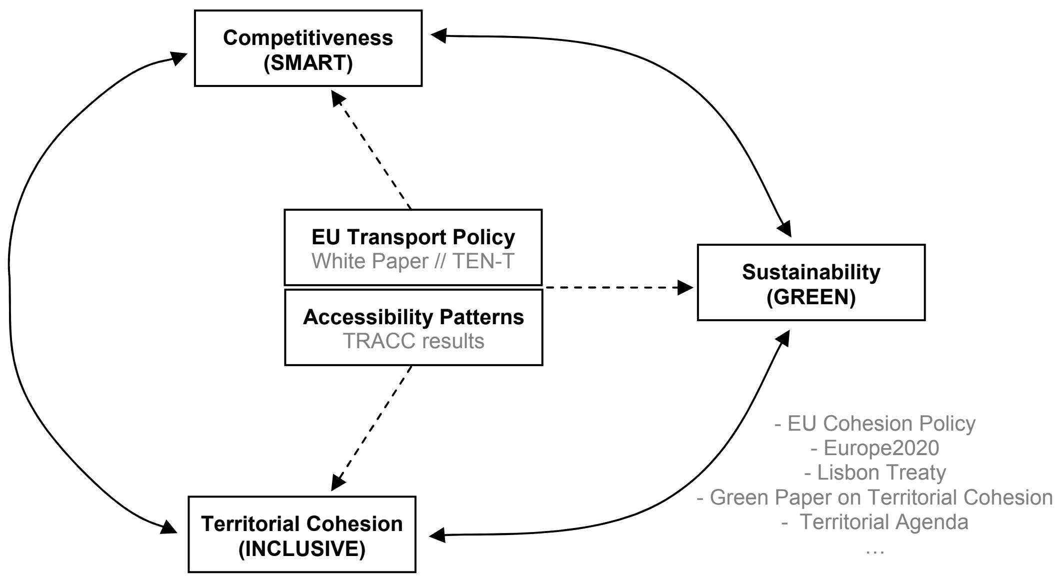


Figure 10. TRACC and the European policy debate

First, the results from passenger and freight accessibility analysis at a European and global level, as well as the results from regional case studies, and the results of the model scenarios on impacts of accessibility will be altogether checked against these general policy assumptions and policy documents. Major European policy development processes will include the Lisbon Treaty (2009), the Europe 2020 Strategy (2010), the EU Cohesion Policy towards 2013 and beyond, the Green Paper on Territorial Cohesion (2008), the Territorial Agenda of the EU (2007), the Hungarian Presidency report on the “updated analysis of the Territorial State and Perspectives of the EU” to be published during the first half of 2011, and the NTCCP report on “EU transport policy on territorial cohesion”.

Secondly, the European Common Transport Policy (CTP) and especially the White Paper on Transport of the EU and the TEN-T policy, both expected to be updated during the first half of the year 2011, will be critically read from a territorial point of view. It will be discussed to what extent they contribute to the territorial and social cohesion objectives stated in the above mentioned policy and strategy documents for the EU. The CTP, TEN-T policy and the Transport White Paper will be confronted with the capacity to maintain and improve the different types of regional accessibility in order to formulate conclusions to contribute to the ongoing political discourse on transport and accessibility policy.

A central element of the *Community Strategic Guidelines on Cohesion 2007-2013* (2005) is the assumption that transport infrastructure and accessibility are necessary conditions for economic growth in the Union, having a direct impact on the attractiveness of regions for businesses and people. This is supported by the *Reports on Economic and Social Cohesion* (2007, 2010), which reiterate how improved accessibility tends to create new job opportunities for rural and urban areas, but warns that potential benefits from improving accessibility depend on the previous competitiveness of the regions concerned, with some regions liable to lose out as they become more open to competition from elsewhere. The reports claim the importance of combining investment in transport infrastructure with support for businesses and human capital development to achieve sustainable economic and social development. The *Territorial Agenda of the EU* (2007) claims the need to support the extension of the TEN-T for economic development in all regions of the EU, especially in the EU12 countries, while the *Green Paper on Territorial Cohesion* (2008) puts the accent on regional and local accessibility as key elements for granting balanced access to services and European transport terminals and networks.

The *Common Transport Policy* is an essential component of the EU policy since the Maastricht Treaty of 1992, in which the concept of trans-European transport networks was introduced for the first time, with a special emphasis on interconnection and interoperability of the diverse national networks. The main policy instruments of the CTP are the White Paper on Transport and the TEN-T programme. The *White Paper on Transport* is the document of strategic reflection providing the conceptual framework for the CTP, having had substantial influence on EU, national and regional policies since 1992 (i.e. liberalisation of transport markets and modal change from road to rail). The 2009 EC communication triggered the debate for the 2011 White Book revision, proposing that focus should now turn on improving efficiency of the transport system through co-modality, technology development, and priority infrastructure investment on links with highest returns. The *TEN-T policy* is intended to increase the co-ordination in the planning of infrastructure projects by the member states. Progress in the TEN-T implementation has been relatively slow due to the scale, complexity and cost of the proposed projects in the past. TEN-T policy is currently also being updated to ease the process of implementation.

The discussion will be carried for the different types of regions, such as urban and rural areas, coastal areas, remote areas (i.e. mountains, islands), and also for core and peripheral regions and for EU-15 and EU-12 countries.

- *Core/Periphery*. Core regions have usually higher accessibility than peripheral regions, and benefit to a higher degree from investments in other parts. Efforts to significantly increase accessibility in peripheral areas may be very cost intensive. Improving the accessibility of peripheral areas while keeping investment policies efficient is a major concern.
- *Remote regions*. Special attention will be given to isolated regions, such as insular, mountain or peripheral regions. The several reports on cohesion state how accessibility on islands is often a problem due to the fact that their population is too small to support reasonable levels of infrastructure, while mountain areas have to face the paradox that deficits of accessibility lead to depopulation but increases in accessibility may conflict with environment protection.
- *EU15/EU12 countries*. Policy recommendations for the new EU member states will take into account the different phase in economic development of the new member states compared with the old member states. Infrastructure investment needs to be adapted to the specific needs and level of economic development of the regions and countries concerned (*Community Strategic Guidelines on Cohesion*).

Annexes

A1 Literature

Ajenjo, M., Alberich, J., Gumà, J., Tarriño, A.; Cladera, J.N. (2004): *Incidència de la xarxa viària en la població, el poblament i la mobilitat habitual de les persones.* Barcelona: Centre d'Estudis Demogràfics, Universitat Autònoma de Barcelona (UAB).

Alberich González, J. (2004): *Construcció i anàlisi comparativa d'indicadors d'accessibilitat per als municipis de Catalunya.* Geography PhD thesis paper. Barcelona: Centre for Demographic Studies, Autonomous University of Barcelona.

Andersson, M., Ejermo, O. (2005): How does accessibility to knowledge sources affect the innovativeness of corporations?— evidence from Sweden. *Annals of Regional Science* 39, 741–765.

Andersson, M., Karlsson, C. (2007): Knowledge in Regional Economic Growth – The Role of Knowledge Accessibility. *Industry and Innovation* 14, 129-149.

Andrei, S. (2010): *TENtec Information System. GIS Module and Methods to include TRACECA Data into TENtec Portal.* Presentation held at TRACECA GIS Experts Seminar, Brussels, 7 July 2010.

Angelidis, M. (2010): *Analysis of the Availability and the Quality of Data on Western Balkans and Turkey.* ESPON 2010 Database Project. Draft Report.

Arnesen, T., Overvåg, K., Gløersen, E., Schürmann, C., Riise, Ø. (2010): *Fjellområder og Fjellkommuner I Sør-Norge. Definisjon, avgrensning og karakterisering*. ØF-rapport 08/2010. Lillehammer: Østlandsforskning.

Aschauer, D.A. (1989): Is public expenditure productive? *Journal of Monetary Economics*, 23, 2, 177-200.

Aschauer, D.A. (1993): Public capital and economic growth. In: The Jerome Levy Economic Institute (ed.): *Public Policy Brief*. Annandale-on-Hudson: Bard College, 9-30.

Axhausen, K.W., Fröhlich, P., Tschopp, M: (2010): Changes in Swiss accessibility since 1850. *Research in Transportation Economics* (forthcoming).

BAK Basel Economics (2004): *Die internationale Verkehrsanbindung der Schweiz in Gefahr? Volkswirtschaftliche Beurteilung der Erreichbarkeit des Wirtschaftssandortes Schweiz und seiner Regionen.* Basel: BAK Basel Economics

BAK Basel Economics (2005): *Globale und kontinentale Erreichbarkeit. Ergebnisse der Modellerweiterung*. Basel: BAK Basel Economics.

BAK Basel Economics (2007): *Die Erreichbarkeit als Standortfaktor. Fakten und Analysen zur Erreichbarkeit der Nordschweiz.* Basel: BAK Basel Economics

Bartošová, Z. (2008): *Modelování prostorových interakcí na příkladu dálnice D3. Diploma thesis. Katedra sociální geografie a regionálního rozvoje.* Praha: PřF UK v.

BBR (2005): *Raumordnungsbericht 2005.* Berichte 21. Bonn: Bundesamt für Bauwesen und Raumordnung.

BBSR (2011): Erreichbarkeitsmodell des BBSR. http://www.bbsr.bund.de/cln_016/nn_23696/BBSR/DE/Raumbeobachtung/Komponenten/Erreichbarkeitsmodell/erreichbarkeitsmodell__node.html?__nnn=true

Benini, R. (ed.) (2007): *Regional polycentric urban system. Final Report*. INTERREG III B CADSES project on Strategy for a Regional Polycentric Urban System in Central Eastern Europe Economic Integrating Zone – Re-PUS. Bologna: Nomisma.

Biehl, D. (ed.) (1986): *The Contribution of Infrastructure to Regional Development*. Final Report of the Infrastructure Studies Group to the Commission of the European Communities. Luxembourg: Office for Official Publications of the European Communities.

Biehl, D. (1991): The role of infrastructure in regional development. In: Vickerman, R.W. (ed.): *Infrastructure and Regional Development*. London: Pion, 9-35.

Bjarnason, H. (2005): *Accessibility analysis for Reykjavik, Iceland*. Lund: Lund University.

Blum, U. (1982): Effects of transportation investments on regional growth: a theoretical and empirical investigation. *Papers of the Regional Science Association*, 49, 169-184.

Blahník, P. (2009): *Historicko-geografická analýza dostupnosti Prahy železniční dopravou v období 1918-2020 pomocí GIS.* Bachalor Thesis. Prague: Charles University in Prague, Faculty of Science, dpt. of applied geoinformatics and cartography.

Bökemann, D., Kramar, H. (1999): *Auswirkungen von Verkehrsinfrastrukturmassnahmen auf die regionale Standortqualität.* Österreichischer Bundesverkehrswegeplan Arbeitspaket N0-S. Wien: TU Wien, Institut für Stadt- und Regionalforschung.

Boruta, T., Ivan, I. (2010): Public transport in rural areas of the Czech Republic – case study of the Jeseník region. *Moravian geographical report* 18 (2), 9–22.

Bougromenko, V.N. (1997): Socio-sustaining roads. XIIIth World meeting of the International Road Federation.

Bozzani ,S., L'Hostis, A. (2006): Lille, une métropole sans aéroport international? Analyse de la performance territoriale du nœud air-fer à grande vitesse de Roissy Charles-de-Gaulle pour l'accessibilité lilloise. *Recherche Transports Sécurité* 92, 157-170.

Bröcker, J. (1998): Operational spatial computable general equilibrium modeling. *The Annals of Regional Science*, 32, 367-387.

Bröcker, J. (2004): Computable general equilibrium analysis in transportation economics. In: Hensher, D.A., Button, K.J. (eds.): *Transport Geography and Spatial Systems*. Handbook 5 of Handbooks in Transport. Kidlington, UK: Pergamon/Elsevier Science, 269-289.

Bröcker, J., Capello, R., Lundqvist, L., Meyer, L., Rouwendal, J., Schneekloth, N., Spairani, A., Spangenberg, M., Spiekermann, K., van Vuuren, D., Vickerman, R., Wegener, M. (2005): *Territorial Impact of EU Transport and TEN Policies*. Final Report of ESPON 2.1.1. Kiel: Institute of Regional Research, Christian Albrechts University. http://www.espon.eu/mmp/online/website/content/projects/243/239/file_374/fr-2.1.1_revised.pdf.

Bröcker, J., Korzhenevych, A., Schürmann, C. (2010): Assessing spatial equity and efficiency impacts of transport infrastructure projects. *Transportation Research Part B*, 44, 7, 795-811.

Bröcker, J., Meyer, R., Schneekloth, N., Schürmann, C., Spiekermann, K., Wegener, M. (2004): *Modelling the Socio-Economic and Spatial Impacts of EU Transport Policy*. Deliverable D6 of IASON (Integrated Appraisal of Spatial Economic and Network Effects of Transport Investments and Policies). Kiel: Institute of Regional Research, Christian Albrechts University.

Bröcker, J., Peschel, K. (1988): Trade. In: Molle, W., Cappelin, R. (eds.): *Regional Impact of Community Policies in Europe*. Aldershot: Avebury.

Bruinsma, F., Rietveld, P. (1993): Urban agglomerations in European infrastructure networks, *Urban Studies* 30, 919-934.

Buhr, W. (1975): *Die Rolle der materiellen Infrastruktur im regionalen Wirtschaftswachstum*. Berlin: Duncker & Humblot.

Capello, R. (2007): A forecasting territorial model of regional growth: the MASST model. *Annals of Regional Science*, 41, 4, 753-787.

Capello, R., Camagni, R., Fratesi, U., Chizzolini, B. (2008): *Modelling Regional Scenarios for an Enlarged Europe*. Berlin/Heidelberg: Springer.

Castells, M. (1989): *The Informational City*. Oxford: Basil Blackwell.

Cattan, N., Grasland, C. (1997/1998): *Les différentiels d'accessibilité des villes moyennes en France*. Volume 1 : L'accessibilité routière. Volume 2. Une approche multimodale, route et fer, Convention n°97 - MT 06, Paris: METI.

Cederlund, K., Erlandsson, U., Törnqvist, G. (1991): Swedish contact routes in the European urban landscape, Unpublished Working Paper. Lund: Department of Social and Economic Geography, University of Lund.

CERTET (2010): Analisi periodica dell'accessibilità aerea., Orario invernale 2009/10 n° 27. Allegato II, Il mercato cargo. Milano: CERTET.

Chapelon, L., Leclerc, R. (2007): *Accessibilité ferroviaire des villes françaises en 2020*. Montpellier: Groupement d'intérêt public RECLUS.

Chatelus, G., Ulied, A. (1995): *Union Territorial Strategies linked to the Transeuropean Transportation Networks*. Final Report to DG VII. Paris/Barcelona: INRETS-DEST/MCRIT.

Christaller, W. (1933): *Die zentralen Orte in Süddeutschland*. Jena. New edition, Darmstadt: Wissenschaftliche Buchgesellschaft, 1968.

Coase, R.H. (1960): The problem of social cost. *Journal of Law and Economics*, 3, 1, 1-44.

Commission for Rural Communities (2009): *Thinking about rural transport. Sustainable rural accessibility – is it really possible?* CRC Web 29.

Commission of the European Communities (2008): *Commission Staff Working Document Accompanying the Green Paper on Territorial Cohesion - Turning Territorial Diversity into Strength*. SEC (2009). Brussels: EC.

Cooper, S., Wright, P., Ball, R. (2009): Measuring the accessibility of opportunities and services in dense urban environments: experiences from London. In: *Proceedings of the European Transport conference 2009*. Association for European Transport (AET).

Copus, A.K. (1992): *An assessment of the peripherality of the Scottish Islands*. Report commissioned by the Shetland, Orkney and Western Isles Island Councils, Aberdeen.

Copus, A.K. (1994): *A peripherality index for the Scottish Highlands and Islands*. Report commissioned by the Highlands and Islands Objective 1 Partnership, Aberdeen.

Copus, A. K. (1997) *A New Peripherality Index for European Regions*. Report prepared for the Highlands and Islands European Partnership. Aberdeen: Rural Policy Group, Agricultural and Rural Economics Department, Scottish Agricultural College.

Copus, A. K. (1999) Peripherality and peripherality indicators, North. *The Journal of Nordregio* 10, 1, 11-15.

Dahlgren, A. (2005): *A proximity analysis application for large source datasets*. Östersund: NRDA.

Decoupigny, C. (2003): Couloirs de trafics et émissions de polluants. In: Mathis, P. (ed.): *Graphes et réseaux. Modélisation multiniveau*. Paris: Lavoisier, 187-211.

de la Barra, T. (1979): *Towards a Framework for Integrated Land Use and Transport Modelling*. PhD Dissertation. Cambridge: University of Cambridge.

de la Barra, T. (1989): *Integrated Land Use and Transport Modelling*. Cambridge: Cambridge University Press.

Dijkstra, L., Poelman, H. (2008) *Remote Rural Regions. How proximity to a city influences the performance of rural regions*, Regional Focus 1/2008. Brussels: European Commission, Regional Policy.

DfT – Department for Transport (2009a): *2008 Core National Local Authority Accessibility Indicators.* Final Report. London: DfT.

DfT – Department for Transport (2009b): *Core Accessibility Indicators Guidance.* London: DfT.

DHC (2006): *Calculation of Scottish public transport accessibility indicators*. Report on Index Calculation.

Dixit, A.K., Stiglitz, J.E. (1977): Monopolistic competition and optimum product diversity. *American Economic Revue*, 67, 297-308.

Domański, R. (1979): Accessibility, efficiency and spatial organization. *Environment and Planning A* 11, 1189-1206.

DRE Aquitaine (2008): *La desserte des territoires. L'accessibilite des voyageurs en Aquitaine.* Bagneux: Direction régionale de l'Équipement en Aquitaine. ttp://www.aquitaine.equipement. gouv.fr/article.php3?id_article=674

Dubois, A., Schürmann, C. (2009): Transport and accessibility in the Baltic Sea Region – structures and perspectives. In: *Informationen zur Raumentwicklung,* 8/9.2009. Bonn: BBR.

Echenique, M. (2004): Econometric models of land use and transportation. In: Hensher, D.A., Button, K.J. (Hg.): *Transport Geography and Spatial Systems*. Handbook 5 of Handbooks in Transport. Kidlington, UK: Pergamon/Elsevier Science, 185-202.

Echenique, M.H., Crowther, D., Lindsay, W. (1969): A spatial model for urban stock and activity. *Regional Studies*, 3, 281-312.

Echenique, M.H., Flowerdew, A.D.J., Hunt, J.D., Mayo, T.R., Skidmore, I.J., Simmonds, D.C. (1990): The MEPLAN models of Bilbao, Leeds and Dortmund *Transport Reviews*, 10, 309-322

EEA – European Environmental Agency (2010): *Corine Land Cover 2000 by Country*. Copenhagen: EEA. http://www.eea.europa.eu/data-and-maps/figures/corine-land-cover-2000-by-country-1.

Erlandsson, U., Törnqvist, G. (1993): Europe in transition. In: Törnqvist, G. (Ed.): *Sweden in the World. National Atlas of Sweden*. Stockholm: Almqvist & Wiksell International, 148-155.

ESPON (2009): *Territorial Dynamics in Europe - Trends in Accessibility*. Territorial Observation 2. Luxembourg: ESPON 2013 Programme.

ESPON 1.1.3 (2006): Enlargement of the European Union and the Wider European Perspective as regards its Polycentric Spatial Structure. Final Report of ESPON 1.1.3. Stockholm: Royal Institute of Technology. http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/ThematicProjects/Polycentricity/fr-1.1.1_revised-full.pdf.

ESPON 1.2.1 (2005): *Transport Services and Networks: Territorial Trends and Basic Supply of Infrastructure for Territorial Cohesion*. Final Report of ESPON 1.2.1. Tours: University of Tours.

ESPON 3.2 (2006): *Spatial scenarios and orientations in relation to the ESDP and cohesion policy* (Third interim report). Brussels: IGEAT, Free University of Brussels. http://www.espon.eu/ mmp/online/website/content/projects/ 260/716/file_1256/3.ir_3.2-full.pdf.

ESPON 3.4.1 (2007): *Europe in the World. Territorial Evidence and Visions*. Luxembourg: ESPON CU.

ESPON FOCI (2010): *Future Orientations for Cities.* Applied Research Project 2013/1/1. Draft Final Report. Luxembourg, Brussels: ESPON CU & ULB.

Eupolis (2007): *Torino a confronto. Benchmarking della competitività e della coesione urbana in Europa.* Rapporto 2006. Torino.

European Commission (1995): *Transeuropäisches Verkehrsnetz. Fakten und Zahlen*. Luxembourg: Office for Official Publications of the European Communities.

European Commission (1998): *Trans-European Transportation Network. Report on the Implementation of the Guidelines. Basic Data on the Networks.* Report to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions on the implementation of the guidelines for the development of the trans-European transport network (Decision 1692/96/EC).

European Commission (1999): *14 TEN Priority Projects.* http://europa.eu.int/en/comm/dg07/tentpp9807/index htm

European Commission (2002a): *Revision of the Trans-European Transport Networks "TEN-T". Community Guidelines.* http://europa.eu.int/comm/transport/themes/network/english/ten-t-en.html. 02-04-2002. Brussels: European Commission.

European Commission (2002b): *Trans-European Transport Network. TEN-T priority projects.* Luxembourg: Office for Official Publications of the European Communities.

European Commission (2003a): *A European Initiative for Growth. Investing Networks and Knowledge for Growth and Jobs.* Final Report to the European Council. COM(2003)690 final/2. Brussels: Commission of the European Communities.

European Commission (2003b): *Vorschlag für eine Entscheidung des Europäischen Parlaments und des Rates zur Änderung des geänderten Vorschlages für eine Entscheidung des Europäischen Parlaments und des Rates zur Änderung der Entscheidung Nr. 1692/96/EG über gemeinschaftlich Leitlinien für den Aufbau eines transeuropäischen Verkehrsnetzes.* Brüssel: Kommission der Europäischen Gemeinschaften.

European Commission (2010): Investing in Europe's Future. Fifth Report on Economic, Social and Territorial Cohesion. Luxembourg: Publication Office of the European Union.

European Communities (1996): Decision No. 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on the Community guidelines for the development of the trans-European transport networks. *Official Journal of the European Communities* 39, L 228, 9, 1-104.

European Communities (2001): Decision No. 1346/2001/EC of the European Parliament and of the Council of 22 May 2001 amending Decision No 1692/96/EC as regards seaports, inland ports and intermodal terminals as well as project No 8 in Annex III. *Official Journal of the European Communities* 44, L 185, 6.7.2001, 1-36.

European Parliament (ed.) (2007): *Regional Disparities and Cohesion: What Strategies for the Future?* IP/B/REGI/IC/2006_201. Brussels: European Parliament.

European Union (2004): Decision No 884/2004/EC of the European Parliament and of the Council of 29 April 2004 amending Decision No 1692/96/EC on Community guidelines for the development of the trans-European transport network. *Official Journal of the European Union L 167, 1–38.*

Eurostat (2007): *Regions in the European Union. Nomenclature of Territorial Units for Statistics. NUTS 2006/EU-27.* 2007 Edition. Luxembourg: Office for Official Publications of the European Communities.

Fan, W., Treyz, F., Treyz, G. (2000): An evolutionary New Economic Geography model. *Journal of Regional Science*, 40, 4, 671-695.

