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Criteria for the Spatial Differentiation of the EU Territory: Geographical Position

Study Programme on European Spatial Planning

Michael Wegener
Heikki Eskelinen
Franz Fürst
Carsten Schürmann
Klaus Spiekermann

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and Housing

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Contributors

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The following individuals directly or indirectly contributed to the report:

Austria	Friedrich Schindegger, Österreichisches Institut für Raumplanung
Belgium	Philippe De Boe, King Baudouin Foundation, Bruxelles
Finland	Heikki Eskelinen, University of Joensuu
France	Madeleine Brocard, CIRTAI, Université de Le Havre Colette Cauvin, Images & Villes, Strasbourg Michel Chesnais, Geosyscom, Caen Claude Grasland, CNRS UMR Géographie-cités, Paris Olivier Joly, CIRTAI, Université de Le Havre Alain L'Hostis, INRETS-TRACE, Lille Philippe Mathis, Université François Rabelais Tours
Germany	Franz Fürst, IRPUD, Universität Dortmund Karl-Peter Schön, Bundesamt für Bauwesen und Raumordnung Carsten Schürmann, IRPUD, Universität Dortmund Klaus Spiekermann, IRPUD, Universität Dortmund Wendelin Strubelt, Bundesamt für Bauwesen und Raumordnung Andrea Weber, Bundesamt für Bauwesen und Raumordnung Michael Wegener, IRPUD, Universität Dortmund
Italy	Ennio Cascetta, Università di Napoli Sergio Conti, Politecnico di Torino Giuseppe Dematteis, Politecnico di Torino Bruno Montella, Università di Napoli Francesca Pagliara, Università di Napoli
Netherlands	Frank Bruinsma, Vrije Universiteit Amsterdam Piet Rietveld, Vrije Universiteit Amsterdam
Spain	José Luis Calvo, Universidad de Zaragoza Andreu Ulied, MCRIT, Barcelona
UK	Roger W. Vickerman, University of Kent at Canterbury

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Preface

Since the informal meeting of Spatial Planning Ministers in Liège in 1993, the EU Member States and the European Commission have been jointly elaborating the European Spatial Development Perspective (ESDP). In the preceding years, through the signing of the Maastricht Treaty, the EU had acquired considerably extended competencies in various policy fields, such as regional policies, trans-European networks and environmental issues. These have a potentially great impact on the spatial development in the Member States and the planning para-meters of their regions and cities. This growing influence on spatial development on the one hand is contrasted by a lack of formal competence and political organisation of spatial planning at the administrative and legislative EU level on the other hand. In opening the political debate on the perspectives of European spatial development the 15 Member States and the European Commission initiated an intensive communication process concern-ing space and territory in the context of European policies. By adopting the ESDP in May 1999, they expressed their agreement on common objectives and concepts for the future development of the territory of the EU.

The ESDP is based on certain assumptions concerning current trends and problems of spatial development in Europe and an assessment thereof. Economic and social cohesion, conservation of natural resources and cultural heritage and a more balanced competitiveness of the European heritage are the underlying objectives of the ESDP. The political guidelines for their realisation as defined in the document are (1) a balanced and polycentric urban system and a new urban-rural relationship, (2) parity of access to infrastructure and knowledge and (3) sustainable develop-ment, prudent management and protection of nature and of cultural heritage.

However, in the process leading up to the adoption of the ESDP it became obvious that, despite all the efforts, large gaps in terms of comparable, spatially relevant data and a sound knowledge of spatial processes in Europe still remain. Acknowledging this, the ESDP is developing strategies to overcome these deficits. The most important of these strategies is the institutionalisation of a “European Spatial Planning Observatory Network” (ESPON). In the ESPON, spatial research institutes of the Member States – as so called *national focal points* – are to prepare and exchange information, thus constituting an obser-vatory in the form of a research network. For Germany, the Federal Office for Building and Regional Planning (BBR) has assumed the function of a national focal point. From 1998 to 2000, the ESPON was tested in the framework of a study programme in accordance with Article 10 of the European Regional Development Fund.

During the ESDP process seven criteria were identified for which reliable indicators are needed to monitor the progress in realising the main objectives of the ESDP, i.e. the support of a balanced and sustainable development of the EU territory and its cities and regions:

- Geographical position
- Economic strength
- Social integration
- Spatial integration
- Land-use pressure
- Natural assets
- Cultural assets

A substantial part of the Study Programme dealt with the elaboration of conceptual approaches and indicators for these seven criteria.[1] It was asked whether and how these criteria can be conceptualised and put into operation as indicators for spatial development, and to what extent it is possible to illustrate these indicators with existing, accessible empirical data. In accordance with the seven criteria, seven international working groups were formed. Germany played an active part in three of the seven working groups: geographical position, economic strength and cultural assets. The work carried out on these three topics as well as the final report as such is now published in bilingual versions in the BBR research report series (*Forschungen*).[2] In the present volume, the findings concerning concepts and indicators of *geographical position* are documented.

The guidelines to the Study Programme of the European Commission define geographical position as the relative location of an area in its European, transnational or regional context. Here, apart from geographical location indicators in the strict sense (e.g. geographical position as measured by the degrees of longitude and latitude) and

(1)
The Study Programme considered three main topics. The other two were strategic studies on rural-urban partnership and innovative cartography of spatial planning in a European context.

(2)
The co-ordination team led by Nordregio, Sweden, has published the final report as CD-ROM. It can be ordered at and **www.nordregio.se** and is also attached to the print publication in Forschungen 103.2.

its limited associations (e.g. in the climatic respect), the affiliation to a certain landscape, to economic and cultural areas such as the Alps, the Mediterranean, coastlines or the "blue banana" is addressed. In this context, accessibility indicators are of special importance. They depict the location of an area (i.e. a region, a city, a corridor) by indicators describing the availability respectively accessibility of certain attributes, such as infrastructure characterising other areas or the very area itself.

The development framework of cities and regions is less and less characterised by "natural" location parameters alone but increasingly influenced by political decisions concerning infrastructure and modes of accessibility. This is not only true for inter- but also for intra-regional conditions. The present working group report deals with the question which indicators and models are suited for characterising the geographical position of the European regions. Large overlaps appeared to other working groups of the Study Programme. Concerning the working group "Spatial Integration" the respective foci and the tasks had to be delimited clearly. Pointedly, "Geographical Position" put the focus on potentials of communication and interlinkages between regions whereas "Spatial Integration" focussed on the analysis of empirical and measurable interaction. Topics of other working groups of the Study Programme were closely related in a causal or substantial way. Especially, the economic development of regions and their locational conditions are closely correlated. In this context, accessibility indicators should help to measure the quality of a location by its consequences and to thereby understand accessibility not as a value as such but as an (important) factor within a complex set of effects.

Interesting in this context is the "exception to the rule": Although, as also stated in the European Spatial Development Perspective, ESDP, central and highly accessible regions do have locational advantages, it is also obvious that there are regions at the European periphery that are very attractive and economically prospering in spite of their relatively poor accessibility.

This raises analytical questions as to the meaning of location, position and infrastructure that are closely connected to questions of political judgement, political action and political options.

Against this background, the composition of the working group "Geographical Position" has deliberately been geographically dispersed: apart from the National Focal Points of two EU member states in the centre of Europe, France and Germany, the National Focal Point of Finland participated and brought in the perspective of the more peripheral countries to the discourse on position and accessibility. However, in the course of the discussion within the working group and in the results presented it appeared that diverse scientific paradigms and diverging points of interest do not correspond to the respective "geographic position". Apart from the final report of the working group that is presented here and that has mainly been compiled by Prof. Michael Wegener, IRPUD, University of Dortmund, the French team around Prof. Philippe Mathis, University of Tours, has contributed an additional report that is presented as part of the overall results of the Study Programme in the internet and on CD-ROM.