Figueira P., Viegas J. (1999): A Proposed Methodology for Measuring Accessibility Taking into Account Economic Relations and Daily Cycles. PTRC P435, AET.

Fiorello, D., Huismans, G., López, Marques, C., Steenberghen, T., Wegener, M., Zografos, G. (2006): Transport Strategies under the Scarcity of Energy Supply. STEPs Final Report, edited by A. Monzon and A. Nuijten. The Hague: Buck Consultants International. http://www.steps-eu.com/ reports.htm.

Florida, R. (2004): *The Rise of the Creative Class*. New York: Basic Books.

Forrester J.W. (1968): *Principles of Systems*. Waltham, MA: Pegasus Communications.

Forslund, U.M., Johansson B. (1995): Assessing road investments: accessibility changes, cost benefit and production effects. *Annals of Regional Science* 29, 155-174.

Fröhlich, P., Tschopp, M., Axhausen, K.W. (2006): Entwicklung der Erreichbarkeit der Schweizer Gemeinden: 1950-2000. *Raumforschung und Raumordnung*, 64,(6), 385-399.

Frost, M.E., Spence, N.A. (1995): The rediscovery of accessibility and economic potential: the critical issue of self-potential. In: *Environment and Planning* A 27, 1833-1848.

Fujita, M., Krugman, P. Venables, A.J. (1999). *The Spatial Economy: Cities, Regions, and International Trade*. Cambridge, MA: MIT Press.

Gadziński, J., Beim, M. (2010): Public transport accessibility in Poznań, REAL CORP reviewed paper. http://www.corp.at/archive/CORP2010_70.pdf.

García Palomares, J. C. (2000): *El impacto de las autopistas orbitales en la accesibilidad del área metropolitana de Madrid.* In: Tecnologias Geográficas para el Dearrollo Sostenible. Alcalá: Dppartamento de Geografia, Universidad de Alcalà, 623-639.

Gløersen, E. (2009): *Strong, Specific and Promissing. Towards a Vision for the Northern Sparsely Populated Areas in 2020.* Nordregio Report 2009: 2. Stockholm: Nordregio.

Gløersen, E., Dubois, A., Copus, A., Schürmann, C. (2006): *Northern Peripheral, Sparsely Populated Regions in the European Union and in Norway.* Nordregio Report 2006:2. Stockholm: Nordregio.

Grasland, C. (2000): L'inégale accessibilité routière des villes de plus de 20 000 habitants., in Mattei M.F. & Pumain D. (eds.), *Données Urbaines* 3 Paris: Anthropos, CNRS-INSEE, 309-326.

Gutiérrez Gallego, J.A., Pérez Pintor, J.M., Mora Aliseda, J. (2010): Dimensión y tipología de los movimientos transfronterizos en la frontera entre España (Extremadura) y Portugal (Alentejo y Región Centro). *Documents d'Anàlisi Geogràfica* 56/1, 133-148.

Gutiérrez, J., González, R., Gómez, G. (1996): The European high-speed train network: predicted effects on accessibility patterns. *Journal of Transport Geography* 4, 227-238.

Gutiérrez, J., Urbano, P. (1996): Accessibility in the European Union: the impact of the trans-European road network. *Journal of Transport Geography* 4, 15-25.

Guzik, R., Kołoś, A. (2003): Evolution of accessibility in Carpathian spa resorts between 1938 and 2000. In: Kurek, W. (ed.): *Issues of Tourism and Health Resort Management*. Prague: Prace Geogr., Inst. Geogr. UJ, 111, 356-368.

Guzik R., (2003): The spatial accessibility of post-elementary education, Krakow: IGiGP, JJagiellonian University. [in Polish].

Györffy, I. (2006): Regional disparities of the transport infrastructure in northenrn Hungary. Downloaded from http://www3.ekf.tuke.sk/konfera2008/zbornik/files/prispevky/gyorffy.pdf, 223–230.

Hamed and Krause (2010): *Monitoring TRACECA Route Attractiveness -TRACECA Route Attractiveness indeX (TRAX).* TRACECA IDEA Project -Working Document. Milan: TRT.

Hanell, T., Bengs, C., Bjarnadóttir, H., Platz, H., Spiekermann, K. (2000): *The Baltic Sea Region Yesterday, Today and Tomorrow – Main Spatial Trends.* Working Paper 2000:10. Stockholm: Nordregio.

Hanes, Z. ((2010): Analýza diferenciace cenové, časové a vzdálenostní akcesibility v rámci sítě ČD. Master thesis. Prague: Department of Social Geography and Regional Development, Charles University, Faculty of Science.

Hernández, J.L. (2002): Temporal accessibility in archipelagos: inter-island shipping in the Canary Islands. *Journal of Transport Geography* 10, 231-239.

Higgs, G., White, S.D. (2000): Alternatives to census-based indicators of social disadvantage in rural communities. *Progress in Planning* 00, 1-81.

Horňák, M. (2005): *Dostupnosť siete diaľnic a rýchlostných ciest v SR*. Bratislava: Department of Human Geography and Demography, Faculty of Science, Commenius University, Bratislava.

Hrnčiarovà, T., Mackovčin, P., Zvara, I. (2009): *Atlas krajiny České republiky/Landscape Atlas of the Czech Republic.* Praha: Ministerstvo životního prostředí České republiky, Výzkumný ústav Silva Taroucy pro krajinu a okrasné zahradnictví, v.v.i..

Hunt, J. D., Abraham, J. E.(2005): Design and implementation of PECAS: a generalised system for the allocation of economic production, exchange and consumption quantities. In: Lee-Gosselin, M.E.H., Doherty, S.T. (eds.): *Integrated Land-Use and Transportation Models: Behavioural Foundations*. St. Louis, MO: Elsevier, 253–274.

Hůrský, J. (1969): *Metody grafického znázornění dojížďky do práce*. Rozpravy ČSAV 79, č. 3. Praha: Academia.

Hůrský, J. (1974): Klasifikace měst ČSR podle polohy v dopravních sítích. *Sborník ČSSZ 79*. (2), 101−107.

Hůrský, J. (1978a): *Metody oblastního členění podle dopravního spádu.* Rozpravy ČSAV 88, č. 6. Praha: Academia.

Hůrský, J. (1978b): *Regionalizace České socialistické republiky na základě převládajícího spádu osobní dopravy.* Studia geographica, 59, Brno: Geografický ústav ČSAV.

IRU – International Road Union (2011): *Truck/coach waiting times at borders*. www.iru.org. Geneva: IRU.

Ivanova, O. (2007): On the development of the new version of the RAEM model for the Netherlands. Paper presented at the Joint Congress of the European Regional Science Association and ASRDLF, Paris. http://sadapt.agroparistech.fr/ersa2007/papers/640.pdf.

Jakimavicius, M., Macerinskiene, A. (2006): Accessibility Based Automobile Transport System Analysis in Lithuanian Regions and Forecasting Potential in Residential Areas. In: Brebbia, C.A., Dolezel, V. (eds.): *Urban Transport XII. Urban Transport and the Environment in the 21st Century.* Southampton: WIT Press Publishing, 141-150.

Jakubauskas, G. (2008): *Improvement of urban transport accessibility for the passengers with reduced mobility by applying intelligent transport systems and services*. Proceedings of the 9th International Conference Reliability and Statistics in Transportation and Communication RelStat'08, Riga, Latvia.

Jochimsen, R. (1966): *Theorie der Infrastruktur. Grundlagen der marktwirtschaftlichen Entwicklung*. Tübingen: Mohr.

Johansson, S., Karlsson, C. (2007): R&D accessibility and regional export diversity. *Annals of Regional Science* 41, 501–523.

Johansson, B., Klaesson, J., Olsson, M. (2002): Time distances and labour market integration. *Papers in Regional Science* 81, 305–327.

Kaluza, P.; Kölzsch, A.; Gastner, M.t.; Blasius, B. (2010): The complex network of global cargo ship movements. *Journal of Royal Society Interface* 7, 1093-1103.

Katsios I., Tsatsaris A., Sakellariou A. (2006): Spatial Typology of the Greek Territory based on Transport Accessibility Indicators: A Cartographical Approach using G.I.S. ERSA Conference Papers, European Regional Science Association.

Keeble, D., Owens, P.L., Thompson, C. (1982) Regional accessibility and economic potential in the European Community. *Regional Studies* 16, 419-432.

Keeble, D., Offord, J., Walker, S. (1988): *Peripheral Regions in a Community of Twelve Member States*. Luxembourg: Commission of the European Communities.

Kelly, M., Flowerdew, R., Francis, B., Harman, j. (2001): Measuring accessibility for remote rural populations. In: Kidner, D.B.; Higgs, G. (ed.) (2001): *GIS research in the UK. Proceedings of the GIS Research UK 9th Annual Conference GISRUK 2001.* University of Glamorgan.

Komornicki, T., Śleszyński, P. (2009): Locational studies for regional airports in Mazovia. *Geographical Studies* 220. Warsaw: IGiPZ PAN. [in Polish].

Komornicki, T., Śleszyński, P., Rosik, P., Pomianowski, W. (2010): Spatial accessibility as a background for Polish transport Policy. *Biuletyn KPZK*. Warsaw [in Polish].

Kotavaara. O., Antikainen H., Rusanen, J. (2010): Population change and accessibility by road and rail networks: GIS and statistical approach to Finland 1970–2007. *Journal of Transport Geography*. doi:10.1016/j.jtrangeo.2010.10.013.

Kraft, S. (2008): Time accessibility – příklad deformace prostoru generované dopravou. *Miscellanea Geographica* 14, 77–84.

Krugman, P. (1991): *Geography and Trade*. Leuven: Leuven University Press.

Krugmann, P., Venables, A. (1995): Globalisation and the inequality of nations. *Quarterly Journal of Economics*, 60, 4, 857-880.

Květoň, V. (2006): *Hodnocení dopravních možností obyvatel: analýza okresů Česka a mikroregionální pohled.* Diplomová práce. Praha: Katedra sociální geografie a regionálního rozvoje PřF UK.

Leontief, W. (1966): *Input-Output-Economics*. Oxford: Oxford University Press.

L'Hostis, A., Menerault, P., Decoupigny, C. (2004): Assessing spatial planning policy with accessibility indicators: the case of Lille's metropolis scenario. In: Beuthe, M., Himanen, V., Reggiani, A., Zamparini, L. (eds.): *Transport Development and Innovation in an Evolving World.* Berlin, Heidelberg, New York: Springer, 293-311.

Linneker, B.J., Spence, N.A. (1992): An accessibility analysis of the impact of the M25 London orbital motorway in Britain. In: *Regional Studies* 26, 31-47. Regional Studies Association.

Lösch, A. (1940): *Die räumliche Ordnung der Wirtschaft*. Jena. New edition, Stuttgart: Fischer, 1962.

López Suárez, E. (2007): *Assessment of transport infrastructure plans: a strategic approach integrating efficiency, cohesion and environmental aspects.* Doctoral Thesis. Madrid: Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Universidad Politécnica de Madrid.

López Suárez, E., Monzón de Cáceres, A., Mancebo Quintana, S., Ortega Pérez, E., Gutiérrez Puebla, J., Gómez, G. (2006): *Impactos territoriales del PEIT: Plan Estratégico de In-fraestructuras y Transporte 2005-2020.* 7th Congress of Transport Engineering, Ciudad Real, Spain.

López Suárez, E., Monzón de Cáceres, A., Mancebo Quintana, S., Ortega Pérez, E. (2008): *Análisis de la accesibilidad territorial debida a la alta velocidad en dos corredores ferroviarios en el marco del PEIT*. 8th Congress of Transport Engineering, 02-04 July 2008, A Coruña, Spain.

López Suárez, E., Ortega Pérez, E., Condeço-Melhorado, A. M. (2009): *Análisis de impactos territoriales del Plan Estratégico de Infraestructuras y Transporte 2005-2020: Cohesión regional y efectos desbordamiento.* Revista ICE Mayo-Junio 2009. N.º 848. Madrid: Secretaria de Estado de Comercio, Ministerio de Industria, Turismo y Comercio de España.

Lovett, A., Haynes, R., Sünnenberg, G., Gale, S. (2000): *The accessibility of primary health care services in East Anglia*. Paper presented at the 9th Int. Symposium on Medical Geography, Montreal, Canada.

Lovett, A., Sünnenberg, G., Haynes, R. (2001): Accessibility to GP surgeries in South Norfolk: A GS-based assessment of the changing situation 1997-2000. In: Kidner, D.B.; Higgs, G. (ed.) (2001): *GIS research in the UK. Proceedings of the GIS Research UK 9th Annual Conference GISRUK 2001.* University of Glamorgan.

Lutter, H., Pütz, T., Spangenberg, M. (1992): *Accessibility and Peripherality of Community Regions: The Role of Road, Long-Distance Railways and Airport Networks*. Report to the European Commission, DG XVI. Bonn: Bundesforschungsanstalt für Landeskunde und Raumordnung.

Lutter, H., Pütz, T., Spangenberg, M. (1993): *Lage und Erreichbarkeit der Regionen in der EG und der Einfluß der Fernverkehrssysteme*. Forschungen zur Raumentwicklung 23. Bonn: Bundesforschungsanstalt für Landeskunde und Raumordnung.

Mackiewicz, A., Ratajczak, W. (1996): Towards a new definition of topological accessibility. *Transportation Research B* 30, 47-79.

Marada, M., Hudeček, T. (2006): Accessibility of Peripheral Regions: A Case of Czechia. *Europa XXI* 15, Warszava, 43-51.

Marshall, A. (1890): *Principles of Economics*. Reprint of the 8th edition of 1920. London: Macmillan, 1966.

Martin, D., Wrigley, H., Barnett, S., Roderick, P. (2001): Increasing the sophistication of access measurement in a rural healthcare study. In: Kidner, D.B.; Higgs, G. (ed.) (2001): *GIS research in the UK. Proceedings of the GIS Research UK 9th Annual Conference GISRUK 2001*. University of Glamorgan.

Mathis, P. (2003) (ed.): *Graphes et réseaux. Modélisation multiniveau*. Paris: Lavoisier.

Matthiessen, C. W. (2000): Bridging the Öresund: potential regional dynamics. Integration of Copenhagen (Denmark) and Malmö–Lund (Sweden). A cross-border project on the European metropolitan level. *Journal of Transport Geography* 8, 171–180.

Matthiessen, C. W. (2004): International air traffic in the Baltic Sea Area: Hub-gateway status and prospects. Copenhagen in focus. *Journal of Transport Geography* 12, 197–206.

Määttä-Juntunen, H., Antikainen, H., Kotavaara, O., Rusanen, J. (2010): Using GIS tools to estimate CO_2 emissions related to the accessibility of large retail stores in the Oulu region, Finland. *Journal of Transport Geography*. doi:10.1016/j.jtrangeo.2010.03.001.

Meriläinen, A. P. (1996): Impact of low-volume road network improvements on rural community development in Finland. *Transportation Research Record* 1559, 100–105.

Michniak, D. (2006): Accessibility of the railway network in Slovakia. *Europa XXI* 15.

Michniak, D. (2002): *Dostupnosť ako geografická kategória a jej výzmnam pre hodnotění územno-správného členenia Slovenska.* Disertation thesis. Bratislava: Geography department of Slovak Academy of Science.

Milego, R., Ramos, M.J. (2010): *Disaggregation of Socioeconomic Data into a Regular Grid: Results of the Methodology Testing Phase*. ESPON 2013 Database Project. Draft report.

Möller, B., Nielsen, P. S. (2007): Analysing transport costs of Danish forest wood chip resources by means of continuous cost surfaces. *Biomass and Bioenergy* 31, 291–298.

Muhammad, S., Jong, T., Ottens, H.F.L.. (2008). Job accessibility under the influence of information and communication technologies, in the Netherlands. *Journal of Transport Geography*, 16(3), 203-216.

Murphy, E., Killen, J.E. (2007): Transportation accessibility issues and the location of a national facility: the case of a new paediatric hospital to serve the Republic of Ireland. In: *Irish Geography* 40(1), 1-16.

Myrdal, G. (1957): *Economic Theory and Underdeveloped Regions*. London: Duckworth.

Naess, P., Gunnar, Roe P. G., Larsen, S. (1995): Travelling Distances, Modal Split and Transportation Energy in Thirty Residential Areas in Oslo. *Journal of Environmental Planning & Management* 38, 349–370.

Naess, P., Mogridge, M. J. H., Sandberg, S. L. (2001): Wider Roads, More Cars. *Natural Resources Forum* 25, 147–155.

National Assembly for Wales (2000): *Welsh index of multiple deprivations*. Cardiff: National Assembly of Wales.

Navrátil, J. (2010): Hodnocení metod analýzy dostupnosti v rámci sociogeografické regionalizace Česka. Master thesis. Prague: Department of Social Geography and Regional Development, Charles University, Faculty of Science.

Nelson, A. (2008): *Estimated travel time to the nearest city of 50,000 or more people in year 2000*. Ispra: Global Environment Monitoring Unit - Joint Research Centre of the European Commission.

Nettleton, M., Pass, D.J., Gareth, W.W., White, R.C. (n.a.): *Public transport accessibility map of access to general practitioners surgeries in Longbridge, Birmingham, UK*.

Niedzielski, M.A., Śleszyński, P. (2008): Analyzing accessibility by transport mode in Warsaw, Poland. *Geographica Polonica* 81 (2), 61-78.

Nogales Galán, J. M., Figueira González, J. R., Gutiérrez Gallego, J. A., Pérez Álvarez, J. A., Cortés Ruiz, T. (2002): Determinación de la accesibilidad a los centros de actividad económica de Extremadura mediante técnicas SIG. 14th International Congress of Graphic Engineering, 5-7 June 2002, Santander, Spain.

Nordregio (ed.) (2004): *Mountain Areas in Europe. Analysis of Mountain Areas in EU Member States, Acceding and other European Countries*. Nordregio Report 2004:1. Stockholm: Nordregio.

Nový, V. (1904): *Isochronická mapa Čech – s úvodem o izochronách vůbec*. Praha: Zeměpisná knihovna.

ÖROK (2007): *Erreichbarkeitsverhältnisse in Österreich 2005. Modellrechnungen für den ÖPNRV und den MIV*. ÖRKOL Schriftenreihe 174. Wien: ÖROK.

Ohlin, B. (1933): *Interregional and International Trade*. Cambridge: Addison Wesley.

Oosterhaven, J., Sturm, J.E., Zwaneveld, P. (1998): Naar een theoretische onderbouwde aanpak can voorwartse economische effecten: Modelmatige definitie. Groningen/Delft: University of Groningen, TNO.

Pavlyuk, D. (2008): *Public transport accessibility and residential land value: a case study of Riga*. Proceedings of the 9th International Conference Reliability and Statistics in Transportation and Communication RelStat'08, Riga, Latvia.

Perroux, F. (1955): Note sur la notion du pôle de croissance. *Economique Appliquée*, 307-320.

Petr, T. (2008): *Akcesibilita čerpacích stanic v ČR s využitím GIS.* Bachalor Thesis, Prague: Charles University in Prague, Faculty of Science, dpt. of applied geoinformatics and cartography.

Porter, M. (1990): *The Competitive Advantage of Nations*. New York: Free Press.

Pšenka, T., Horňák, M. (2009): Priestorové rozdiely v konkurencieschopnosti vlakovej a autobusovej diaľkovej osobnej dopravy na Slovensku. In: Kvizda, M., Tomeš, Z. (eds.): *Konkurenceschopnost a konkurence v železniční dopravě – ekonomické, právní a regionální faktory konkurenceschopnosti železnice.* Recenzovaný sborník k seminři Telč 2009. Brno: Masarykova univerzita Brno, Fakulta ekonomicko-správní, 62–71.

Putman, S.H. (1983) *Integrated Urban Models: Policy Analysis of Transportation and Land Use*. London: Pion.

Quinet, E., Vickerman, R. (2004): *Principles of Transport Economics*. Cheltenham: Edward Elgar.

Rajman, J. (2009): *Analýza reálné dostupnosti Prahy silniční dopravou v průběhu dne a týdne pomocí GIS*. Bachalor Thesis, Prague: Charles University in Prague, Faculty of Science, dpt. of applied geoinformatics and cartography.

RAND Europe (2006): *TIGRIS XL 1.0 – Documentatie*. Leiden: RAND Europe.

Ravenstein, E.G. (1985/89): The laws of migration. *Journal of the Royal Statistical Society* 48, 167-227 und 52, 241-301.

Rietveld, P., Bruinsma, F. (1998) Is Transport Infrastructure Effective? Transport Infrastructure and Accessibility: Impacts on the Space Economy, Berlin/Heidelberg/New York, Springer.

Rohr, C., Williams, I.N. (1994): Modelling the regional economic impacts of the Channel Tunnel. *Environment and Planning B*, 21, 555-568.

RRG – RRG Spatial Planning and Geoinformation (2011): *RRG GIS Database User Manual. Dataset: Trans-European Transport Networks*. Oldenburg: RRG. http://www.brrg.de/database.php?language=de&cId=2.

Sassen, S. (1991): *The Global City*. New York: Princeton University Press.

Schade, W. (2005): *Strategic Sustainability Analysis: Concept and Application for the Assessment of European Transport Policy*. Karlsruhe Papers in Economic Policy Research 17. Baden-Baden: Nomos.

Schmitt, P., Dubois, A., Roto, J., Sterling, J., Schürmann, C. (2008): *Exploring the Baltic Sea Region – On territorial capital and spatial integration*. Nordregio Report 2008:3. Stockholm: Nordregio.

Schürmann, C. (2004): *Morphological analysis of urban areas based on 45-minutes isochrones*. Annex Report D to ESPON Project 1.1.1 on Potentials for Polycentric Development in Europe. Oldenburg: RRG.

Schürmann, C., Spiekermann, K. (2006): *Accessibility analysis of the Baltic Sea Region*. Final Report. Study for the BSR INTERREG IIIB Joint Secretariat within the framework of the preparatory process for the BSR Transnational Programme 2007-2013. Dortmund/Oldenburg: S&W, RRG.

Schürmann, C., Spiekermann, K. (2010): Erreichbarkeit ausgewählter zentralörtlicher Einrichtungen in Bayern. Dortmund: S&W.

Schürmann, C., Spiekermann, K. (2011): *Räumliche Wirkungen von Verkehrsprojekten. Ex post Analysen im stadtregionalen Kontext*. BBSR-Online Publikation 2/2011. Bonn: Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR),

Schürmann, C., Talaat, A. (2000): *Towards a European Peripherality Index. Final Report*. Report for General Directorate XVI Regional Policy of the European Commission. Berichte aus dem Institut für Raumplanung 53. Dortmund: IRPUD.

Schürmann, C., Spiekermann, K., Wegener, M. (1997): *Accessibility Indicators*. Berichte aus dem Institut für Raumplanung 39. Dortmund: Institute of Spatial Planning, University of Dortmund.

Sergeyeva, I. (1998): Conception of creating an accessible city space in St Petersburg, Russia. In: *8th International Conference on Transport and Mobility for Elderly and Disabled People*, Perth, Australia, vol. 2, 427-429.

Silva, C., Pinho, P. (2010): The Structural Accessibility Layer (SAL): revealing how urban structure constrains travel choice. *Environment and Planning A* 42(11), 2735-2752.

Simmonds, D. (1999): The design of the DELTA land-use modelling package. *Environment and Planning B*, 26, 665-684.