We would like to thank all those who have contributed to this study, the members of the working groups and those who participated in discussions as part of the study programme. We would also like to thank the European Commission and the national Ministers responsible for spatial development who co-financed their focal points for the elaboration of the Study Programme.

In the course of the Study Programme, around 200 experts from the 15 EU Member States co-operated in a multi-layered international network: the network of national focal points, the national networks of spatial planning experts and 13 international working groups. As a test phase for a future spatial planning observatory network it proved to be a challenging and enriching experience. We firmly believe that the network approach of the Study Programme has shown its advantages and potential for the observation of spatial development in the European Union, and we hope that this approach will be continued in the near future.

Dr. Karl Peter Schön

Federal Office for Building
and Regional Planning
Bonn

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1 Introduction

At the end of 1997 the Ministers of Spatial Planning of the member states of the EU proposed the establishment of an observatory on European spatial development in the form of a network of national research institutions. As a test phase of such a network (European Spatial Planning Observatory Network – ESPON), the European Commission in December 1998 launched a Study Programme on European Spatial Planning (SPESP).

The Study Programme serves to further develop and implement the European Spatial Development Perspective (ESDP). By linking institutions of all Member States working in research and policy analysis of spatial development, national perspectives are to be complemented by a European dimension.

The networking occurs at two levels: At the European level national research institutions of spatial development (National Focal Points) co-operate with each other, whereas at the level of Member States, the National Focal Points organise national networks of experts. From these national networks international working groups are established to work on specific themes of the Study Programme.

The Call for Tender of the first phase of the ESPON Study Programme specified three studies. The first study "Analysis of the Components of the European Territory" is to develop a series of (quantitative and if necessary qualitative) indicators for spatial differentiation of regions, cities and corridors with respect to the criteria geographical position, economic strength, social integration, spatial integration, land use pressure, natural assets and cultural assets. The indicators are to reflect actual conditions and changes over time, environmental, economic, social and cultural topics and spatial details of areas, lines and points. The validity of the indicators is to be examined by maps showing typologies of regions, cities and corridors based on multivariate analysis of the indicators.

For studying the first group of indicators, indicators of *geographical position*, a working group (Working Group 1.1) consisting of the National Focal Points of Finland, France and Germany was established. The group had a first meeting in Bonn in January 1999, subsequent meetings in conjunction with the major ESPON conferences in Stockholm (February 1999), Nijmegen (June 1999) and Rome (October 1999) and a final meeting in Paris in November 1999. This report documents the results of the Working Group.

Before starting its work, the group had to find answers to a number of basic questions:

(1) *For what purpose are indicators to be developed?* The term "spatial differentiation" used in the Call for Tender seemed to be too narrow. It became increasingly clear that the Commission hoped to use the indicators also for *targeting policies*, i.e. for identifying areas which are suitable or eligible for specific EU policies, such as receiving subsidies from the Structural Funds. By the same token the indicators should be suitable for being used in *policy analysis*, i.e. for ex-post analyses of the impacts of such policies, e.g. whether the areas benefiting from the policies achieved the intended targets for which they were selected. Finally, from a scientific point of view, indicators may be selected for their explanatory power, i.e. because they are suitable for being used for *predicting other indicators* which cannot easily be measured. The Working Group decided that, if possible, the indicators selected should serve all four purposes: spatial differentiation, targeting policies, policy analysis and predicting other indicators.

(2) *For which areas are indicators to be developed?* The Call for Tender referred to "regions, cities and corridors" but failed to specify the intended spatial scope and spatial resolution of the analysis. Was only the territory of the present European Union to be covered or also future accession countries? How about studies covering only one country or parts of a country? In the case of regions, what size of regions in terms of the *Nomenclature d'Unités Territoriales Statistiques* (NUTS) levels 0, 1, 2, 3 , 4 or 5? In the case of cities, only major cities or all cities? And what is a corridor: a set of regions or cities along a major transport line? The Working Group decided to confine itself in the present phase to NUTS-3 regions and to cities in the present EU and to leave the consideration of other European regions and smaller areas for later research.