Simmonds, D.C., Skinner, A. (2003): The South and West Yorkshire strategic land-use/transportation model. In: Clarke, G., Stillwell, J. (eds): *Applied GIS and Spatial Analysis.* Chichester: Wiley, 195-214.

Smith, D.K.; Gibb, R. (1993): The regional impact of the Channel Tunnel: A return to potential analysis. In: *Geoforum* 24.2, 183-192.

Spangenberg, M., Pütz, T. (2002): Raumordnerische Anforderungen and en Schienenverkehr. *Informationen zur Raumentwicklung* 10, 595-607.

Spiekermann, K. (2009): *Update of Air and Multimodal Potential Accessibility Indicators* Dortmund: Spiekermann & Wegener, Urban and Regional Research (S&W).

Spiekermann, K., Aalbu, H. (2004): *Nordic Peripherality in Europe*. Nordregio Report 2005:4. Stockholm: Nordregio.

Spiekermann, K., Grimm, J., Schürmann, C. (2001): *Transport Systems and Accessibility*. Study for the INTERREG IIc Project GEMACA II (Group for European Urban Areas Comparative Analysis). Dortmund: Spiekermann & Wegener, Urban and Regional Research and Institute of Spatial Planning, University of Dortmund.

Spiekermann, K., Neubauer, J. (2002): *European Accessibility and Peripherality: Concepts, Models and Indicators*. Nordregio Working Paper 2002:9. Stockholm: Nordregio.

Spiekermann, K., Schürmann, C. (2007): *Update of Selected Potential Accessibility Indicators*. Final Report. Dortmund: Spiekermann & Wegener Urban and Regional Research. http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/ScientificBriefingNetworking/UpdateOnAccessibilityMaps/espon_accessibility_update_2006_fr_070207.pdf.

Spiekermann, K., Wegener, M. (1994) Trans-European Networks and unequal accessibility in Europe, Paper presented at the NECTAR Working Group 3 Workshop 'Infrastructure and Peripheral Regions in Europe' at Molde College, Molde, Norway, 30 September and 1 October 1994.

Spiekermann, K., Wegener, M. (1996): Trans-European networks and unequal accessibility in Europe. *European Journal of Regional Development* 4, 35-42.

Spiekermann, K., Wegener, M. (2005): Modelling Regional Development in AlpenCorS: Scenario Results. Final Report for AlpenCorS. Dortmund: Spiekermann & Wegener Urban and Regional Research. http://www.spiekermann-wegener.de/pro/pdf/AlpenCorS_Final_Report.pdf.

Spiekermann, K., Wegener, M., Günther, K., Komornicki, K., Korcelli, P., Wisniewski, R., Fiorello, D., Maffi, S., Martino, A., Zani, L. (2007): Preparatory Study on Feasibility of Flows Analysis. Final Report of ESPON 1.4.4. Dortmund: Spiekermann & Wegener Urban and Regional Research. http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/StudiesScientificSupportProjects/Flows/fr-1.4.4_revised_23-3-2007.pdf.

Tappeiner, U., Gramm, D., Pecher, C., Tasser, E., Linztmeyer, F., Marzelli, S., Tappeiner, G. (2008a): *Typology of the Alps Based on Social, Economic and Environmental Aspects.* Final Report DIAMONT WP 8: Specification and Test of Data for an Alpine Wide Information System. Bozen: EURAC.

Tappeiner, U., Borsdorf, A., Tasser, E. (2008b): *Alpenatlas / Atlas des Alps / Atlante delle Alpi / Atlas Alp / Mapping the Alps: Society - Economy - Environment.* Heidelberg: Spektrum Akademischer Verlag.

Taylor, Z. (2003): Accessibility to facilities versus daily mobility of rural dwellers: The case of Poland. In: Higgs, G. (ed.): *Rural Services and Social Exclusion*. European Research in Regional Science 12. London: Pion, 95-125.

TfL – Transport for London (2010): *Measuring public transport accessibility levels. PTALs Summary*. London: TfL.

TINA Secretariat (1999): *TINA Transport Infrastructure Needs Assessment. Identification of the Network Components for a Future Trans-European Transport Network in Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.* Final Report. Vienna: TINA Secretariat.

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

Tóth, G. (2006): Centre-Periphery Analysis about the Hungarian Public Road System. http://www-sre.wu-wien.ac.at/ersa/ersaconfs/ersa06/papers/11.pdf.

Treyz, G.I. (1980): Design of a multi-regional policy analysis model. *Journal of Regional Science*, 20, 191-206.

Treyz, G.I., Rickman, D.S., Shao, G. (1992): The REMI economic-demographic forecasting and simulation model. *International Regional Science Review*, 14, 3, 221-253.

Tykkylainen, M. (1981): Accessibility in the provinces of Finland. *Fennia* 159, 361-396.

Vickerman, R.W. (1994): Regional science and new transport infrastructure. In Cuadrado Rouro, J., Nijkamp,P, Salva, P. (eds.): *Moving Frontiers: Economic Restructuring, Regional Development and Emerging Networks.* Aldershot: Avebury, 151-165,

Vickerman, R.W. (1999): The transport sector, new economic geography and economic development in peripheral regions. In: Beuthe, M, Nijkamp, P. (Eds.): *New Contributions to Transportation Analysis in Europe*. Ashgate, 45-66.

Vickerman, R. W., Spiekermann, K., Wegener, M. (1999): Accessibility and economic development in Europe. *Regional Studies* 33, 1, 1-15.

Von Thünen, J.H. (1826): Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie. Hamburg.

Weber, A. (1909): *Über den Standort der Industrien*. Tübingen: Mohr.

Wegener, M. (2008): *SASI Model Description*. Working Paper 08/01. Dortmund: Spiekermann & Wegener Urban and Regional Research. http://www.spiekermann-wegener.de/mod/pdf/AP_ 0801.pdf.

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

Wegener, M., Eskelinnen, H., Fürst, F., Schürmann, C., Spiekermann, K. (2001): *Criteria for the Spatial Differentiation of the EU Territory: Geographical Position*. Forschungen 102.2, Bonn: Bundesamt für Bauwesen und Raumordnung.

White, S. (2001): Using GIS to explore variations in primary healthcare provision in rural areas. In: Kidner, D.B.; Higgs, G. (ed.) (2001): *GIS research in the UK. Proceedings of the GIS Research UK 9th Annual Conference GISRUK 2001.* University of Glamorgan.

Williamson, O.E. (1966): *Markets and Hierarchies, Analysis and Antitrust Implications*. New York: Macmillan.

World Bank (2009): Reshaping Economic Geography. World Development Report 2009. Washington D.C.: The International Bank for Reconstruction and Development / The World Bank.

Zanin, Chr.; Lambert, N.; Ysebaert, R. (2010): *Mapping Guide. Cartography for ESPON Projects.* ESPON 2013 Database Project. Draft Report as of June 2010.

Zipf, G.K. (1949): *Human Behaviour and the Principle of Least Effort*. Cambridge, MA: Addison Wesley.

A2 Portrait of regional case study areas selected

This section provides a brief presentation of each macro region selected with the zoom-in areas for in-depth analysis. Each presentation includes a territorial and socioeconomic characterisation of the case study and its transport infrastructure together with the reasons for the selection and two maps showing the macro region and its zoom-in regions and the population density.

The following case study regions have been chosen and will be presented below:

- EURAM
- Northern Italy
- Bavaria
- Czech Republic
- Poland
- Baltic States
- Finland

A2.1 Mediterranean Arc Euroregion (EURAM) regional case study

The macro region

The Mediterranean Arc Euroregion, the EURAM, covers Spanish and French crossborder regions, and Andorra. It is stretching over three different states, contains some autonomous communities, about 10 regions and departments, several hundred counties, and about 2,000 municipalities. It has more than 1000 km of coastal areas, mountain regions with highs up to 3,000 m, four islands, highly populated metropolitan regions with densities up to 15,500 inh./km², and sparsely populated rural areas with densities below 10 inh./km². (Figures A1, A2)

Between 1998 and 2008, the EURAM population increased by 20 % up to 14.2 million inhabitants and the number of jobs by 2.1 million (50 %). Approximately 13 % of the EURAM population are now foreigners, most of them attracted to fill job vacancies generated during the period of strong growth of 3.5 % GDP per year between 1997 and 2007, but a significant number were also attracted by the climate and quality of life of the region. About one in every five immigrants to the EURAM is from another EU-25 nation, and in some places the proportion stands at one in every three, similar to the level found in the American Sunbelt.

The present territorial organisation of the EURAM involves a large number of jurisdictions and a complex distribution of responsibilities and resources between administrations. This introduces rigidities and inefficiencies in the public sector: on the one hand it hinders the attainment of scale economies in the supply of public services and, on the other, the difficulties of reaching consensus under very different political agendas often create insurmountable obstacles to carry out major strategic projects.

The spatial structure

The population in the EURAM region is heavily concentrated along the coastal fringe along the Mediterranean Sea. The three main agglomerations in the EURAM region are Barcelona's (5 million inhabitants), Valencia's (1.8 million inhabitants) and Alacant-Elx (0.8 million inhabitants).

Barcelona's metropolitan region concentrates some 5 million inhabitants which represents about 70 % of the population of Catalonia autonomous community in only 10 % of its territory. The metropolitan region of Barcelona is composed of seven counties and 800 municipalities, and it includes 18 cities with more than 50,000 inhabitants, only 7 with more than 100,000 inhabitants The municipality of Barcelona itself has 1.6 million inhabitants.

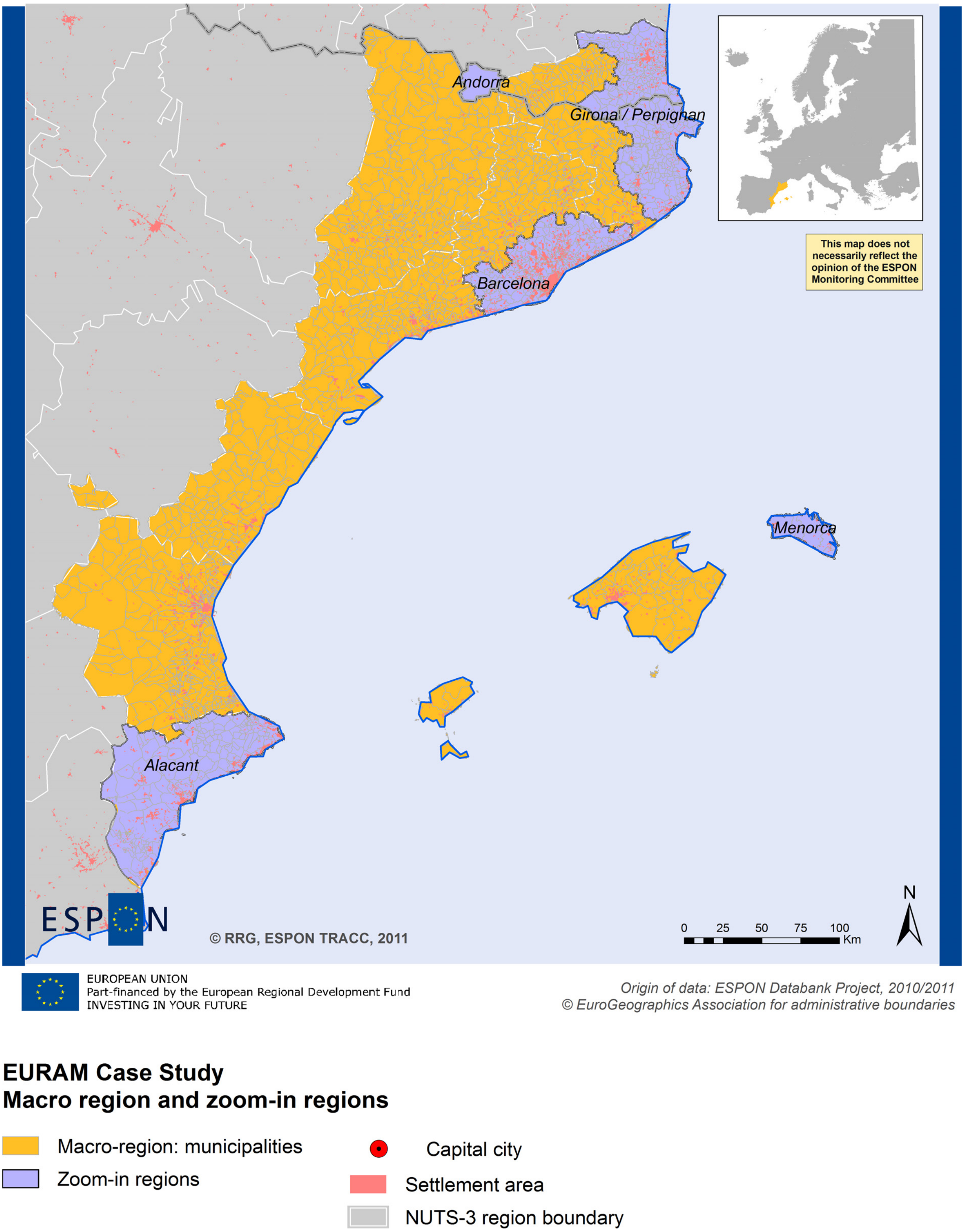
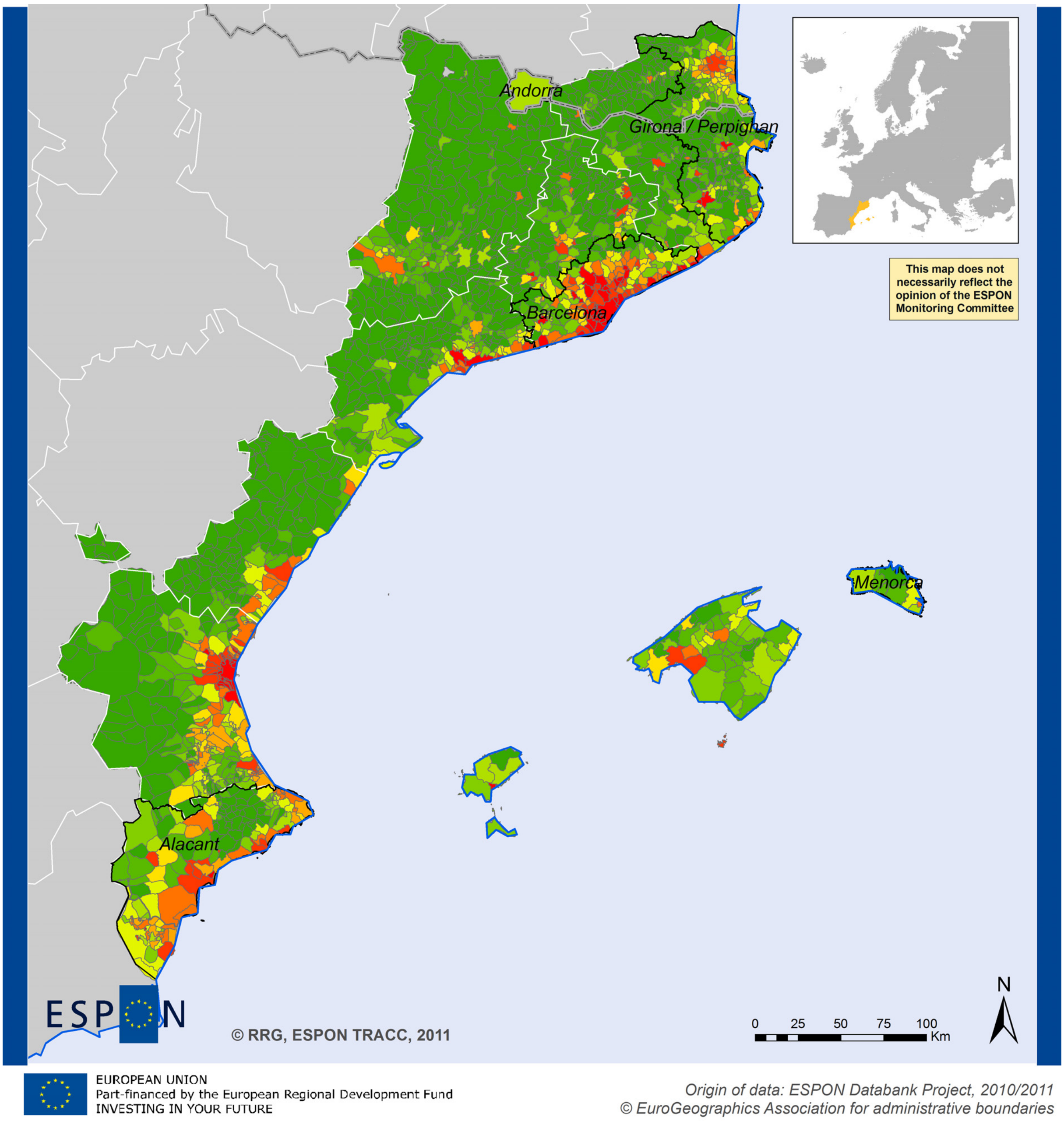


Figure A1. EURAM case study - macro region and zoom-in areas



EURAM Case Study
Population density (inh./sqkm, 2006)

- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 1000
- 1001 - 2000
- 2000 < ...
- Zoom-in regions
- NUTS-3 region boundary

Figure A2. EURAM case study - population density (2006)

Valencia's metropolitan region concentrates some 1.8 million inhabitants, representing 35 % of its autonomous community population, while Alacant-Elx metropolitan region holds 760,000 inhabitants. Both regions together accommodate 50 % of the region's population in 10 % of its territory.

The Balearic insular region is composed of four islands, Majorca, Minorca, Eivissa and Formetera, and has 1.1 million inhabitants. It is a heavily frequented summer destination (as many other EURAM coastal regions), having its transport and service infrastructures prepared for some 10 million visitors yearly.

The department of Pyrénées-Orientales has 437,000 inhabitants. Its head city Perpignan houses the largest fruit and vegetables market in Europe, managing some 1.5 million tonnes of products yearly, and constituting an important logistics centre connected to air and to sea modes.

Andorra is an independent state in the heart of the Pyrenees with 85.000 inhabitants. It is located at a high between 800 m and 3,000 m. Population is mainly settled in two narrow river valleys between mountains. Being a major tourist, leisure and commercial centre oriented to both Spanish and French visitors, it registers important flows of visitors, mostly by car (some 25,000 vehicles across its borders daily), and therefore transport infrastructures is a major concern.

Socioeconomic portrait

The EURAM has an important industrial tradition. The sector is characterised by the presence of some multinational firms attracted during the 1980s and 1990. But it is essentially composed of a broad network of small and medium-sized family firms in mature sectors, sometimes constituting sectoral clusters such as ceramics, footwear, textiles, toy industry, furniture, or agri-food. The relocation of some major multinational industrial firms may be inevitable; nonetheless, de-industrialisation of the territory is a major political objective in the mid-term.

Agriculture accounts for 2 % of EURAM's GDP and employs 2 % of its active population. Nevertheless, the agro-food industry is of considerable importance in the EURAM, producing 15 % of Spanish food exports and hosting some of the largest food production, transformation and distribution firms of Spain. Agricultural land in the EURAM has a trend to decrease in extension.

With 60 million visitors per year, Spain ranks second only to France as the world's leading tourism destination. Some 30 million visit the EURAM regions every year (15 million in Catalonia; 10 million in Balearic Islands; 5 million in Valencia). Tourism is expected to evolve towards the provision of additional services related to education and training, health and wellbeing, sport and leisure and cultural and business activities, and constitutes a strategic sector in the EURAM.

After the present downturn, the construction sector should slowly recover in the EURAM, although growing at a slower pace than in the past decade. In 2004, Spain's six leading building firms had a joint turnover of around 35 billion Euros, threefold increase with respect to 1999. The construction sector is in a process of business diversification towards other economic sectors such as concessions and infrastructure management, which account now in many cases for up to 50 % of their business turnover. Most of these major firms are immersed in a process of growing internationalisation.

Transport aspects

Mobility for both passengers and freight in the EURAM will continue to grow in the future with the pace of economy. Urban trips motivated by factors other than work and medium to long-distance travel will increase and become more variable throughout the day and the territory, while international and intercontinental travel may undergo exponential growth. In 1981, 28 %

individuals living in the Barcelona urban region worked outside their home municipality. By 2001 this percentage had risen to 47 %; forecasts indicate that this figure will rise to 60 % by 2026.

The long distance road corridors of the EURAM comprise essentially the Mediterranean axis along the coast (integrated by two parallel motorways), three axes linking the cost to Zaragoza (from Barcelona, Tarragona and Valencia) and two axes linking the coast to Madrid (from Valencia and Alacant). All these axes are served by motorways, and some of them are tolled. Road capacity in these corridors has already difficulties in fulfilling demand needs in many sections, notably around metropolitan areas. Particularly during peak tourism seasons some motorway and trunk road sections reach congestion levels that are unacceptable.

Within ten years, the Spanish high-speed train network has become one of the most developed in the world, together with those of France and Japan. There are many new sections being built across the Iberian peninsula and, following the inauguration of the Barcelona-Madrid line in 2008, it is expected that by 2012 the line connects to France in Perpignan. The missing stretch from Perpignan to Montpellier may not be connected, however, until after 2020. In the Community of Valencia, the three provincial capitals will be both interlinked and connected to Madrid by the HST in five years. The continuity of the high-speed Mediterranean corridor along the EURAM would be ensured with a new Tarragona-Castelló section which is not scheduled yet.

The explosion of low-cost companies has led to a sharp rise in air traffic in the EURAM, linked to the increase in tourism. Air traffic in the EURAM rose from 56 million passenger in 2000 to 87 million passenger 2007. In 2007, Barcelona handled around 33 million passengers, Palma 23 million passengers and Alacant 9 million passengers. The global traffic growth has benefited some regional airports such as Girona, whose traffic has increased since 2000 by 644 % up to 5 million passengers. The current capacity of the EURAM airport system, taking planned extensions into account, is globally sufficient in the short and medium terms. Spanish airports are managed by a public entity, Aena, with a centralized model.

The port of Valencia currently leads the container traffic in the western Mediterranean with 3.6 MTEU in 2008 (+20 % compared to 2007), while the port of Barcelona handled 2.6 MTEU (+0 % compared to 2007). While other competitive hubs like Algeciras or TangerMed are better located geographically on the Suez-Gibraltar route, the ports of Barcelona-Tarragona and Valencia-Sagunt still offer excellent opportunities to become maritime gateways for southern Europe. Pursing this strategy, all major ports in the Mediterranean basin are currently undergoing extensions or planning them to capture a higher share of Asian imports to Europe, which are currently handled by 75 % in the ports of northern Europe.

If the EURAM is to become the Mediterranean's logistic gateway of Europe, the Mediterranean corridor to Central Europe should be able to accommodate far greater flows of goods. The provision of competitive rail services might contribute to reduce the pressure on motorways. Despite public support, however, railways play a modest role in goods transport in the corridor. Rail network is scarcer than in central Europe, while new lines require important investments due to difficult topographies and heavily populated environments.

Expected results

Accessibility analysis will be performed in the EURAM region in a LAU-2 resolution. Accessibility runs will include accessibility to road and rail networks, to airports and ports. Results will provide an image of accessibility in a coastal corridor confined between sea, and hilly unpopulated hinterland areas. It will also provide contrast between different kinds of region types such as mountainous, metropolitan, sea-side, and scarcely populated areas. Results will be discussed more specifically for the following zoom-in areas:

- Andorra will provide insight on accessibility in a small independent mountain country enclave with complex topography but important accessibility requirements due to primary tourist industry targeted on Spanish and French visitors.
- Pyrénées Orientales / Girona will study accessibility in a transborder region.
- Barcelona will show accessibility in the most important urban agglomeration in the EURAM
- Alacant will provide knowledge on accessibility in a coastal region focused on international tourism.
- Menorca zoom-in area will analyze accessibility in an island, which being a biosphere reserve, needs to make compatible accessibility with environment preserving.

A2.2 Northern Italy regional case study

The macro region

The case study area consists of Northern Italy, including the following administrative regions: Valle d'Aosta, Piemonte, Liguria, Lombardia, Veneto, Trentino Alto Adige, Friuli Venezia Giulia and Emilia Romagna. The area covers around 120,000 km^2. (Figures A3, A4)

The macro region is north-bounded by Alps, which form a natural border with neighbouring countries (France, Switzerland, Austria, Slovenia). This barrier is however crossed by several natural or artificial passages (like the Frejus tunnel, the Simplon tunnel or the Brenner tunnel) that connect Northern Italy with Northern Europe by road and rail. Improvements of north-south corridors are being undertaken (new rail Gotthard basis-tunnel) or are planned (new rail Brenner tunnel) even if corresponding investments on the Italian territory are lacking. Neighbouring regions of France, Switzerland, Austria and Slovenia can be reached with a number of smaller customs throughout the borders.

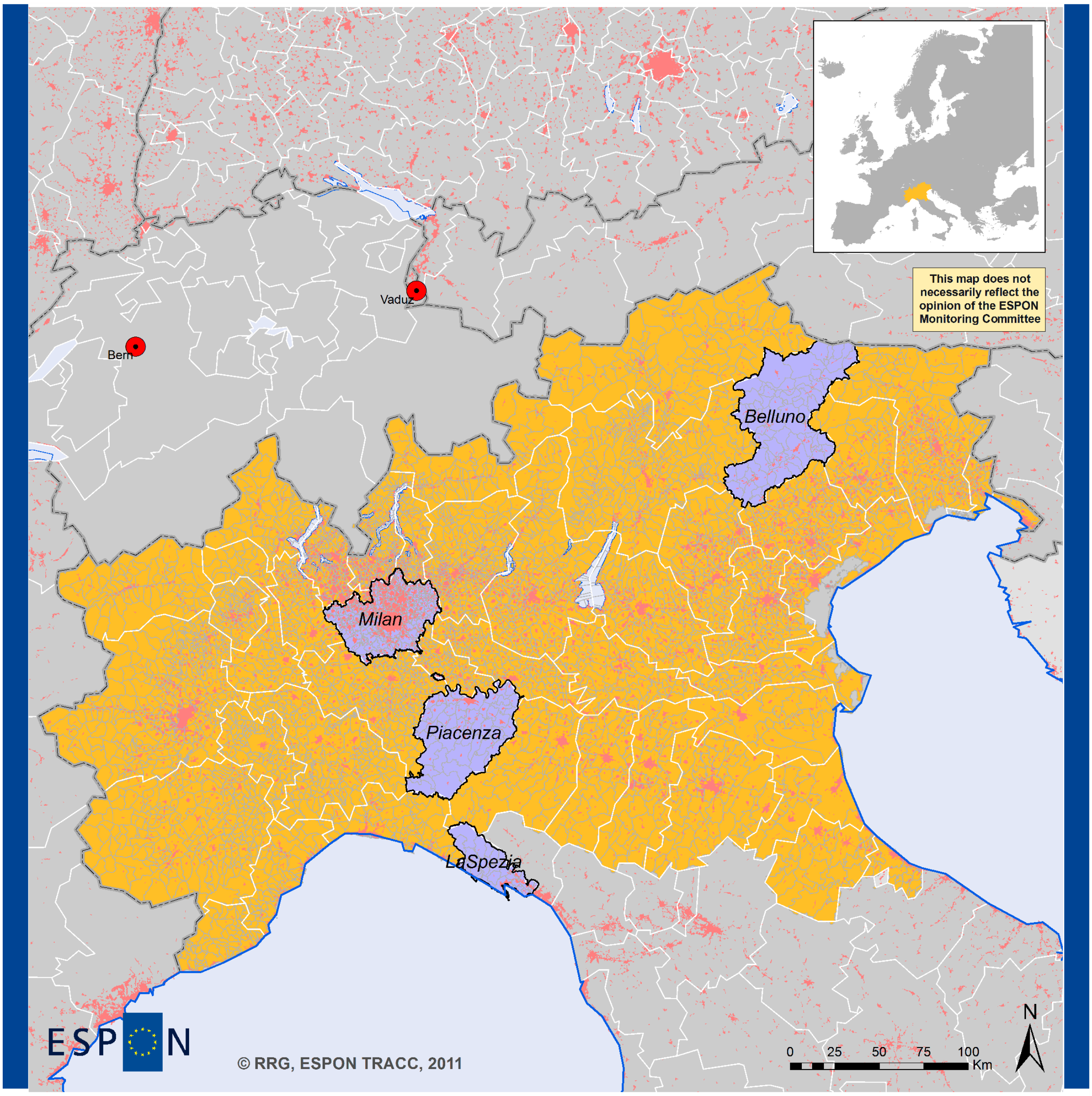
South border of the study area is not much more than an administrative separation, at least on the south-eastern side, where there is a clear territorial continuity with other regions. On the south-western side of the study area the Apennines are a more physical barrier but both road and rail connections are well established and further improved after the opening of the high speed rail track in 2009.

Four zoom-in areas will be analysed in more detail:

The Milan metropolitan area is the major centre of the macro-region, covering a surface of about 2,000 km², with a population of about 3,900,000 inhabitants. Milan is in middle of the macro region and it is the hub of regional rail services as well as of motorways, national and regional roads. Its accessibility is therefore very high if not for problems of congestion.

The Piacenza Province is placed on the north-south corridor linking the city of Milan with the rest of the Peninsula (Florence, Rome, Naples, etc.). It has about 288,000 inhabitants living on a total area of 2,589 km². Most of the area is flat, but its south-west part include some mountains, Piacenza Province is an example of an area with good transport infrastructures (and other planned) with an internal mobility but also generating mobility towards main centres like Milan and Bologna.

The Province of La Spezia is one of the four provinces of Liguria Region, with an area of about 881 km², and a total population of 223,503 inhabitants. Given its position, with sea on the one side and mountains on the other, La Spezia connections are channelled through the coast and a limited number of passes. Thus its level of accessibility is low if compared to other provinces. A new rail track for national services could make available capacity for local rail services in the future.



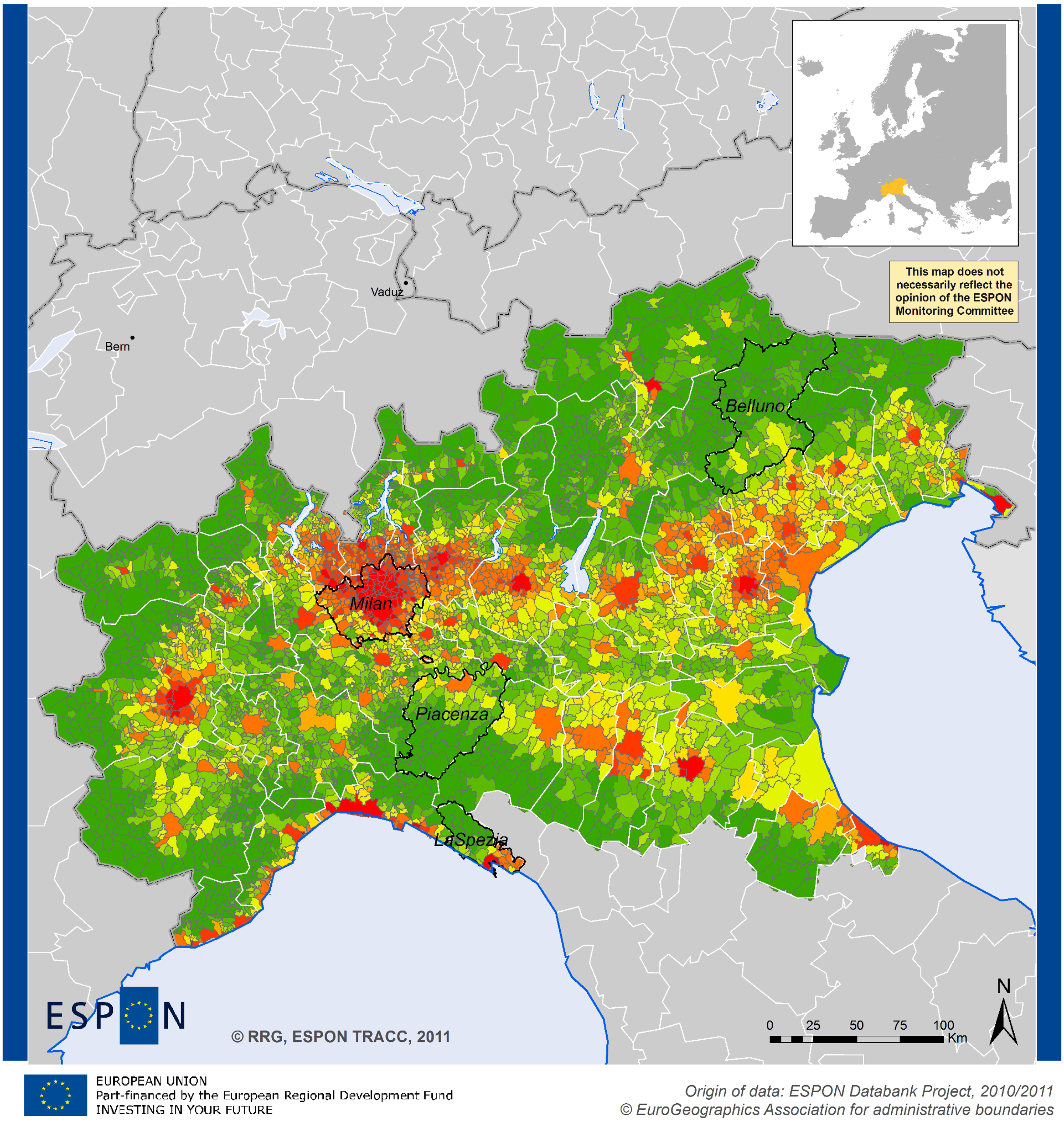
EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Origin of data: ESPON Databank Project, 2010/2011
© EuroGeographics Association for administrative boundaries

Northern Italy Case Study
Macro region and zoom-in regions

Macro-region: municipalities
Zoom-in regions
Capital city
Settlement area
NUTS-3 region boundary

Figure A3. Northern Italy case study - macro region and zoom-in areas



Northern Italy Case Study
Population density (inh./sqkm, 2006)

- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 1000
- 1001 - 2000
- 2000 < ...
- Zoom-in regions
- NUTS-3 region boundary

Figure A4. Northern Italy case study - population density (2006)

Belluno province is a mountain area of 3.700 km², populated by 214,000 inhabitants but attracting thousands of tourist especially in the winter season. This area is not crossed by any motorway or trunk rail line. Motorway A27 and a local railway provides connections to south, while most direct links to north, east and west are provided by national roads crossing mountain passes allowing only limited speeds and capacity.

The spatial structure

Despite 46% share of the territory of Northern Italy is classified as 'mountain', the average population density is 230 persons per km^2, above the national average of 200 persons per km^2.

The dominant spatial feature of Northern Italy is the 'enlarged city'. Especially in northern part of the area just below the Alps, on the west-east axis between Turin and Venice, urbanisation is virtually continuous to form what has been called 'Padan megalopolis'. Another 'enlarged city' can be identified in the southern part of the area, on the axis Turin-Bologna. In between urbanisation is less predominant and several medium cities (20,000 to 50,000 inhabitants) characterise a more polycentric structure. The 'enlarged city' model is reflected in the absence of a dominating centre. Milan is the biggest city in the area with about 1.3 million inhabitants (i.e. less than 5% of the overall population in macro region). Other large cities are Turin (0.9 million inhabitants), Genoa (0.6 million), Bologna (0.38 million). This means that the main four cities of the area account for just a bit more than 10% of the overall population in the region. The largest part of the inhabitants populate the 'enlarged city' made of a number of small municipalities, many of which are separate entities only from an administrative point of view.

Socioeconomic portrait

Northern Italy is the richest and most populated area of the country. About 27 million inhabitants live in the case study region, i.e. nearly one half of the whole Italian population. Also, about 60% of the national Gross Domestic Product is generated in this area. The industrial structure mainly consists of a number of small or even familiar firms spread over all the territory. There are several 'districts' specialised in specific productions (e.g. silk, glasses, ceramic, shoes). Nevertheless, beginning with 1970s, the industrial production decreased making room for the growth of services and tertiary activities. Milan is the major economic centre in Italy. Formerly an industrial area, it is now a service and financial centre, the site of the Italian stock exchange and of most of the international companies as well as one of the world fashion capitals.

The contribution of births to population development is almost null and population has slightly increased in the last years especially because of immigration from southern Italy and from abroad. In agricultural and industrial sector immigrants (especially from Eastern Europe, North and Central Africa) represent a significant share of manpower.

Transport aspects

Transport infrastructures and services are generally well developed in Northern Italy. However, the high population density coupled with the 'enlarged city' form of urbanisation and the economic structure made of many small firms generate a large amount of transport demand that gives rise to congestion problems.

The major road infrastructures are the west-east A4 and the A1 north-south motorways, but on both axes other motorways exist. Nevertheless, especially the A4 it has been often subjected to severe congestion problems. Recently the opening of a fourth lane between Brescia and Milan has relieved traffic. Furthermore the building of new infrastructures started between 2009 and 2010, namely the 'Brebemi' motorway, linking the city of Milan to Brescia via Bergamo and the

‘Pedemontana’ motorway, connecting the A4 motorway from Dalmine to the Malpensa airport crossing the provinces of Lecco, Monza and Como. Other motorways projects are in still in a more or less advanced planning phase.

Besides motorways, an extensive network of national and regional roads connect all parts of the macro-regions. Also mountain areas are generally very well connected since many of them are tourist resorts especially in winter time.

Railways in the macro-region are especially developed around the Milan node, but most of the municipalities in the area (at least those not located in the mountains) are reasonably close to railways. However, infrastructures are basically those developed in the first half of the 20th century (indeed, some railway lines existing until the mid-1960s have been abandoned so that total railway length is today a bit shorter than 50 years ago). Railways were built to connect main cities to each other and to connect medium centres to the main poles (especially Milan and Turin) developing according to a radial model. The development of population and activities scattered throughout the territory of the area have seriously disadvantaged railways, which are more suitable for carrying large volumes of passengers (and freight) over fixed paths. Furthermore, in the last ten or fifteen years Italian railways have chosen to develop the high speed network rather than local services. The outcome has been that such services suffer from underinvestment in rolling stock and infrastructures update. They are overcrowded during peak time and renowned for their unreliability (delays). All in all, despite a quite extended railway network, train services are well below the best European standards. Only the recently inaugurated high-speed line connecting Milan to Rome in three hours can be considered a quality service that has increased the connectivity of the area.

Expected results

Accessibility analysis will be carried out for the Northern Italy macro region at the municipal level for road and rail (being other modes not significant for the passenger trips in the area). Different indicators of accessibility will be produced such as potential accessibility, isochronic accessibility measure to main cities, airports accessibility. Road accessibility will take into account congestion of the road network rather than free-flow speed. Rail accessibility will consider actual timetables including the need for interchanges. The impact of new motorway infrastructures will be also considered as alternative scenario.

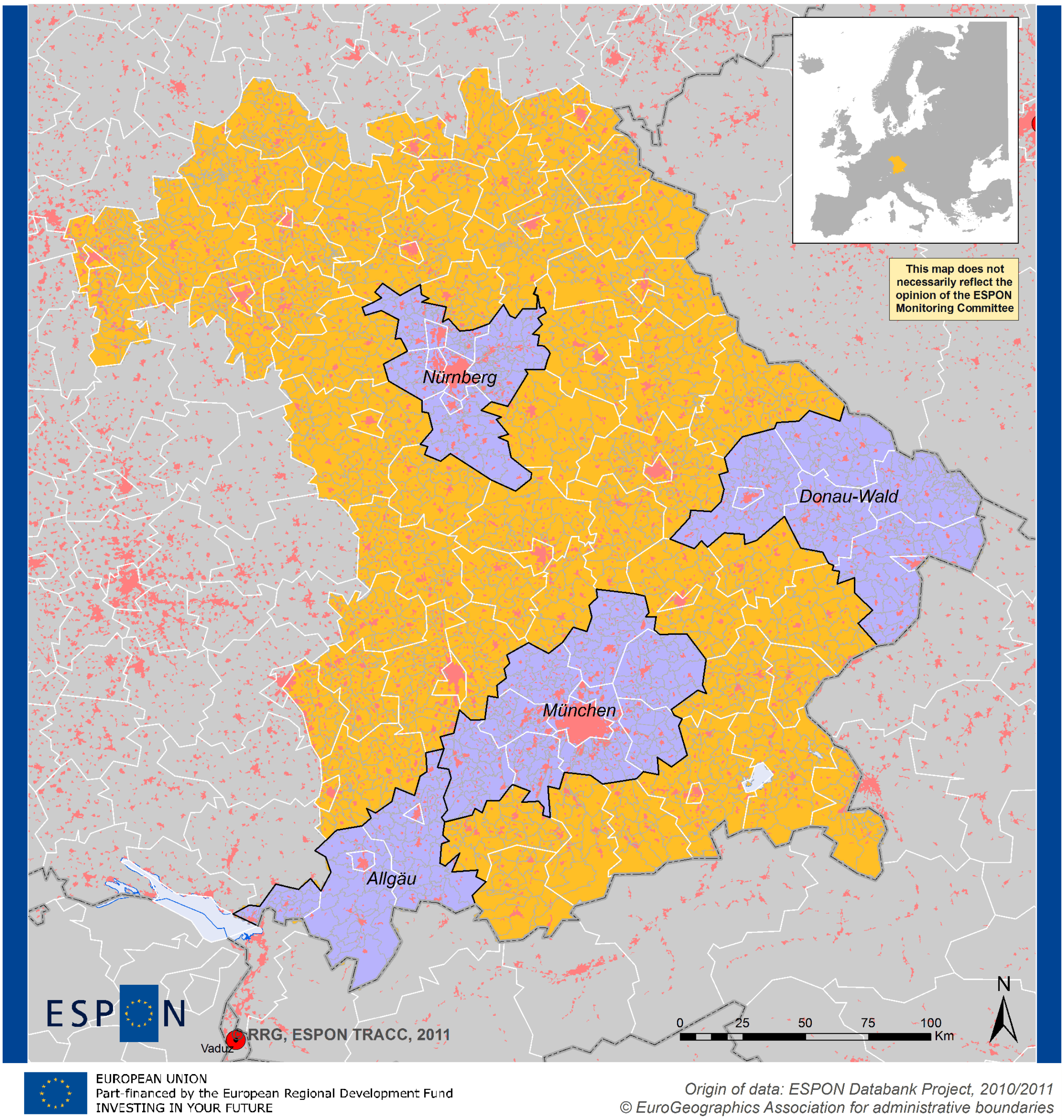
The indicators will show differences of accessibility in different parts of the macro region. Results will be interpreted taking into account the different characteristics of the areas (major centres, peripheral zones, mountains areas, etc.).

A2.3 Bavaria regional case study

The macro region

The Federal State of Bavaria is located in the southern part of Germany. With an area of about 70,500 km², Bavaria is the largest NUTS-1 region in Germany. With a total population of 12.5 million people it is the second largest state of Germany, only the high-density state of North Rhine-Westphalia has more inhabitants. Bavaria consists of seven NUTS-2 regions, 96 NUTS-3 regions and 2056 municipalities (Figures A5, A6).

In the macro region of Bavaria there are very different types of regions ranging from a high-density monocentric agglomeration and medium-sized polycentric agglomerations via semi-urban surroundings of the agglomerations to rural structures with small and medium-sized cities which include also mountainous areas, in particular the Alps.



Bavaria Case Study
Macro region and zoom-in regions

Macro-region: municipalities

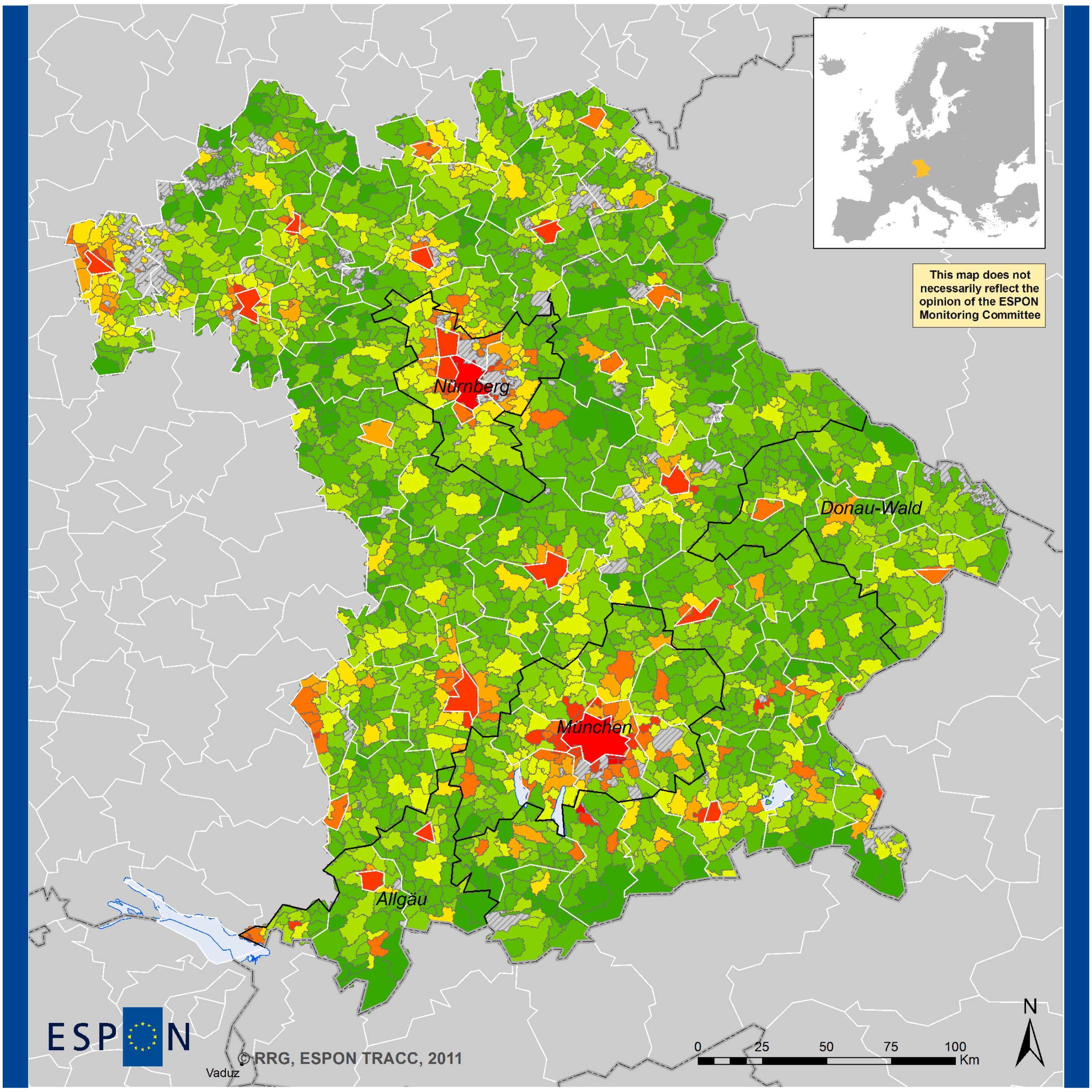
Zoom-in regions

Capital city

Settlement area

NUTS-3 region boundary

Figure A5. Bavaria case study - macro region and zoom-in areas



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Origin of data: ESPON Databank Project, 2010/2011
© EuroGeographics Association for administrative boundaries

Bavaria Case Study
Population density (inh./sqkm, 2006)

- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 1000
- 1001 - 2000
- 2000 < ...
- Zoom-in regions
- NUTS-3 region boundary
- Areas not belonging to any municipality

Figure A6. Bavaria case study - population density (2006)

Spatial structure

Munich is the capital of Bavaria and the largest city with a population of more than 1.3 million in the municipality and about 2.5 million in the agglomeration. Nuremberg with about 0.5 million inhabitants and Augsburg with 250,000 inhabitants follow next, but are clearly smaller in size. There are only five more cities with a population of slightly more than 100,000. Two thirds of the population live in small and medium-sized cities and rural areas of less than 20,000 inhabitants per municipality.