(3) *How many indicators are to be developed?* From a dissemination point of view a limited number of well established, clearly defined and “officially certified” reference indicators seems to be preferable. Only if the number of indicators is small and their calculation transparent and unambiguously defined, can they be applied in a wide range of contexts and different points in time and yet produce well understood and comparable results. From a scientific point of view, however, the number of indicators should be large in order to respond to different situations and policy questions and reflect advances in scientific theory and method, computing resources, data availability and changing policy issues. The Working Group decided to adopt a two-level approach: to recommend a limited set of *reference indicators* and at the same time keep its options open for a larger, potentially unlimited set of *specific indicators*.

(4) *How are the indicators to be selected?* Depending on the purpose for which the indicators are to be used, different selection criteria may be used. If spatial differentiation is the main purpose, indicators should be selected by their discriminatory power in terms of explained statistical variance. This criterion implies that indicators should, ideally, be orthogonal, or statistically independent, of one another. If, however, targeting policies or policy analysis are the main purpose, policy relevance should be the main selection criterion. This criterion may conflict with the requirement of statistical independence because indicators that in the past have been highly correlated may be addressed by different policies in the future. Finally, if predicting other indicators is the main purpose, explanatory power should be the selection criterion, and this may conflict with all of the above criteria. The Working Group decided to search for indicators that satisfied all three criteria, discriminatory power, policy relevance and explanatory power, if necessary at the expense of statistical independence.

Based on these principles, the Working Group developed two sets of indicators of geographical position: one limited set of *reference indicators* and a larger, more open set of *specific indicators*. The presentation of the two sets of indicators proceeds as follows:

After this introduction, Chapter 2 contains definitions of the concept of geographical position in terms of four types of indicators: geographical, physical, cultural and accessibility indicators. Because of their importance and complexity, Chapters 3 and 4 are devoted to accessibility indicators. Chapter 3 provides a theoretical framework for accessibility indicators, and Chapter 4 reviews existing accessibility indicators in EU countries. In Chapter 5 the criteria used for the choice of indicators are stated and the resulting reference indicators and possible additional specific indicators are explained. In Chapter 6 all reference indicators are presented in maps. In addition, cohesion indicators for comparing spatial distributions of accessibility and groups of NUTS-3 regions derived from by cluster analyses are presented.

Chapter 7 discusses some conclusions for European spatial policy that can be drawn from the presentation of indicators and suggests further fields of policy application. In Chapter 8 recommendations for future research are made. Chapter 9 contains conclusions.

Further research on accessibility including multi-scale accessibility indicators, accessibility by country, rail-road terminals, traffic corridors, changes of travel cost, travel time or traffic flows due to driving restrictions or infrastructure closings or openings, *chronocartes* and time-space maps is presented in the second part of the report (Mathis, 2000).

The recommendations for future work address four areas: the adoption of a set of reference indicators of geographical position, the maintenance of an integrated database, the development of a manual of indicators and further exploratory research.

As relevant areas for future research are identified: the refinement of existing accessibility indicators by taking account of time table information in rail and air networks, of multi- and intermodality in passenger and freight transport, of political, economic and cultural barriers, the examination of different types of indicators, the calculation of accessibility indicators for different types of actors and users, the exploration of new concepts of accessibility indicators, such as indicators dealing with telecommunications, the analysis of multiscalar indicators and the further development of advanced techniques of visualisation.

Other important issues remain outside the aim and scope of the present phase of ESPON but may need to be addressed in the longer-range future. The interdependency between accessibility and regional development, though it has been a topic of several large 4th RTD Framework projects, will remain on the research agenda. The potential impact of information technology on accessibility – and hence regional development – is a large and hardly approached research area. Also the constraints set by spatially dispersed demand on the use of new transport technologies need to be studied. The capacity of network infrastructure and demand for transport are very unevenly distributed. Because the supply of infrastructure cannot be increased gradually (the problem of indivisibility), spatially dispersed demand sets serious constraints to the utilisation of such systems. In this situation, the process of technology diffusion is an essential issue in regional development.