Consequently, the spatial structure of the macro region of Bavaria is very heterogeneous. The agglomerations of Munich and Nuremberg are major centres in a more urbanised arc starting in the north-west of Bavaria and running through the two agglomerations towards the south. From this arc towards the outer boundaries of Bavaria, the regions are getting less dense, more rural and peripheral. In terms of area size, rural areas are dominating the macro region of Bavaria.

Socio-economic portrait

Bavaria is considered to be one of the most successful regions of Germany during the economic transformation in the last decades. Since World War II Bavaria developed from an agrarian economy to a high-tech economy with a concentration of modern industries in and around the larger cities. GDP growth rates of Bavaria have been usually higher than for Germany as a whole. Compared to the average GDP (in PPS) of EU 27 the index for Bavaria is about 135. Unemployment rates in Bavaria are the lowest in Germany and currently little above 4 percent. Consequently, Bavaria has experienced steady population increases during the last decades based on a positive migration balance, also with all other German states.

Transport aspects

As most German regions, the macro region of Bavaria is very well served by the national motorway network in which major investments have been made during the last decades. Within Bavaria, a mesh-like motorway structure with only very few remaining gaps is connecting the different parts of the state. Several motorways lead to other parts of Germany as well as to international destinations such as Prague, Vienna or via the Brenner motorway to northern Italy. The motorway network is amended by a dense system of national and state roads connecting also small and medium-sized towns.

The public transport network is based on a relatively dense rail network composed of high-speed train services and regional and local train services. However, as in other parts of Germany, the rail services in Bavaria have been reduced in rural areas whereas agglomerations partly have seen investments in new infrastructure and services. The rail network is amended by tram and underground networks in the agglomerations and by a dense bus network serving small and medium-sized cities and rural areas. However, the frequency of many bus lines serving rural areas is rather low so that some areas are only served by school buses.

Less important for the analysis of regional and local accessibility patterns are the air and waterway connections of Bavaria. The Munich airport located more than 30 km northeast of the city centre is one of the major German airport hubs serving many national, international and intercontinetal destinations. Though located far away from the sea, Bavaria is well integrated into the European inland waterway system. Via the navigable rivers of the Main flowing into the Rhine and the Danube and the connecting Main-Danube-Canal, Bavaria has waterway links to ports located at the North Sea as well as at the Black Sea and the eastern parts of the Mediterranean Sea.

Expected results

The accessibility model will be set up for the entire macro region of Bavaria. Modes addressed are road and public transport. The road network includes all roads down to all residential streets. The public transport network is derived from the public transport time table covering all public transport services in Bavaria including all rail, underground, tram and bus services. The raster model will be run for a raster representation of the Bavarian territory. For this, Bavaria was disaggregated into some seven million raster cells of 1 ha in size. Population was also disaggregated to these raster cells.

The accessibility model for the Bavarian macro region will be used to compute a wide variety of accessibility indicators. Results can be presented for the raster level and can be aggregated to municipalities. Results will be presented for the whole macro region, but in more spatial detail also for selected specific types of regions. For this, four zoom-in areas are foreseen:

- The Munich region will give insights into accessibility patterns in a large urban area with a monocentric spatial structure.
- The Nurenberg region will provide knowledge about accessibility patterns in a medium-sized urban area with a polycentric spatial structure.
- The Allgäu region in the south-western parts of Bavaria including parts of the Alps and its foot-hills will depict accessibility patterns of rural and mountainous areas.
- The Donau-Wald region in the eastern parts of Bavaria will provide imformation about the accessibility situation of rural areas.

The accessibility analysis for the case study macro region of Bavaria and the zoom-in areas will provide understanding of regional and local accessibility patterns for a variety of regional types including large agglomerations, urban-rural settings, rural areas and mountain areas. By a precise representation of road and public transport networks, the differences of accessibility patterns by the two modes of transport in the different types of regions will become visible.

A2.4 Czech Republic regional case study

The macro region

The Czech Republic is a landlocked country situated in Central Europe. Its area comprises the historical territories of Bohemia, Moravia and a part of Silesia. It shares borders with Poland (762 km), Germany (810 km), Austria (466 km) and Slovakia (252 km). The capital city is Prague. The area covers 78,864 km² (21st position in Europe) with a population of 10.5 million (12th in Europe). The average density of population is approximately 130 inhabitants/km². The Czech Republic is located between two mountain systems. The western and central parts of the country include the Czech Highlands, the eastern part is formed by the Carpathian mountain range.

The spatial structure

The Czech Republic can be divided into lower (municipalities) and higher (regions) territorial self-governing units. In 1997, a constitutional act established higher territorial self-governing units (the regions or provinces), which did not correspond to the regional demarcations valid between 1960 and 1989. However, this act did not regulate the organisation or the structure or competences of bodies at the regional level. Therefore the regional system at the beginning functioned only formally (de iure). The state administration and self-government started to work at the regional level as late as 2000 (de facto). It means since then the Czech Republic has the new administrative structure of 14 NUTS-3 regions (Figure A7, A8).

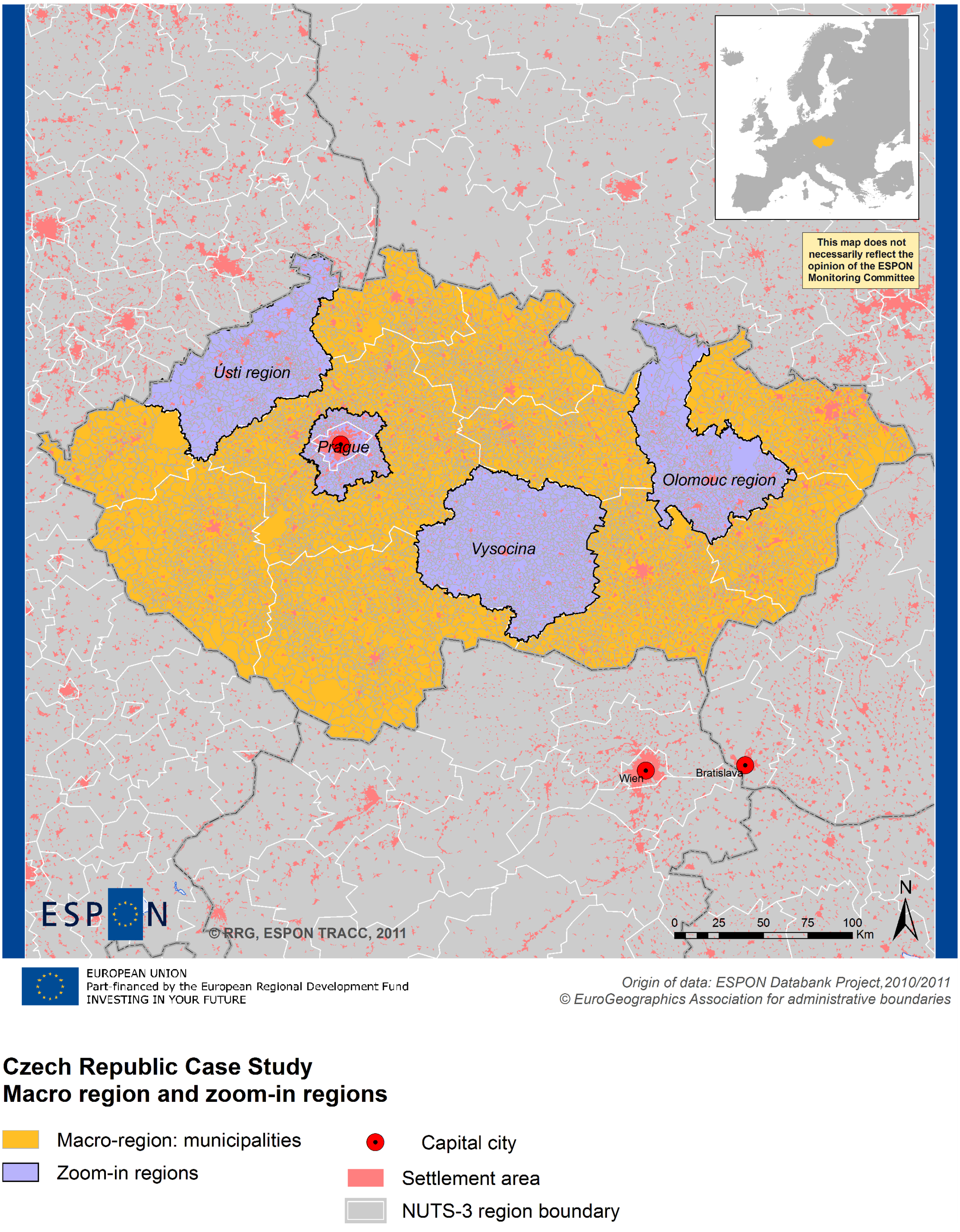


Figure A7. Czech Republic case study - macro region and zoom-in areas

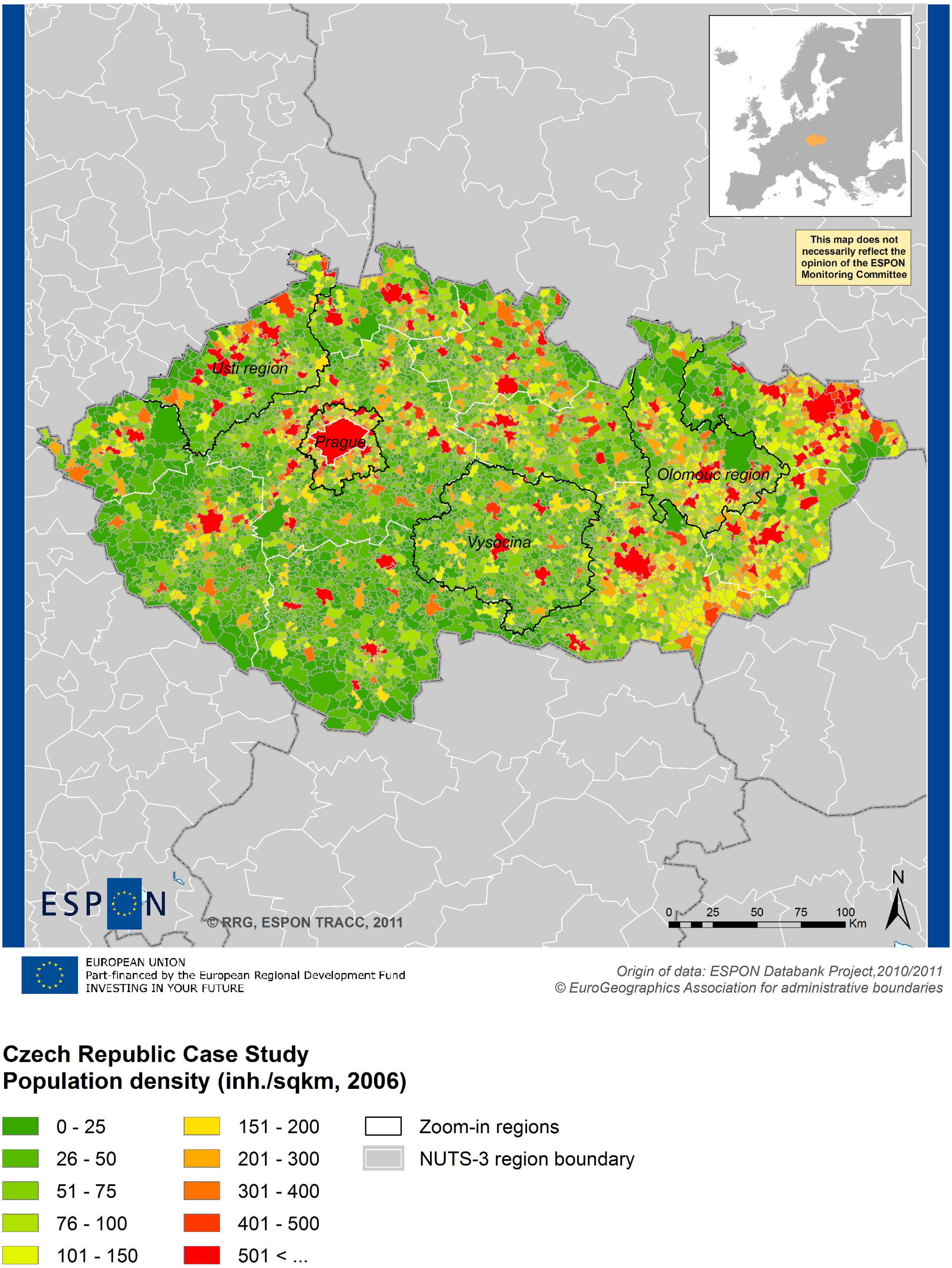


Figure A8. Czech Republic case study - population density (2006)

Municipalities administer their territories within the framework of autonomous competence. Besides, they execute delegated competences on behalf of the state. Within their self-competence, all municipalities (either villages, towns or cities) have equal rights and obligations. Execution of the delegated competences depends on the size of the municipality and the territory it administers. Municipalities are divided into three groups, according to the scope of competencies delegated:

- Municipalities with the basic range of the transferred competency – of which there were 6,249 municipalities on 1st January 2008.
- Municipalities with authorised municipal offices – 388 municipalities whose municipal offices exercise transferred state competency, especially in the domain of offences, construction administration and agricultural land resources.
- Municipalities with extended powers – 205 municipalities, which exercise in their territory the largest range of the transferred state competency especially in the domain of issue of passports, driving and trading licences, waste management, transport and road management etc.

Czech NUTS-2 regions are always made up of one to three NUTS-3 regions called “kraj”. NUTS-2 regions are only statistical units without self-government and responsibility. On the other hand NUTS-3 regions (kraje) play a key role in regional development governance.

The Czech Republic is characterised by a fragmented structure of settlements, with a historically high number of municipalities (6249 in 2006). As mentioned above there is a large number of municipalities in the Czech Republic of which only a minor part can be regarded as towns by international standards. Nonetheless the urban areas play an important role in the development of the regions. From the functionality viewpoint, the following urbanised areas (mostly regional capitals) can be identified: Prague agglomeration (1.7 million inhabitants), East-Bohemian agglomeration (Hradec Králové and Pardubice cities, 370,000 inhabitants.), North-Bohemian conurbation (650,000), Liberec agglomeration (200,000), Plzeň (330,000), České Budějovice (150,000), Karlovy Vary (200,000), Ostrava agglomeration (890,000), Brno agglomeration (590,000), Central-Moravian conurbation (Olomouc, 370,000) and Zlín (240,000).

With regards to the potential for further development, the Czech spatial development policy defines twelve main development areas. Far more frequent requests are made for zoning changes in the following areas because they are centres of international or nationwide businesses: Prague, Ostrava, Brno, Hradec Králové-Pardubice, Plzeň, Ústí nad Labem, Liberec, Olomouc, Zlín, České Budějovice, Jihlava and Karlovy Vary. These development areas are linked by eleven development axes.

The northern part of Czechia is more densely populated, and there is a higher rate of urbanisation; the area south of the line Karlovy Vary - Plzeň - Prague - Pardubice - Olomouc - Brno is rather rural, less industrialised.

Socioeconomic portrait

Regional development and differences in the Czech Republic are strongly influenced by a unique position of Prague in the Czech economy. The capital city of Prague (NUTS-2 region) is currently one of the most dynamic and most successful regions of Central Europe. Prague forms a quarter of Czech GDP; and its value is twice the Czech average and 173 % of the EU average (2008). Prague is a key administrative centre in Czechia and has a modern services economy, specialising in financial services and activities related to tourism. As the largest city by far in the Czech Republic (1.2 million), it is also the location of the main national companies and the principal bodies concerned with scientific research and education. Prague has become a favoured destination for foreign banking activity during the transformation period and holds this position to present time. Prague belongs to the five wealthiest regions in the whole European Union. At the same time it is the wealthiest region in the new EU member states. On the other hand, Prague has also number of serious problems typical for large metropolitan regions, as for example a disrupted environment, transport problems, pollution, criminality, etc.

The remaining NUTS-2 regions in the Czech Republic can be placed into four groups:

- regions with strong economic growth that are catching up with the EU average (about 70 %): South-West (Jihozápad) and Central Bohemia (Střední Čechy),
- regions of low-moderate economic growth: South-East (Jihovýchod) and North-East (Severovýchod),
- regions lagging because of very slow growth: Central Moravia (Střední Morava),
- declining regions: Moravia-Silesia (Moravskoslezsko) and North-West (Severozápad), i.e. regions including coal basins.

Long-term unemployment is high – about 13 %, but in some districts even over 20 % – in coal basin regions, i.e. Moravia- Silesia region and Ústí region. The minimum value is in the Prague metropolitan area (up to 3 % registered). In other NUTS-3 regions the unemployment rate decreases from west to east. In general, rural areas show worse performance than metropolitan regions.

Transport aspects

Due to its position in Central Europe, the Czech Republic is well-advantaged to make the most of its good transport accessibility. The country is indeed covered with a dense network of railways and roads, but it does not always meet the standards expected from transport. Railway network density is historically higher in the northern part of the Czech territory. The main corridors are the axes Dresden - Prague - Brno - Vienna and Katowice - Ostrava - Břeclav - Vienna. Main motorways are constructed radially from Prague to other regional capitals. The main motorway connects Prague, Brno and Ostrava (D1).

Since 1990 the shares of the various modes of transport have changed substantially, in relation with a general transformation of the society and the country’s accession to the EU. The greatest decline in performance, and the volume carried, was noted by the railway, by public road transport (passenger), and water transport (which was always minor). On the other hand, transport by heavy trucks over 12.5 tonnes has increased substantially, as well as individual road passenger and air transport. The performance of all the transport modes with a negative impact on the environment has increased. Prague international airport ranks among main Central European ones. Its performance has increased from 1.8 million passengers in 1989 to 11.6 million in 2009. Prague airport handles near 94 % of air passengers in Czechia.

Expected results

Accessibility analysis will be performed in the Czech Republic for a LAU-2 resolution. Accessibility analysis will include time accessibility (rail and road) to airports and important economic settlement centres. These analyses will provide images of the accessibility in different types of Czech regions (urban and metropolitan regions, rural and peripheral, lagging regions etc.). The following regions have been chosen as zoom-in areas:

- The Prague metropolitan area as a key economic and service node of Czechia. It consist of the capital city of Prague and its surroundings (districts Prague-East and Prague-West) characterised by intensive commuting, suburbanisation, increasing concentration of inhabitants and economic wealth.

- The Ústí region (NUTS-3), a part of the north-western NUTS-2 region. Situated in north-west Bohemia at the border to Saxony it represents a coal basin area with long-term high unemployment, below-average education, low tourist attractiveness and economic decline in general. On the other hand, this region has a good position on the important development axis connecting Dresden and Prague. The border parts are relatively mountainous (Ore Mountains).
- The Vysočina region (NUTS-3 region, regional capital Jihlava, part of the south-eastern NUTS-2 region) as representative of mostly rural regions with low density of population and settlement systems formed by small municipalities (almost 80 % have less than 500 inhabitants) and a network of regional towns and cities without one dominating centre. The Vysočina region includes peripheral zones between Bohemian and Moravians settlement cores.
- The Olomouc region (NUTS-3, part of the Central Moravia NUTS-2 region) as region of elongated shape and high inner contrast between the Olomouc regional capital agglomeration in the south (370,000 population) and the Jeseníky mountains in the north. The rural area of Jeseníky isolates one of the most peripheral areas in Czechia, the Jeseníky district, from the rest of the country. From the point of view of economic development it is lagging region, but it has great development potential by the quality of its human capital.

A2.5 Poland regional case study

The macro region

Poland covers an area of 312,685 km², which makes it the ninth largest country in Europe. Since the beginning of the 1990s population of Poland has remained rather constant in size and equals about 38.1 million people (ranking eighth in Europe and sixth in the European Union).

The territory of Poland has been divided rather arbitrarily into 6 NUTS-1 regions (regiony) and 66 NUTS-3 subregions (podregiony) for statistical purposes. The 16 NUTS-2 regions correspond to the 16 voivodships (województwa). The voivodships are divided into 379 NUTS-4 districts or counties (powiaty) including 65 cities with powiat status. The powiats are further subdivided into 2478 municipalities or communes (gminy). The gmina is the basic unit of the country's territorial structure. The gmina, powiat and voivodship councilmen as well as mayors of rural and urban gminas and mayors of major cities are elected in general, equal, direct election.

The northern border of Poland runs partly (about 440 km) along the Baltic Sea coast. Poland shares the rest of the border (3511 km) with its seven neighbouring countries including, since 2004, 1,908 km of internal EU borders (since 2007 within the Schengen zone) with Germany, the Czech Republic, Slovakia and Lithuania and, since 2007, about 1,163 km of new eastern Schengen borders with Ukraine, Belarus and Russia. The Sudety mountains are located on the Polish-Czech border and the Carpathian mountains are along Poland's border with Slovakia. However, the majority of the country is lowland (Figures A9, A10).

The spatial structure

The Polish urban system is characterised by a polycentric structure. In comparison with the urban systems of other European countries, the capital of Poland (Warsaw) is less dominant in the Polish urban hierarchy. The population of Warsaw is about 1.7 million people (only 4.5 % of the total population of the country). Besides Warsaw, the population of Kraków, Łódź, Wrocław and Poznań is more than 500,000 inhabitants, and in twelve other cities the population exceeds 200,000 inhabitants.

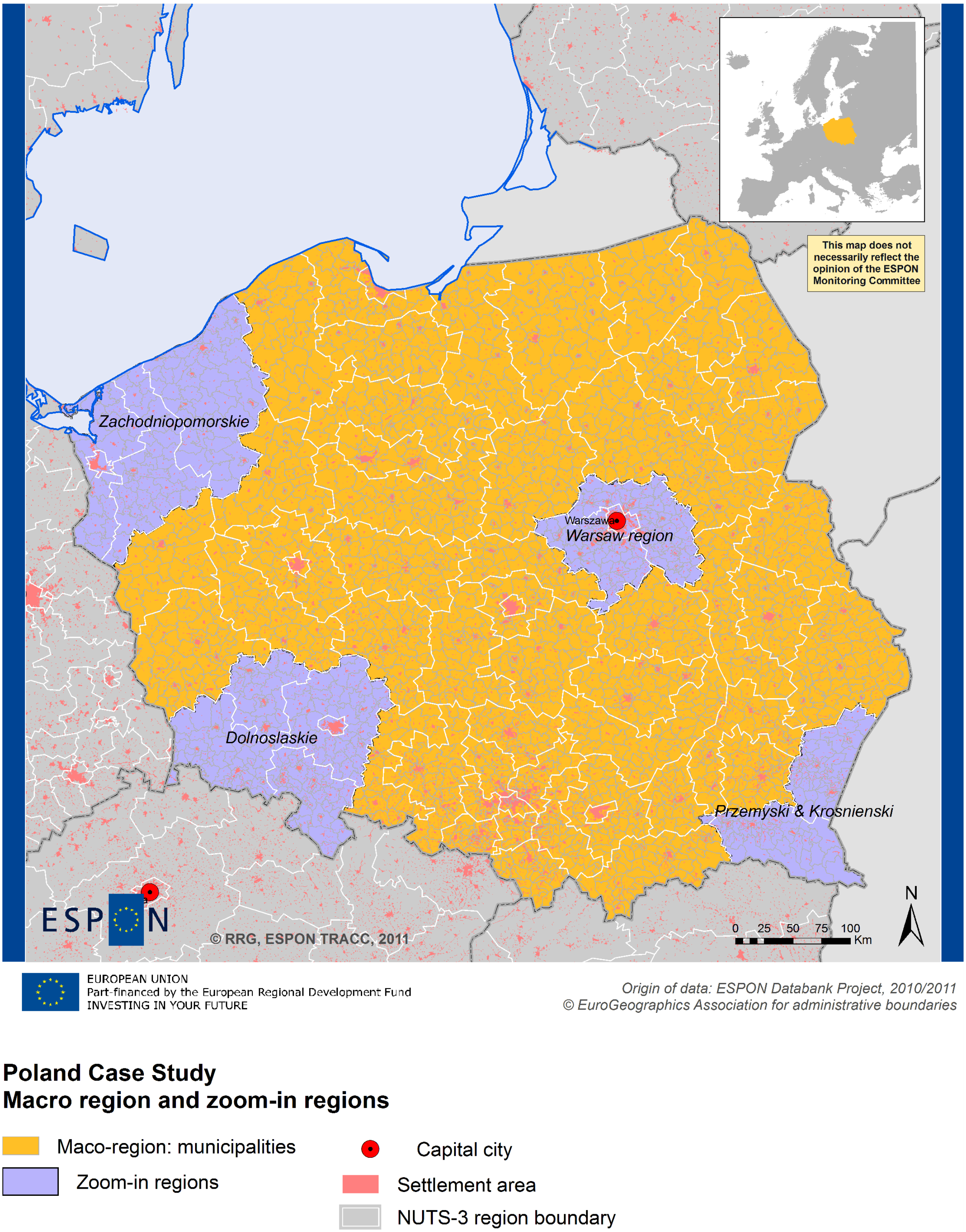


Figure A9. Poland case study - macro region and zoom-in areas

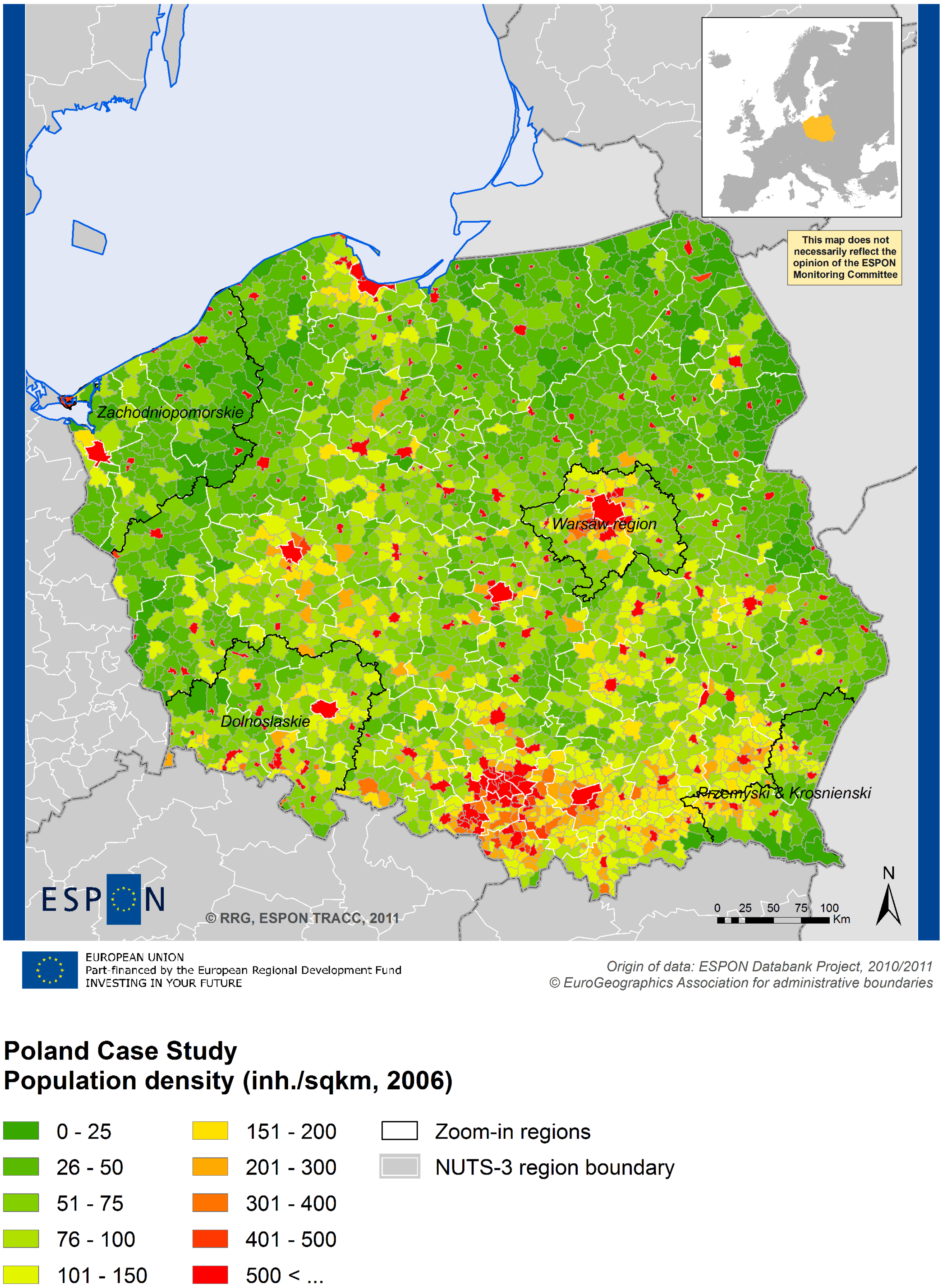


Figure A10. Poland case study - population density (2006)

The NUTS-2 population density differs from 59 persons per km² in north-eastern Poland (Warmińsko-Mazurskie and Podlaskie voivodships) to more than 200 persons per km² in the south-central part of the country (217 persons per km² in Małopolskie and 377 persons per km² in Śląskie voivodships). The average population density in Poland is about 122 persons per km².

Socioeconomic portrait

During the last two decades Polish GDP has expanded rapidly and Poland today ranks sixth in the EU in terms of real GDP (PPS-based). The Polish economy avoided a decline in GDP during the financial crisis and has created the highest GDP growth in the EU in 2009. However, the restructuring of heavy industry and the agricultural sector after 1989 led to the higher rate of unemployment (20 % of the economically active population without job in 2002-2003). In the following years the situation has improved and the unemployment rate has decreased to the level of 9.5 % in 2008. However, due to the financial crisis, it has increased again to 11.9 % in 2009 (in the Warmińsko-Mazurskie voivodship it still exceeds 20 %).

Poland's large internal market of 38 million consumers could help in being more independent of world economy than the rest of Eastern European countries. However, as early as 1995, 70 % of Polish export was directed to EU members (particularly to Germany).

The GDP structure is formed mainly by the service sector (65 %), followed by industry (32 %) and agriculture (3 %). The overemployment in agriculture (about 15 % of the workforce), particularly in the eastern parts of the country, still remains an obstacle to modernisation.

The spatial structure of industry in Poland has its roots in the time when Poland was partitioned by the Prussian, Austrian and Russian empires. The western and southern parts of Poland became more industrialised than the central and eastern parts (with the exception of metropolitan areas and the Świętokrzyskie voivodship). Despite the strong decline of coal mining and metallurgy in terms of employment, the main industrial part of Poland remains the industrial conurbation of the Upper Silesia voivodship. The automobile industry has developed to a considerable extent in south-western Poland but most of the headquarters and foreign direct investments are located in Warsaw and its surroundings or in the other large metropolitan areas.

For several years Poland has experienced a large amount of emigration to the UK and Ireland where 1 million Poles outnumber other immigrants from eastern Europe.

Transport aspects

Before 1989 the Polish transport system was characterised by freight traffic flows in the east-west direction between the Soviet Union and the GDR and in the north-south direction between the Polish harbours and the Upper Silesian coal region. After 1989 the decline in freight transport and the rapid increase in private mobility and motorisation (much faster than GDP growth) led to more than 400 motor vehicles per 1,000 inhabitants in 2008. In spite of this process, the 1990s were the decade of further delay in major decisions concerning transport infrastructure investments. After 2000 Poland is making up for the lost time by the biggest national motorway construction programme in Europe.

Road traffic is particularly concentrated in high population density areas – the Upper Silesia region and Warsaw. The highest traffic volumes are observed on the international roads: the existing motorway sections of the A4, A2 and A1 and the E-75 (Upper Silesia-central Poland section), the E-77 (from Gdańsk through Warsaw to Kraków) and the E-67 from (Wrocław through Warsaw to the Polish-Lithuanian border). The main transit road is the route from Germany through Poznań and Warsaw to the Baltic States.

Poland suffers from the lack of a proper railway infrastructure. The large decrease of technical speeds on many railway lines has enforced the modal shift from rail to road. According to the government's plan, the first Polish high-speed railway will run from Warsaw to Poznań, Wrocław and Łódź (Y line) in 2020.

Poland's regional airports are catching up with the country's main airport in Warsaw after the accession to the EU (nearly 55 % of all 20.8 million passengers in Polish airports flew through regional airports in 2008). The main flight destinations are the UK and Germany.

The port cargo operations, which are decreasing in recent years, are concentrated in Gdansk and Gdynia (Pomorskie voivodeship), and at a smaller scale also in Szczecin and Świnoujście (Zachodniopomorskie voivodeship).

Expected results

Accessibility analysis will be performed in Poland at the LAU-2 level (isochronic accessibility measure to main cities, road and railway networks, airports and ports and potential accessibility). The results of the accessibility study will provide information on the important differences in accessibility from a European and national perspective, particularly in the case of the south-western part of Poland, which has very poor road and railway connections to Warsaw. The following zoom-in areas for in-depth analysis are planned:

- The Warsaw region, which includes three NUTS-3 regions (Warsaw, Warszawski-Wschodni and Warszawski-Zachodni), is developing very fast while its road accessibility is relatively poor; it will change in the next decade after the realization of the A2 motorway section to Warsaw and other express roads including the southern Warsaw bypass.
- Dolnośląskie (Lower Silesia Voivodeship) (NUTS-2 region) is chosen due to the poor road and railway connection to Warsaw and good accessibility to European core areas. The accessibility of its capital Wrocław will change significantly after the realisation of the S8 express road and high-speed train to Warsaw.
- Zachodniopomorskie (West Pomerania Voivodeship) (NUTS-2 region) will be studied due to the existence of a port, a regional airport, fragmented motorway and expressroad sections and foreseen accessibility changes in the next decade.
- Przemyski and Krośnieński (two neighbouring NUTS-3 regions) are selected due to the 236 km of eastern Schengen border with Ukraine, the unexplored Bieszczady mountains and their very poor accessibility (which will change slightly after the completion of the A4 motorway in 2012/2013).

A2.6 Baltic States regional case study

The macro region

The macro region of the Baltic States includes six zoom-in areas, two per country. In each country one zoom-in area represents a seaport region (of which two are the capital regions at the same time), and the other one represents a more peripheral region towards the eastern border (Figures A11, A12).

The following zoom-in regions are chosen:

- *Estonia*. The capital city region of Tallinn was selected as it represents the capital and the major seaport of Estonia, with the highest concentration of public and private services and infrastructures. Vöru in turn is a small town in the rural southern part of the country, located at the cross-roads of important east-west and north-south transport axes.

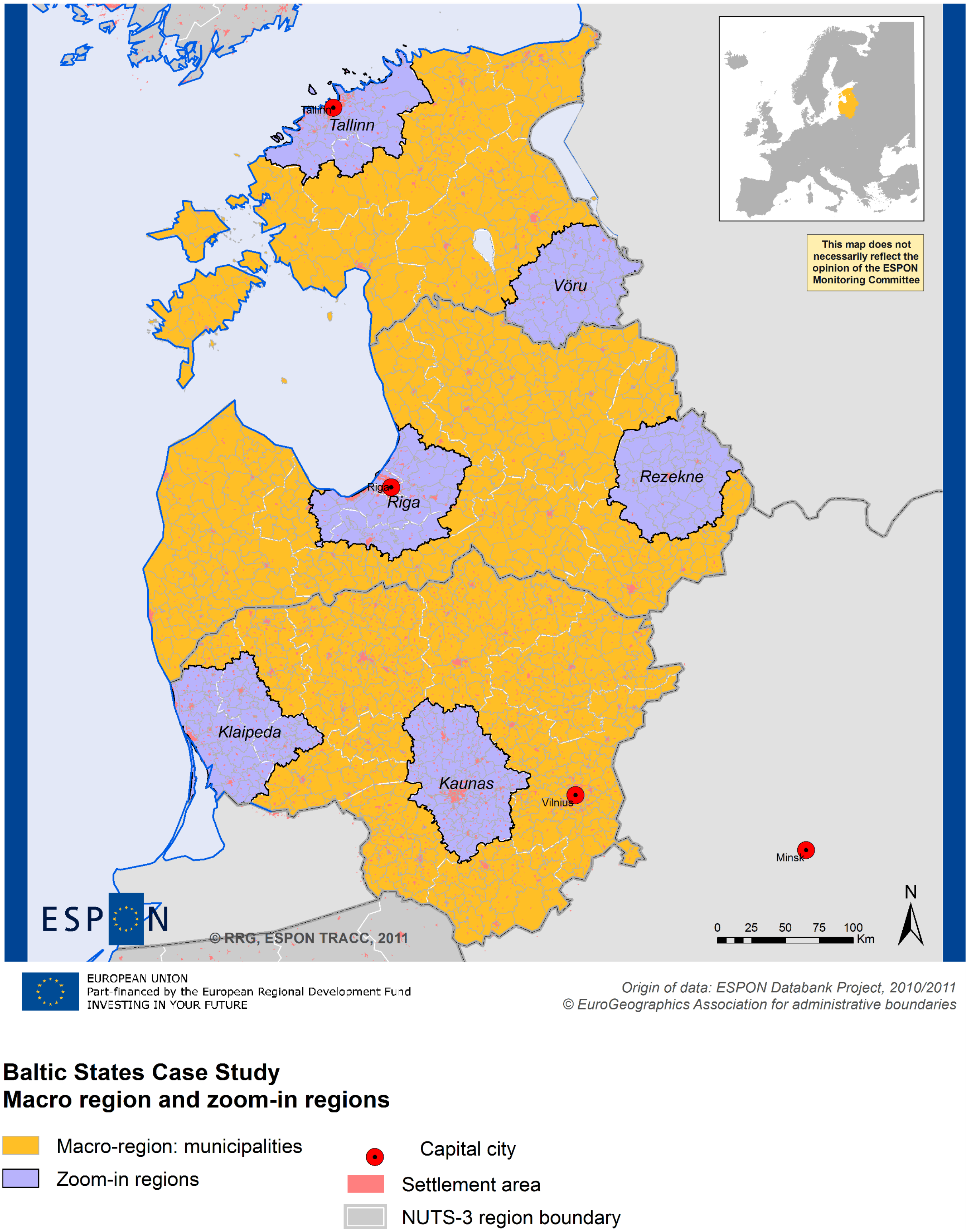


Figure A11. Baltic States case study -:macro region and zoom-in areas

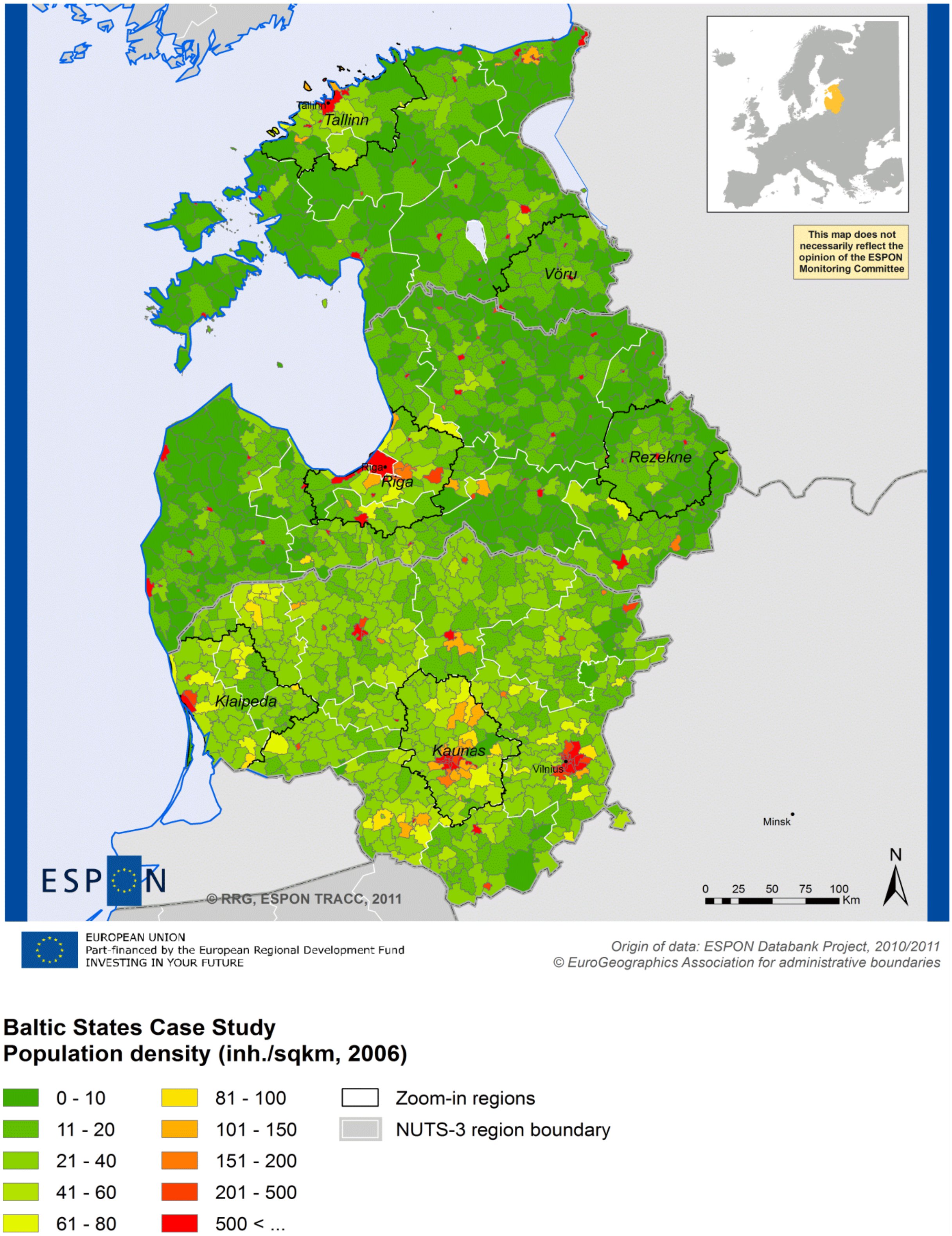


Figure A12. Baltic States case study - population density (2006)

- *Latvia*. Similar to the case of Tallinn, Riga was selected as it is the capital and the main seaport of the country. Rezekne is a medium-sized town in the eastern, rural part of the country towards the Russian border, where the economic performance in terms of GDP per capita is extremely poor compared to the EU27 average, corresponding to the level of Belarus.
- *Lithuania*. Klaipeda was selected as a zoom-in region because it represents the main port of Lithuania, connecting the country to western Europe and Scandinavia via several ferry services. Kaunas, in addition, is located in the central part of Lithuania at the crossroads of all north-south and east-west transport arteries, being a region with relatively high population densities (at least in the context of the Baltic States).

The spatial structure

All the three Baltic States are rural countries with generally low population densities, lacking a system of cities and agglomerations. Only the capital city regions and to some extend the seaports are agglomerated areas, concentrating most of the private and public services. The other parts of the countries are rural areas, with small and medium-sized towns with population of less than 25,000 inhabitants, often less than 5,000 inhabitants, resulting in extremely poor population densities of less than 50 people per km^2.

Most of the cities and towns in the Baltic States experienced a population decline in the last decade, only the capital cities remained stable in terms of population in this period. In case of Klaipeda and Riga city regions, some suburbanisation processes could be observed since the year 2000, where the surrounding smaller towns increased population over-proportionally compared to the core city.

The economic performance of the overall macro region is poor, experiencing employment rates and GDP per capita figures of only 25-50 % of the EU27 average. Only the capital city regions reach the European average. The dominance in the primary sector, in particular in Latvia and Lithuania, underlines the predominantly rural character of the macro region.

Previous accessibility studies have revealed that only the capitals gained accessibility levels above the EU27 average, while all other parts of the countries lagged significantly behind, in terms of population potential, accessibility to population and also accessibility to GDP, with accessibility levels in the European context similar to those of peripheral territories in northern Scandinavia, not only due to the extremely low population densities, but also to a lack of high-quality transport infrastructure.

Transport aspects

Despite the low population density and poorly developed city systems, all three countries face a number of severe problems in the transport sector:

- A major obstacle to transport is the general layout of the main transport infrastructure: for historical reasons all main road and rail infrastructures are west-east oriented, connecting central parts of Russia with the Baltic Sea seaports. Until today this remained the main trade flow direction in this area. In contrast, north-south oriented transport arteries are very scarce and, if they exist, are often of poor quality. For instance there is no direct north-south train connection Poland to Tallinn. This is a major obstacle for the three capital city regions of Vilnius, Riga and Tallinn to move closer together.
- All three countries are lacking high-level transport systems, such as motorways or high-speed train sections. There are only few motorway and dual-carriageway sections, opened to traffic only recently, and almost no high-quality rail lines. The remaining road networks are preliminary designed to meet regional transport demand rather than long-distance inter-city traffic.

- The secondary road networks developed differently in the three countries: while for Lithuania (140%) and Estonia (125%) these networks increased significantly since the beginning of the 1990s, the lengths of these networks in Latvia declined to 92% in the same period.
- While the general density of the road networks is quite good, the density of the rail networks is rather low. Apart from the main railway lines connecting the capital cities with the main ports and with Russia, almost no substantial rail links are available.
- All three countries have at least one major ferry seaport which is tightly embedded into Baltic Sea shipping networks, but none of the countries have any inland waterway network, which would allow feeder shipping services from/to the main ferry hubs. Therefore, all incoming goods must be transshipped in the ferry seaports to road and railway services. Unfortunately, the hinterland connections of these ports are of low quality as well. Some of the ferry services connecting to the Baltic seaports belong to the top 25 connections in terms of number of weekly ferry services (for instance, Helsinki-Tallinn ferry ranked 3 with 392 weekly ferry services in 2007).
- Each of the three countries has one international airport in the capital city region. Even though these airports provide quite a number of services to various countries, the number of direct destinations served is rather low compared to major airports in Central Europe. Since there are no other commercial airports in these countries except the three main ones, all commercial air services have to go through these three, which requires good accessibility of these airports in a regional context. Unfortunately, this is the case only to some degree.