2 Geographical Position: Definitions

The first official draft of the European Spatial Development Perspective (ESDP) defined geographical position as "the relative location of an area within a continental, transnational or regional context" (ESDP, 1997, 53).

In their proposals for their contribution to ESPON many National Focal Points noted that geographical position is a comprehensive topic related to all other indicators. Several National Focal Points (Denmark, Netherlands, Portugal, Sweden, UK) proposed general approaches for the construction of indicators taking into account relative location but did not propose specific indicators of geographical position. One National Focal Point (Spain) underlined that each indicator should be analysed both with respect to internal endowment and accessibility to external resources. Only few National Focal Points (Austria, France, Germany, Ireland, Italy) suggested sets of variables which could be used for the production of indicators of geographical position. These included a broad range of aspects:

Geographical:
latitude, longitude, altitude

Physical:
mountains, seashores, natural resources, climate

Settlement:
land cover, population density, city networks

Infrastructure:
transport networks, network density, (multimodal) nodes

Connections:
distance, time, cost, boundaries, perceived distance, time and cost budgets

Accessibility:
economic potential, population potential

Social:
equity, sustainability, peripherality

However, it became also apparent that this broad range of aspects would imply potential overlap with the aspects covered by Working Groups "Spatial Integration", "Natural Assets" and "Cultural Assets'" In order to take account of the diversity of interpretations associated with geographical position and to avoid too much overlap with other indicator groups, the following definitions of geographical position are proposed:

2.1 Geographical Indicators

Regions, cities and corridors can be distinguished by their geographical position in the strict sense, i.e. by geographical latitude and longitude. These indicators are relevant for the localisation of geographical entities on maps and in geographical information systems. Beyond that they have only little meaning, except that, say, locations beyond 75º northern latitude are likely to have strong winters. However, geographical coordinates can be used to calculate Euclidean distances between points.

2.2 Physical Indicators

Mountains, seashores and other natural resources are important assets of geographical location. Mountainous areas offer scenic views and opportunities for hiking, fishing and a variety of winter sports. Seashores invite sailing, fishing and bathing and are the economic basis of a major part of tourism in Mediterranean countries. Other natural resources such as national parks or wildlife and plant preservation areas are also important tourist attractions; they are also covered by Working Group "Natural Assets".

The geographical location of regions, cities and corridors determines their climate, which is a highly relevant factor of development. Regions and cities in northern Europe have short summers and strong winters with limited access to their ports. Regions on the Atlantic coast owe their relatively mild climate to the Gulf Stream but in return suffer from frequent rainfall, whereas regions and cities in central and eastern Europe enjoy a relatively stable continental climate. For regions in southern Europe their warm climate is an important asset for their tourist industries and increasingly attracts after-retirement migration.

2.3 Cultural Indicators

One of the assets of Europe is the diversity of its cultural and historical traditions, each of which is associated with a particular macro region or group of countries. The Nordic countries are connected by their common Protestant culture and their long-standing welfare-state orientation. The Mediterranean countries are linked by their common roots in ancient history and culture and by similar climate, life styles and forms of settlement. Romanic, Francophone and English- and German-speaking countries and regions are closer to one another by their common language. Cultural indicators are also addressed by Working Group “Cultural Assets”.

Beyond these historically grown cultural identities there are also synthetic macro regions constructed for analytical or political reasons. The “Blue Banana”, the “Sunbelt”, the “Atlantic Arch” or the “Baltic Sea Region” are constructs created for the purpose of either identifying a group of regions with similar socio-economic characteristics or of establishing a common sense of identification between regions towards joint action.

2.4 Accessibility Indicators

The geographical, physical and cultural indicators discussed so far make important contributions to differentiate regions, cities and corridors and are all closely related to location. However, they measure features related to location, not the impact of location as such. This, however, is achieved by accessibility indicators. Accessibility indicators describe the location of an area with respect to opportunities, activities or assets existing in other areas and in the area itself, where “area” may be a region, a city or a corridor.