Altogether, there is no high-quality transport infrastructure interconnecting the three Baltic States. The present TEN-T outline plans try to overcome this handicap by implementing new prioritized road and rail axes in north-south direction, connecting Tallinn in the north with Poland in the south.

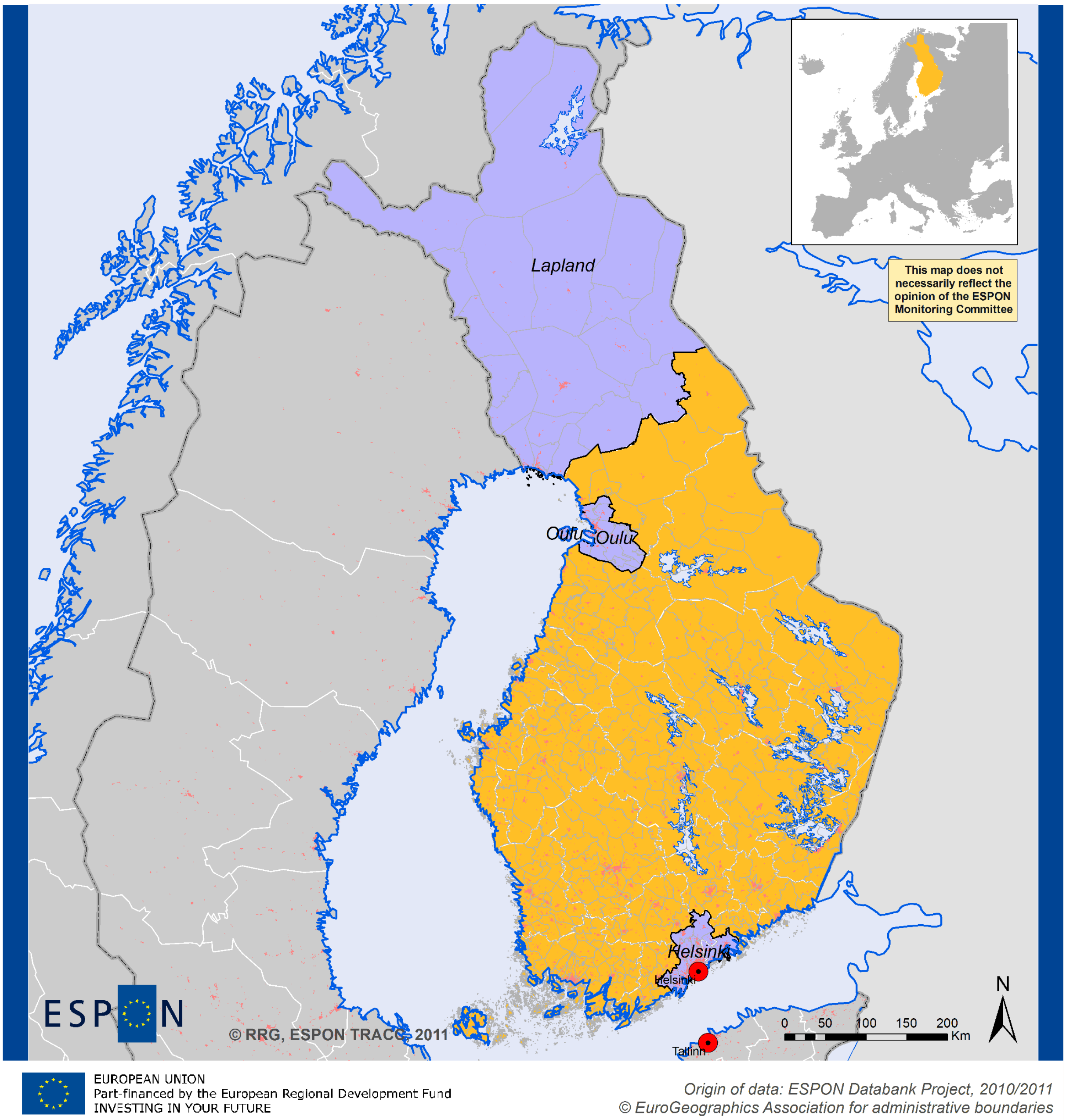
Expected results

The accessibility model will be set up for the entire macro region (i.e. for the whole of Estonia, Latvia and Lithuania), including road, railways, ferry and flight connections. The spatial base level will be a 2.5x2.5 km raster grid, for which travel times and accessibilities will be calculated. The raster results will then be aggregated to municipality level. Based on this overall computation, the analysis will zoom into the six zoom-in regions to reveal small-scale local and regional accessibility patterns. The results will be compared not only between the six zoom-in regions, but also to the other parts of the macro region.

A2.7 Finland regional case study

The macro region

Finland is the eighth largest country in Europe in terms of area and the most sparsely populated country in the European Union. Situated in the Fennoscandian region of northern Europe, it is bordered by Sweden, Norway and Russia, while Estonia lies to its south across the Gulf of Finland. Hence, in terms of transport, Finland is situated almost like an island with respect to the rest of the European Union. Around 5.4 million people live in Finland, with a majority being concentrated in the southern part of the country. Finland is a country of thousands of lakes and islands (almost 200,000 lakes and 200,000 islands), mostly flat with few hills, with its highest point the Halti at 1.324 metres in the northern tip of the country. In addition to the harsh climate, the amount of population and economic activities have remained low due to the fact that the topography of the region poses serious challenges to accessibility. (Figures A13, A14).



Finland Case Study
Macro region and zoom-in regions

Maco-region: municipalities

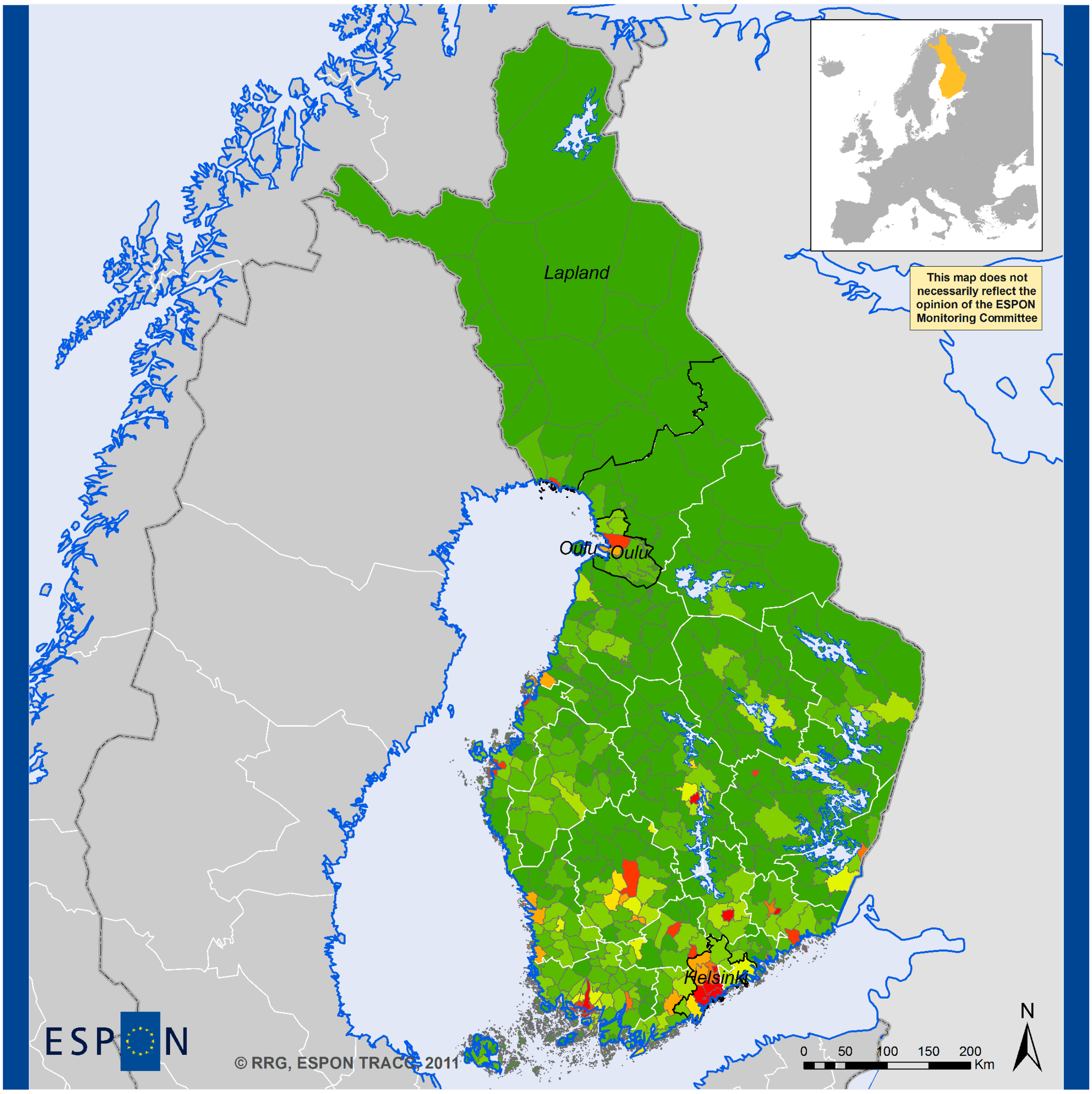
Zoom-in regions

Capital city

Settlement area

NUTS-3 region boundary

Figure A13. Finland case study - macro region and zoom-in areas



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Origin of data: ESPON Databank Project, 2010/2011
© EuroGeographics Association for administrative boundaries

Finland Case Study
Population density (inh./sqkm, 2006)

0 - 10	81 - 100	Zoom-in regions
11 - 20	101 - 150	NUTS-3 region boundary
21 - 40	151 - 200	
41 - 60	201 - 500	
61 - 80	500 < ...	

Figure A14. Finland case study - population density (2006)

The selected zoom-in areas will provide insight on the three unique regional cases in the European context having high importance in the context of the country.

- The Greater Helsinki zoom-in area is the unquestionable metropolis of Finland with population over one million and the northernmost capital city of the EU member countries.
- The Lapland zoom-in region represents an extreme periphery in the European context.
- The Oulu zoom-in region is one of the northernmost European growth centres.

The spatial structure

Around 5.4 million people live in Finland, with a majority being concentrated in the southern part of the country. The Greater Helsinki concentrates 25 % of the country's population, including three cities with more than 100,000 inhabitants (Helsinki, Espoo and Vantaa). Other major cities in the region are Tampere (210,000 inhabitants), Turku (175,000 inhabitants), Oulu (140,000 inhabitants), Jyväskylä (130,000 inhabitants) and Lahti (100,000 inhabitants). There are no other cities other than these with more than 100,000 inhabitants.

The Helsinki metropolitan region, roughly corresponding to the NUTS-3 level region of Uusimaa, consists of 18 municipalities with a total population of around 1.4 million people, making it the most densely populated region in Finland. Most of the population lives in the capital city of Helsinki and its three immediate neighbour cities. Due to being located at the coast along the Gulf of Finland, the region encompasses a large number of islands of different sizes, but they do not have any significant demographic role. Generally, the population density decreases fast as one moves away from the city of Helsinki. The main transport corridors of course make exceptions to this.

The Oulu region consists of ten municipalities located within the NUTS-3 region of Northern Ostrobothnia, located in the mid of Finland on the shores of the Bothnian Bay. Oulu, the main municipality of the region, has a population of about 140.000 inhabitants, making it the most populous city in northern Finland. The region is characterised by a single and relatively small urban centre surrounded by rural areas. The population density drops rapidly as one moves away from the city of Oulu, and large areas in the region are totally unpopulated. Settlements have concentrated historically at the coast and at the mouths of rivers, a pattern which remains even today, although a distinctive semi-urban area has been formed around the city of Oulu.

The NUTS-3 region of Lapland is the northernmost region of Finland, being a vast region constituting almost a third of the entire country but housing only 180.000 inhabitants, a half of which is concentrated in the three biggest population centres. This signifies that most of the region is extremely sparsely populated, and indeed, large areas of the region are totally unpopulated. The region of Lapland consists of overall 21 municipalities, which differ significantly both in their area and population. The largest population centres are located in the south-western part of the region, positioned mostly at the mouths of the great rivers running into the Bothnian Bay. The northern parts of the region are extremely sparsely populated with only small local centres.

Socioeconomic portrait

Helsinki's metropolitan region is Finland's major political, educational, financial, cultural and research centre. Approximately 70 % of foreign companies operating in Finland have settled in the Helsinki region. The employment rate in the region is high: 63 %, which is considerably higher than in the rest of the country (57 %). Indeed, the region is more than self-sufficient in jobs. Currently less than one percent of the population work in agriculture. Industry and services account for 18.6 % and 80.8 % of the workplaces, respectively. The share of the industry has been in constant decline for several decades, which is compensated by the growth in services-related activities. The region accounts for about 35 % of the entire GDP of Finland. The GDP per capita is over 46,000 € which is 135 % of the national average.

Most of the people in the Oulu region work either at the service sector (75 %) and industrial sector (24 %). Traditionally the economy of the region has relied on the wood-processing industry, which has benefited from the location close to the rivers. The relative importance of the traditional industry has been in constant decline, and has been replaced especially by high-technology industry. However, the industries have suffered from the economic downturns during the past decade, resulting in relatively high unemployment (14.5 %), which is four percentage units higher than the national average, especially among young people. However, related to the fact that the age structure is tilted towards younger generations, which can be regarded as a potential socioeconomic advantage for the region. The population of the region has been in constant increase for a long period of time, due to immigration from the peripheral areas of northern Finland, but also the result of a high birth rate. Specifically, the population growth has been strongest in the neighbouring municipalities of Oulu, and Oulu itself.

The region of Lapland is generally considered to be one of the least developed and most peripheral parts of Finland, where many socioeconomic problems are apparent. For example, the unemployment rate is several percentage points higher than the national average, and is the second highest among the NUTS-3 regions of Finland. Generally, the population of the region is in steady decline, and the age structure is becoming increasingly older. The population of the region peaked in 1993, but since then the amount of population has decreased by almost 20 000 people. The negative trend has affected the entire region, except for the regional capital and certain individual population centres benefiting from the expanding tourism industry. While 6 % of the population work in the agricultural sector, 14 % do so in industry and construction, and services account for the major share of the sources of livelihood. Tourism in particular has become an important form of economic activity during the past few decades. Although the role of industry has been in slow but steady decline, two paper mills and a large steelworks operate in the south-west corner of the region.

Transport aspects

Due to its position as the capital of Finland since early 19th century, Helsinki and the surrounding region is well connected to the rest of the country by roads, railways and air traffic. Especially the railway network has been designed to connect Helsinki efficiently to the regional centres around the country. The region includes the main international airport of Finland, located remotely from Central Europe, while serving as an important connection hub between Europe and East Asia. The most important port of Finland is also located in the region as well. In addition to very busy freight traffic, there are passenger ferries operating mostly to Stockholm in Sweden, and Tallinn in Estonia. Domestic passenger traffic by the sea is, however, almost non-existent.

The Oulu region, In spite of being located far from the main populated centres of Finland, and extremely far away from Central Europe, can be considered to be relatively well accessible, at least in the national context. The Oulu region has an airport, having several daily connections to the capital city Helsinki. A remarkable scenario to consider in this context is the intention of Air Baltic Corporation to establish a north Scandinavian flight hub in Oulu. Finnish fast speed trains operate to Oulu, but the current condition of the railway and the congestion of the route reduce the actual benefit of the high-speed traffic. The shortest travel time from Oulu to Helsinki is 6 hours by train. Railway connections are also provided to many other regional centres especially in the south, but not at very short intervals. The Oulu region is also located advantageously with respect to the road network, as the most important highway running from Helsinki up north through the entire country run through the Oulu region. The region has the second biggest airport in Finland by passenger volume. Port of Oulu is one of the busiest harbours within the Bothnian Bay, but it only handles freight traffic.

Lapland has significantly varying conditions accessibility and transport conditions within the region. The south-western part of the region is well connected to the rest of Finland by the road, railway and air connections. The airports in the northern parts of the region improve the domestic and charter-based international tourism accessibility in their surrounding areas. The eastern and western parts of Lapland are also reached by railway connections. However, long internal distances causes that the region is mainly accessible by road. Two big harbours are located in the industrialised south-west part of the region, serving the needs of the heavy industry. Unlike any other region in Finland, Lapland has transborder connections to three other countries, but the low amount of population in the northern regions of Sweden and Norway is a limiting factor to the volume of economic interaction. Connections to Russia are relatively limited.

Expected results

Accessibility analysis will be performed at least at LAU-2 resolution; the use of more accurate resolutions such as 2x2 km raster grid in the computation of municipal accessibility is an option. Accessibility indicators will be calculated for the entire Finland including transport by road and rail, possibly also including airline and maritime connections.

The case of Helsinki region is an illustrative example of high and good quality of accessibility in spite of the physical remoteness. The typologies associated with this case study include at least urban and semi-urban areas, in the northern context.

The Oulu region in northern Finland represents the case of a competitive growth centre located high up in the north. The region is particularly interesting from the accessibility point of view in the sense that the urbanised area is closely surrounded by deeply rural and peripheral areas.

The region of Lapland represents a case of extreme periphery in the European context. The importance of the accessibility in this kind of periphery should be taken in to account, due to the difference in remoteness when compared to the rural regions in the rest of Europe, and also the remoteness in the local habitation structure and infrastructure. The accessibility of these regions remains a relatively unstudied question.

A3 Assessment of data situation

As base for the conclusions of the data situation presented in Chapter 6 of this report, this annex provides an assessment of the data situation with respect to European network data, the ESPON database and the data situation in the EU candidate countries and the Western Balkan.

A3.1 European network data

Several Europe-wide transport network data sources were identified that potentially could be used for Europe-wide or regional modelling in TRACC:

- ESPON local data (ESPON LD)
- ESRI´s Digital Chart of the World (DCTW)
- Eurostat GISCO/DG Move
- Navteq
- OAG
- OpenStreetMap (OSM)
- RRG GIS Database
- TeleAtlas
- TRANS-TOOLS

The list of network data comprises open ('free of charge') datasets (ESRI´s Digital Chart of the World, OpenStreetMap), project datasets (ESPON local data, TRANS-TOOLS), European Commission datasets (Eurostat GISCO/DG Move), as well as databases of commercial data vendors (Navteq, OAG, RRG GIS Database, TeleAtlas). The databases were assessed with evaluation criteria developed in the project (Table A1). The criteria reflect the potential of the network data for European accessibility travel and freight modelling. Table A2 provides the assessment results.

Concerning the available *modes*, most of the datasets comprise road and railways; only TRANS-TOOLS, TeleAtlas and RRG additionally provide flight and waterway networks. Freight terminals are only provided by RRG, TRANS-TOOLS and (to some extent) OSM. OAG, representing a collector of special aviation data, only provides flight networks.

The *spatial coverage* of the databases is generally good, except for the ESPON Local Data, which only comprises the Czech Republic, Hungary, Romania and Slovakia; the GISCO networks do not provide data for the Western Balkan and east European countries. Data for North Africa, as required by the freight model, are included in all data sources except for the ESPON LC, GISCO and RRG networks.

The *network density*, however, is very different. ESPON Local Data, Navteq, OAG and TeleAtlas can provide high network density, including all network links and nodes. OpenStreetMap provides generally high network densities in western Europe, but in other parts the density is poor in rural areas. The RRG GIS Database covers all trunk roads, but secondary roads are included only for selected areas, whereas it contains all railways and all navigable waterways in Europe. DCTW, GISCO and TRANS-TOOLS cover only major links resulting in a rather low network density.

Five data sources come with built-in *network topologies* (GISCO, Navteq, RRG, TeleAtlas, TRANS-TOOLS). ESPON Local Data, DCTW and OSM do not provide network topologies; i.e. the topology would have to be established before they can be used for modelling purposes.

Most of the data sources provide the network data for an actual year (Navteq, OAG, OSM, RRG, TeleAtlas), for other networks this information is not available (ESPON Local Data, GISCO, TRANS-TOOLS). A *temporal dimension*, i.e. network evolution over time, however, is only available with the RRG GIS Database, which includes a historical period of 50 years as well as a 30-year forecasting period of the networks, including a coding of the trans-European transport network outline plans.

Table A1. Criteria for the evaluation of Europe-wide transport network data

Criterion	Comment
Modes: road, rail (incl. stations), air (incl. airports), waterways, ferries (incl. ports)	For the Europe-wide accessibility modelling all four modes indicated are required. In addition, specific types of facilities such as intermodal freight terminals are needed for freight modelling, and functional connector links are required to link the centroids to the networks, and to link intermodal networks with each other.
Spatial coverage	The dataset needs to cover all countries of the ESPON space, plus EU candidate countries plus countries of the Western Balkan. Furthermore, external zones of the accessibility models cover Eastern European countries (Belarus, Moldova, Ukraine, and Russia). For the freight model even countries in North Africa are included as external zones.
Network density	The networks need to have a certain density which is sufficient to connect all NUTS-3 region centroids. At least all trunk roads, all railway lines and all navigable waterways and ferries need to be included, as well as all scheduled flights in Europe. The minimum network density required is the density used in accessibility potential modelling for ESPON projects 1.2.1, 1.1.1, 2.1.1, 1.1.3 and the recent Accessibility Updates.
Network topology	In order to avoid time-consuming procedures in which usually errors in the database would be detected, the datasets should already include built-in network topologies, i.e. a correct topology between the links and nodes of a network.
Updates	The databases need to have sufficient updates (2008-2011). Older reference years cannot be used. Some accessibility indicators as the potential accessibility need to be calculated for 2011.
Temporal dimension	In order to assess the impacts of transport policies, scenarios of future transport infrastructures until 2030 or 2050 need to be available in the networks, based on the TEN-T and national outline plans. The SASI model covers also a backcasting period starting in 1981, requiring network input data in five year intervals from 1981 onwards to the present.
Attributes: link types, lengths, travel times (rail), speed limits, degree of urbanization (road), frequency (ferries, flights), IATA codes (airports), costs, capacities	All links in the networks need to have at least attributes providing information on link lengths, link speeds (either average speed, or maximum speed), for rail and flight networks even timetable travel times are needed. For ferries and flights information on service frequencies is required as well. Based on this information, minimum paths based on travel time can be computed by the accessibility models. Ideally, also cost and capacity information is provided with the networks. Capacities, however, can often be deduced from link types.
Data format	In order to facilitate a smooth integration of the network database, the data should already be available in a GIS format (like ArcView shapefile, MapInfo tab file etc.). Raster formats or ASCII formats cannot be used.
Price	Ideally the dataset should be usable free of charge by TRACC. High data costs may be an exclusion criterion for the dataset.
Legal restrictions	Any other legal restrictions that need to be considered.
Continuity	Previous ESPON projects (1.2.1, 1.1.1, 2.1.1, 1.1.3 and the recent Accessibility Updates) already generated a number of accessibility indicators, where TRACC is expected to update these indicators. In order to enable reliable comparisons of the updated indicators with the previous ones, input data with similar characteristics should be used to ensure continuity without artefacts.
General data availability	Some datasets may, for any reasons, generally not become available to ESPON, even if they comply with all requirements.

Table A2. Evaluation of network datasets

Criteria	ESPON LD	DCTW	GISCO [8]	Navteq	OAG	OSM	RRG	TeleAtlas	TRANS-TOOLS
Mode[1]									
Road	+	+	+	+	--	+	+	+	+
Rail	+	+	+	+	--	+	+	+	+
Flights	--	--	--	--	+	--	+[2]	--	+
Water	--	--	--	--	--	--	+		+
ILC [9]	--	--	--	--	+	+	+	--	-
Coverage									
ESPON	[3]	+	+	+	+	+	+	+	+
candidates	--	+	+	+	+	+	+	+	+
Balkan	--	+	--	+	+	+	+	+	+
East Europe		+	--	+	+	+	+	+	+
North Africa	--	+	--	+	+	+	--	+	--
Network density	high; all roads and railways	low; only trunk roads & major railways	low; only trunk roads & major railways	high; all roads and railways	high: all scheduled flights	different; in cities all net-works, in rural parts only major infra-structures	different: all railways, all trunk roads, in selected areas also secon-dary roads	high; all roads and railways	medium. all major infra-structures; secondary missing.
Network topology	not available, need to be build	not available, need to be build; pro-blems with connectivity.	available	available	not required	not available, need to be build; pro-blems with connectivity.	available	available	available
Reference year	n.a.	2008	n.a.	actual year	actual year	actual year (depending on community)	actual year	actual year	2005
Temporal dimension	no	no	no	no [4]	no	no	every year since 1950	no [4]	no
Attributes:									
Speed	--	--	--	+	+	--	+	+	+
Time	--	--	--	+	+	--	+	+	+
Costs	--	--	--	+	+	--	--	+	+
Capacities	--	--	--	+	+	--	+	+	+

Table A2. Evaluation of network datasets (continued)

Criteria	ESPON LD	DCTW	GISCO [8]	Navteq	OAG	OSM	RRG	TeleAtlas	TRANS-TOOLS
Data format	shapefile geo-database	shapefile	shapefile	shapefile	web [5]	shapefile	shapefile, geodatabase	shapefile	shapefile
Price	free	free	n.a.	high	free [7]	free	free [6]	high	free
Continuity	compiled in other ESPON project, but no acc calc	---	internal EC usage (DG Move)	---	---	---	used to calculate previous ESPON acc indicators	---	used in various research projects
Data availability	yes	yes	currently not available, later WMS service	only upon licensing	huge efforts for data gathering from website	yes	yes	only upon licensing	yes

1 modes: required are routable modal networks, not just background layer.
2 flight network data collected by S&W in a previous study; however, flight networks tightly integrated into RRG GIS Database.
3 network data only available for Czech Republic, Hungary, Romania, and Slovakia.
4 upon request past years could be licensed separately
5 data to be extracted from website
6 free usage within TRACC project, since RRG is project partner
7 free when data manually compiled from website; otherwise license fee to be paid
8 information provided by Sorin Andrei (DG Move) on TENtec at a GIS Experts Meeting in Brussels, 7 July 10 (Andrei, 2010)
9 ILC = Intermodal logistics centre (intermodal terminal, freight village)

Relevant speed, time, cost and capacity *attributes* required for accessibility calculations can only be provided by half of the databases (Navteq, OAG, RRG, TeleAtlas, TRANS-TOOLS), whereas the other ones are missing any such information. Information on capacity, however, can also be approximated from the link type fields (if available).

All databases offer the network data in a GIS *format* (ArcView shapefiles or Geodatabase). Except for Navteq and TeleAtlas, all databases can be used for free in TRACC. However, the GISCO datasets are currently not available, but at a later point in time GISCO/DG Move will make the networks available as WMF service. Navteq and TeleAtlas data, as being two commercial data vendors, need to be licensed for any usage. License fees depend on the actual scope of usage, however, they can be generally considered as very high for both data vendors.

The RRG GIS Database and also the TRANS-TOOLS data have already been used in several research projects, ESPON projects and consultant projects for various DGs of the European Union; the RRG data, moreover, have already been used to compute the previous ESPON potential accessibility indicators, that way ensuring continuity if used in TRACC.

Table A3 reports the detailed findings of the evaluation. It is concluded that the TRANS-TOOLS database should be used for modelling of European freight accessibility in TRACC, if necessary complemented with additional information from the RRG GIS Database (like information on ILC), whereas for modelling Europe-wide accessibility travel the RRG GIS Database should be used (enriched with latest data for flight networks). OSM and the ESPON Local Data may also provide additional information to TRANS-TOOLS and RRG GIS Database. The TRANS-TOOLS network database is currently being updated and improved in the project ETISplus with respect to the addition of international terminals, improved interconnections between modes, and network topology of ferry lines and airlines.

Table A3. Summary of network database assessment

Data source	Pros	Cons	Conclusions
TRANS-TOOLS, RRG	Free of charge, full coverage, all modes, required data formats, at European level sufficiently dense, already used in modelling, speed / cost / time information available, built-in network topology, RRG includes temporal dimension, flexible, RRG to include TEN-T outline plans	At regional level road networks not dense enough	TRANS-TOOLS to be used as base network for freight modelling, RRG to be used as base network for travel modelling. RRG to complement TRANS-TOOLS with missing information
OSM, DCTW, ESPON Local Data	Free of charge, full coverage (except ESPON Local Data), road and rail modes, required data formats, OSM and ESPON Local Data sufficiently dense	All networks without topology; information on speeds, costs or time are missing; no information on TEN outline plans, no temporal dimension, no flight and waterway networks	OSM and ESPON Local Data to complement existing network data for regional case studies, if required; DCTW not to be used in TRACC
Navteq, TeleAtlas, OAG	Full coverage, all modes except flights (Navteq, TeleAtlas), complete networks, built-in topology; information on speeds, time and capacities available; actuality	No temporal dimension, commercial datasets, high prices, legal restrictions, no flexibility due to internal formats	Navteq & TeleAtlas not to be used due to price and legal restrictions
GISCO / DG Move	Free of charge, full coding of TEN networks, full coverage except Western Balkans, road and rail modes, sufficiently dense for Europe-wide modelling.	Currently not available, several required attributes not available	Currently data cannot be used

In all cases the necessary connector links, i.e. links connecting NUTS-3 region centroids to the networks and connecting different modal networks with each other, need to be generated automatically by scripts within the GIS.

In addition, information on heavy-goods vehicle waiting times at border crossings has to be retrieved from the IRU website to be used for Europe-wide freight modelling.

A3.2 ESPON database

The ESPON database available to all ESPON projects will be the main database for the socio-economic data. The ESPON database is subdivided into six themes (directory names of the CD-ROM in italics)

- *Basic* statistical data for the ESPON space at NUTS-3 level
- *Grid data* for the ESPON space and the EU candidate countries and Western Balkan (disaggregated socio-economic data on GDP, unemployment and active population)
- *Historical* statistical data for the ESPON space, based on older NUTS classifications
- *Local data* (statistical and geographical) for Bulgaria, Czech Republic, Hungary, Romania and Slovakia at municipality level
- Basis statistical data for the *neighbouring* EU candidate countries and Western Balkan at NUTS-3 level
- *World data*: geographical datasets.

The datasets required in TRACC will be extracted from these themes, and compiled and processed in the format required by the Europe-wide models.

Apart from the statistical data, the ESPON database also includes geographical boundaries for the different NUTS levels (NUTS-3, 2, 1, and 0) for different NUTS versions, which can be used for data illustrations and mapping. The ESPON database provides also pre-processed *mapkits* and map layouts in ArcGIS format at different scales and with different extent (ESPON Space, ESPON Space and candidate countries, global mapkit, and local mapkit), which will be used by all ESPON projects to generate maps with standardized map layout.

It is, however, worth mentioning that the geographical layers of the ESPON mapkits are not suitable to perform geographical analyses, such as layers overlay, since they are highly generalized, which allows production of good-looking maps, but limits their usefulness in spatial analysis.

A3.3 EU candidate countries and the Western Balkan

In order to include the EU candidate countries and the countries of the Western Balkan as internal zones for the Europe-wide accessibility models, both network data and socio-economic data at a sufficient regional subdivision are required. In order to work with socio-economic data in GIS, also appropriate region boundary layers are required. The ESPON 2013 Database project assessed the data availability in these countries (Angelidis, 2010). Following is a brief overview of the data situation with respect to these two data groups.

Network data

Both the assessed RRG GIS Database and the TRANS-TOOLS database include network data for these countries with sufficient network density from a European perspective. It still needs to be checked whether all region centroids are connected properly to the network. If this is not the case, individual network links will have to be added.

Regional subdivision

In order to include these countries into the models, a regional subdivision corresponding to the NUTS-3 regions in the EU countries needs to be available. The ESPON 2013 Database project (Angelidis, 2010, 4) confirms that Turkey, Croatia and FYROM already adopted the NUTS classification, including the NUTS-3 level, while the rest of the countries are currently in the process of adoption, where existing administrative divisions can easily be associated with respective NUTS levels. Table A4 provides an assignment of these divisions to the NUTS system.

Table A4. Corresponding NUTS levels in EU candidate countries and Western Balkans

Country	**NUTS equivalent territorial divisions**		
	NUTS-1	**NUTS-2**	**NUTS-3**
Albania	Country	Country	12 prefectures
Bosnia and Herzegovina	Country or FBiH, RS, Brsko districtx	FBiH, RS, Brsko districtx	10 cantons
Croatia	Country	Regiia	Counties
FYROM	Country	Country	Statistical regions
Kosovo	Country	Country	Country
Montenegro	Country	Country	Country
Serbia	Central Serbia, Voivodina	Central Serbia, Voivodina	21 districts
Turkey	Regions	Sub-regions	Provinces

The draft version of the *ESPON Space and candidates mapkit* developed by the ESPON 2013 Database project (Zanin et al., 2010) includes shapefiles for the equivalent NUTS classification in these countries. However, as partly 'non-official' boundaries were used (Angelidis, 2010, 6), it still needs to be clarified whether they can be used in ESPON free of any legal restrictions.

Socio-economic data

Most of the required socio-economic data at country level are already available with project partners. At regional level (i.e. NUTS-3), the ESPON 2013 Database project made a rough assessment of the data availability (Angelidis, 2010, 33ff; see Table A5 for full overview), revealing

(i) a very good availability of population data (total population, by sex, by age groups, by educational attainment) for different points in time
(ii) a lack of household data
(iii) a lack of land use data and data on buildings and dwellings
(iv) a fairly good availability of data on employment, unemployment and active population, however, some of these data not more recent than 2000 or 2001 or even early or mid-1990s
(v) partial availability of GDP data

The lack of statistical land use data may be alleviated by using the CORINE land use data at raster level, which is also available for the Western Balkan countries (EEA, 2010). A lack of other statistical data may also be compensated by the ‘experimental’ ESPON grid data (Milego and Ramos, 2010), which provides raster data on GDP, active population and unemployment for all countries of the ESPON space, plus the EU candidate countries and countries of the Western Balkan. These grid data can either be used to disaggregate available datasets from the national level to the NUTS-3 level, or the grid data can directly be aggregated to the NUTS-3 level.

Table A5. NUTS-3 data availability in EU candidate countries and Western Balkan Countries (Angelidis, 2010, 33ff, simplified)

Data	**Albania**	**Bosnia-Herzegovina (1)**	**Croatia**	**FYROM**	**Serbia**	**Montenegro**	**Kosovo (2)**	**Turkey**
NUTS-3 equivalent region	12 Prefectures	3 Districts (FBiH, RS, and Brsko)	21 Jupanija	8 Statisticki Regioni / SR	Districts	1 (total country)	7 Districts-	81 ILLER
Population census years 1985 - 2008	1999, 2001	1991	1991, 2001	1991, 2002	1991, 2002 (3)	1991, 2003	1991	1985, 1990, 1997, 2000 (4)
Total population	1989, 2001c	1991, 1995, 2001 -2002 2007 (FBiH)	1991, 1995, 2001, 2002 -2008	1991, 2002	1991, 1995, 2002, 1998-2005.	1981, 1991, 2003	1981, 1991, 2006, 2007	1990, 2000
Population by sex:	2001	1991, 2000-2003, 2007 FBiH)	1991,1995,2001 2008	1991, 2002	1991, 1995, 1998-2007	1981, 1991, 2003	1991, 2006, 2007	1990, 2000
Population by age group	2001	1991, 2000-2003 2007 FBiH)	1991, 2001	1991, 2002	1991, 1995, 1998-2005.	1991, 2003	1991, 2006, 2007	1990, 2000
Population by sex and age group	2001	1991	1991, 2001	1991, 2002	1991, 1995, 1998-2005	1991, 2003	1991	1990, 2000
Population per education level	2001	1991	1991, 2001	1991, 2002	1991, 1995, 1998-2005,	2003-2008, 2003	1991	1990, 2000
Total active population	2001	1991, 2007	1991, 2001 2002	1991, 2002	1991, 1995, 2002	1991, 2003	1991	1990, 2000
Active population by sex	2001	1991, 2007	1991, 2001	1991, 2002	1991, 1995, 2002	1991, 2003	1991	1990, 2000
Number of employed per sons	2001	1991, 2007	1991, 2001	1991 2002	1991, 1995, 1998-2006, 2002, 2006	1991, 2003, 2004-2007	1991	1990, 2000
Number of unemployed persons	2001	1991, 2007	1991, 2001	1991, 2002	1991, 1995, 1998-2006, 2002, 2006	1991, 2003, 2004-2007	1991	2000, 2004- 2007
Employment per primary, secondary, tertiary sector	2001	1991, 2007	1991, 2001	1991, 2002,	1991, 1995, 1998-2006, 2002, 2006)	1991, 2003, 2004-2007	1991	1981-2001
GDP		2005-2007 (FBiH)		2004-2006		2000-2004	no data	1990, 2000

1 Federation of Bosnia and Herzegovina (FBiH), Republic of Srpska (RS), and Brsko District 3 Census not carried out in Kosovo and Metohia.
2 Under UN Security Council Resolution 1244 4 Turkey: 1997 only housing, 2000: only population census

A4 Project planning

A4.1 Detailed timetable

The detailed timetable of the TRACC project for the three Work Packages Co-ordination, Research and Dissemination is presented in Table A8.

A4.2 Work towards Draft Final Report

The Draft Final Report is due twelve months after the delivery of this Interim Report. Project work will mainly concentrate on the preparation (Task 2) and implementation of the different accessibility analyses at global, European and regional/local scale (Tasks 3, 4, 5), on the accessibility impact modelling (Task 6) and on the development of policy conclusions (Task 7).

All project partners will be involved in the work towards the Draft Final Report. TPG meetings are scheduled for June and December 2011 to discuss preliminary results and to prepare for the Draft Final Report. A meeting of the TPG with the Sounding Board is scheduled for June 2011.

A4.3 Interlinkages with ESPON projects

The TRACC project will take advantage of existing ESPON results. Particular attention will be paid to earlier work on European accessibility in the Study Programme on European Spatial Planning (SPESP) and in previous ESPON projects 1.2.1, 1.1.1, 2.1.1 and 1.1.3 and the recent Accessibility Updates. As described in Chapter 4, the TRACC project will use the main accessibility indicators developed in those projects, in particular the potential accessibility indicator and will update these to the year 2011.

With respect to projects from the ESPON 2013 Programme, TRACC is an intensive user of already available and forthcoming results. The database developed by the ESPON 2013 Database Project is the key information source for socio-economic data in TRACC. The typologies developed by the ESPON Typology compilation project was used for the selection of case study regions (see Chapter 5) and will be further used when analysing the accessibility results at various levels considered. Classifications of the European urban system with respect to the functionality of cities developed by FOCI on future orientations for cities will be used when analysing access to the urban system. Results of the ESPON projects DEMIFER on demography and migratory flows, ReRisk on rising energy prices and TIPTAP on territorial impacts of transport and agricultural policies will be used when modelling the impacts of transport policies and rising transport energy prices. The methodologies of the INTERCO project on indicators of territorial cohesion will be reflected when analysing the results of the TRACC accessibility and impact modelling in terms of cohesion. It will have to be found out whether the TRACC project might also benefit of interim results of other ESPON projects such as TIGER on globalisation, ATTREG on the attractivity of regions and cities, and the new ESPON project SeGi on services of general interest.

On the other hand, ongoing ESPON projects such as ATTREG on the attractivity of regions and cities) and ARTS on regional and territorial sensitivity have already expressed their interest in using accessibility data provided by TRACC. Beyond individual accessibility provision, TRACC will deliver the accessibility indicators calculated to the ESPON database.

A4.4 Distribution of research tasks among partners

Table A9 shows the distribution of research tasks among project partners by indicating for each Subtask the leading project partner and the degree of contributions (major, small or none) of other project partners to that Subtask.

Table A8. Timetable of project activities

Tasks	Subtasks	2010				2011				2012			
0 Co-ordination	Co-ordination		M		M		M		M	M			
1 Methodology and indicators	1.1 European and global accessibility models and indicators												
	1.2 Regional and local accessibility models and indicators												
	1.3 Models to forecast the impacts of accessibility on regions												
	1.5 Core set of accessibility indicators												
2 Network and socio-economic data	2.1 European network data												
	2.2 Socio-economic data												
	2.3 European network and socio-economic data												
	2.4 Regional network and socio-economic data												
3 European accessibil-ity: travel	3.1 European travel accessibility												
	3.2 European travel accessibility measured by other indicators												
	3.3 Global travel accessibility												
4 European accessibil-ity: freight transport	4.1 European freight accessibility												
	4.2 European freight accessibility measured by other indicators												
	4.3 Global freight accessibility												
5 Regional accessibil-ity	5.1 Typology of regional accessibility patterns												
	5.2 Selection of regional case studies												
	5.2 Case studies on regional accessibility patterns												
	5.3 Europe-wide modelling of regional accessibility												
	5.4 European v. regional accessibility												
6 Impacts of accessi-bility	6.1 Accessibility and regional development												
	6.2 Long-term scenarios of European transport												
	6.3 Spatial impacts of European transport scenarios												
7 Policy implications	7.1 Policy-relevant findings												
	7.2 Policy conclusions												
	7.3 Further research needs												
8 Dissemination	Dissemination			R		R				R	R		

M	Meetings
R	Reports

Table A9. Research tasks and project partner responsibility

Tasks	Subtasks	S&W (LP)	Prf UK (PP2)	RRG (PP3)	Mcrit (PP4)	FOGIS (PP5)	TRT (PP6)	IGIPZ PAN (PP7)
0 Co-ordination	Co-ordination	Lead						
1 Methodology and indicators	1.1 European and global accessibility models and indicators							
	1.2 Regional and local accessibility models and indicators	Lead						
	1.3 Models to forecast the impacts of accessibility on regions							
	1.4 Core set of accessibility indicators							
2 Network and socio-economic data	2.1 European network data							
	2.2 Socio-economic data			Lead				
	2.3 European network and socio-economic data							
	2.4 Regional network and socio-economic data							
3 European accessibil-ity: travel	3.1 European travel accessibility							
	3.2 European travel accessibility measured by other indicators	Lead						
	3.3 Global travel accessibility							
4 European accessibil-ity: freight transport	4.1 European freight accessibility							
	4.2 European freight accessibility measured by other indicators						Lead	
	4.3 Global freight accessibility							
5 Regional accessibility	5.1 Typology of regional accessibility patterns							
	5.2 Selection of regional case studies							
	5.3 Case studies on regional accessibility patterns				Lead			
	5.4 Europe-wide modelling of regional accessibility							
	5.5 European v. regional accessibility							
6 Impacts of accessibil-ity	6.1 Accessibility and regional development							
	6.2 Long-term scenarios of European transport	Lead						
	6.3 Spatial impacts of European transport scenarios							
7 Policy implications	7.1 Policy-relevant findings							
	7.2 Policy conclusions				Lead			
	7.3 Further research needs							
8 Dissemination	Dissemination	Lead						

Lead	Task leader with major contribution
	Major contribution
	Small contribution

A4.5 Barriers for project implementation

A potential barrier for project implementation for research projects dealing with accessibility indicators is always the availability of proper network data. However, as shown in Chapter 6, the project is in a very good situation with respect to Europe-wide as well as to regional network data. In consequence, the TPG does not see any major barriers for the implementation of the TRACC project.

A4.6 Deliveries and outputs envisaged

The TRACC project is expected to disseminate its results to the wider political and scientific audience. To do so, there are a couple of formal requirements such as the different project reports and the presentations at ESPON seminars and there will be a couple of other opportunities to present results of the TRACC project.

Draft Final Report

The Draft Final Report will be due 21 months after the beginning of the project, i.e. one year after this Interim Report. The report will take into account the feedback on the Interim Report from an ESPON seminar and the Sounding Board.

The Draft Final Report will consist of an executive summary, the report with main results and a scientific report supported by diagrams, tables and maps. A tentative Table of Contents of the Draft Final Report might look like:

A Executive Summary (10 pages)

B Main results (50 pages)
- 1 Objectives, state of the art and research concept (summary)
- 2 Global accessibility of European regions
- 3 European accessibility of European regions
- 4 Regional accessibility of European regions
- 5 Regional development impacts of transport policy options
- 6 Policy conclusions

C Scientific Report
- 1 State of the art in accessibility modelling
- 2 TRACC methodology
- 3 Global accessibility of European regions (extended version)
  - 3.1 Global accessibility travel
  - 3.2 Global accessibility freight
- 4 European accessibility of European regions (extended version)
  - 4.1 European accessibility travel
  - 4.2 European accessibility freight
- 5 Regional accessibility of European regions (extended version)
  - 5.1 Regional accessibility Europe-wide
  - 5.2 Regional accessibility in regional case studies
  - 5.3 Regional vs European accessibility
- 6 Regional development impacts of transport policy options (extended version)
  - 6.1 Long-term scenarios of European transport
  - 6.2 Regional impacts of transport policy scenarios and rising energy prices
- 7 TRACC indicator database

Final Report

The Final Report will be due four months after the Draft Final Report. It will be a revision of the Draft Final Report on the basis of comments received.

ESPON events

The project team will present the research concept and preliminary and final results at the internal and external ESPON Seminars which take place twice a year as well as at other ESPON events organised by the ESPON CU or the ESP Network or at events such as the DG REGIO Open Days.

These dissemination activities will be planned in close co-operation with the ESPON CU to avoid overlap with activities organised in Priority 4 of the ESPON 2013 Programme "Capitalisation, ownership and participation: capacity building, dialogue and networking".

Conferences

The project partners will use every opportunity to present and discuss the research concept and preliminary and final results at scientific conferences. Given the theme of the project, transport accessibility and regional development, the project partners plan to give presentations on the project at the following international conferences:

- World Conference on Transport Research (WCTR)
- Congress of the European Regional Science Association (ERSA)
- International Conference of the Regional Studies Association (RSA)
- Congress of the Association of European Schools of Planning (AESOP)

and at national conferences with similar focus. In addition it can be expected that project partners will be invited to give presentations on the project not only at academic workshops or seminars but to wider audiences and the general public.

Papers

The project partners will publish the results of the project in scientific journals and books during and after the project.

www.espon.eu

The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.