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. While these indicators may contain valuable information about the area itself, they fail to recognise that many destinations of interest may lie far away from the area.

More complex accessibility indicators distinguish between destinations in the area itself and destinations in other areas. Their formulation always includes a spatial impedance term describing the ease of reaching the destinations by measures such as travel time, cost or inconvenience. Depending on the form of the spatial impedance term, accessibility indicators can be used to analyse the impact of location only or the impact of location *and* the ease of spatial interaction. In the first case the spatial impedance term is phrased in terms of Euclidean distance. In the second case the distance between two areas is calculated as travel time or travel cost over networks. This makes it possible to analyse the effects of transport infrastructure improvements on geographical position.

There is a large variety of approaches to measuring accessibility in the geographic and economic literature. However, there are only few attempts to classify and compare accessibility indicators in a systematic way. As accessibility indicators are the most important and most policy-relevant indicators of geographical position, the following two chapters of this report address theoretical and empirical issues of measuring accessibility.

3 Accessibility: Theoretical 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.

3.1 Why Accessibility?

The important role of transport infrastructure 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 (see Linneker, 1997).

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 (e.g. Biehl, 1986, 1991; Keeble et al., 1982, 1988). However, this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today (cf. Bröcker and Peschel, 1988). Attempts to explain *changes* in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful. The reason for this failure may be that in countries with an already highly developed transport infrastructure further transport network improvements bring only marginal benefits. The conclusion is that transport improvements have strong impacts on regional development only where they result in removing a *bottleneck* (Blum, 1982; Biehl, 1986, 1991).

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. Some analysts argue that regional development policies directed at the creation of infrastructure in lagging regions have not succeeded in reducing regional disparities in Europe (Vickerman, 1991a), whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions (Bröcker and Peschel, 1988). From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region, for instance, makes it easier for producers in the peripheral region to market their products in the large cities, however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies (Vickerman, 1991b). While these two effects may partly cancel each other out, one factor unambiguously increases existing differences in welfare. New transport infrastructure tends to be built not between core and periphery but within and between core regions, because this is where transport demand is highest (Vickerman, 1991a). It can therefore be assumed that the trans-European networks will largely benefit the core regions of Europe.

These developments have to be seen in the light of changes in the field of transport and communications which will fundamentally change the way transport infrastructure influences spatial development (see Masser et al., 1992). 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 goods transports and person trips, however, they may also increase transport by their ability to create new markets.

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

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

- The introduction of totally new, superior levels of transport such as the high-speed rail system may create new locational advantages, but also disadvantages for regions not served by the new networks.
- Another factor adding to the importance of transport is the general increase in the volume of goods movements (due to changes in logistics such as just-in-time delivery) and travel (due to growing affluence and leisure time).

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

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

3.2 Dimensions of Accessibility

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 3.1.

3.2.1 Origins

Accessibility indicators are calculated for areas such as regions, cities or corridors. 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.

3.2.2 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.

3.2.3 Spatial Impedance

Simple accessibility indicators only consider transport infrastructure in the area itself, expressed by measures such as total length of motorways or number of railway stations (e.g. Biehl, 1986, 1991), or in the vicinity of the area, expressed by measures such as access to the nearest nodes of interregional networks like motorway exits,

Table 3.1
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).
Spatial 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 or 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 personal travel or only goods transport, or both, may be considered.
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 transport infrastructure investments or other transport policies, including their impacts on convergence or divergence in accessibility between areas.

intercity stations, freight terminals or airports (e.g. Lutter et al., 1992a, 1992b, 1993). While these indicators may contain valuable information about the area itself, they fail to recognise that many destinations of interest may lie far away from the area.

More complex accessibility indicators distinguish between destinations in the area itself and destinations in other areas and take into account that the latter are more distant. 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) and may include aspects of capacity, congestion, convenience, reliability or safety. There are two different approaches:

– *Euclidean distance.* If no transport network is considered, geographical or Euclidean distance between areas are taken as spatial impedance: Origins and destinations are assumed to be concentrated in nodal points in the centre of the areas called centroids (see Section 3.2.8), 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 (see Section 3.5.3).

– *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. In this case, 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 as above, and the centroids are linked to the nearest network node by non-network access links. The mean length or travel time or cost of the access links and of the 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 (see Section 3.2.8).

3.2.4 Constraints

The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types or 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 into link travel times. Regulations on maximum driving hours can be converted into a barrier (see Section 3.2.5) at the link on the minimum path (see Section 3.2.3) 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.

3.2.5 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 EU countries have been achieved through the Schengen Protocol. However, movement of people from immigration countries into the EU 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 mostly 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 mostly 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 (Bökemann, 1982). For instance, exchange of people and goods between regions with the same culture and language will be more intensive than between regions with different cultures and languages.

3.2.6 Types of Transport

The majority of accessibility indicators are expressed in terms of personal travel. However, if origins and destinations are economic activities (firms or employment), access for goods and services is intended.

For the calculation of accessibility for goods transport, goods transport needs to be modelled in terms of freight-specific terminals such as intermodal terminals or ports or freight-specific modes such as inland waterways. There are only few studies on goods transport accessibility.

3.2.7 Modes

Network-based accessibility indicators may be calculated for road, rail, 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. The aggregation of accessibility indicators is discussed in Section 3.4.1.
- 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.

3.2.8 Spatial Scale

Issues of spatial scale associated with calculating accessibility indicators have two aspects: spatial scope and spatial resolution.

Spatial scope

As pointed out in Grasland (1999), the area of interest for ESPON are the fifteen Member States of the European Union (cf. Chapter 1). However, as accessibility indicators measure access to destinations in other regions, the total study area, which includes also the areas considered as potential destinations when calculating accessibility indicators, needs to be larger. It is suggested that the total study area encompasses all countries of Europe, including the European part of Russia, but that accessibility indicators are calculated only for the areas of the European Union.

In a later phase of the research, also accessibility indicators for the future accession countries should be calculated.

Spatial resolution

Origins and destinations are located in areas representing regions, cities or corridors. 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 (see Section 3.2.3). 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 (see Section 3.2.9) 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 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.

For the first phase of ESPON it is suggested to concentrate on NUTS-3 regions and an equivalent number of cities (the centroids of NUTS-3 regions) and to leave smaller regions and cities for later research.

The issue of corridors requires further clarification. If the task addressed in the call for tender of ESPON (see Chapter 1) were to identify European transport corridors, i.e. transport axes between European regions with high-level, multi-model transport links and particularly heavy traffic flows, the task would not require indicator research but a European transport model. If, however, the task were to identify corridors as axes of regions or cities with particularly high accessibility, the task would not differ from calculating accessibility indicators for regions and cities. Because of the ambiguity of the specification of the task, it is suggested to ignore corridors for the time being and to concentrate on regions and cities.

3.2.9 Equity

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

- On a regional scale, the decline in accessibility from centroids or network nodes to interstitial areas (see Section 3.2.8) affects decisions on the linkage between interregional and intraregional transport networks.
- On a European scale, spatial equity is related to the „cohesion“ objective of the European Union to reduce existing disparities in income and economic activity between regions. To analyse cohesion, accessibility indicators may be calculated for specific groups of regions or cities in order 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 since the accession of Ireland, Greece, Spain, Portugal, Finland and Sweden and will continue to do so through further enlargements of the Union towards the east.

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 their locational disadvantage 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 (see Section 3.2.3) may be used as benchmarks against which improvements in network accessibility can be measured.

3.2.10 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 transport infrastructure investments 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 (see Section 3.6). However, with appropriate cohesion indicators, accessibility analysis can be used to monitor and forecast the achievement of cohesion goals of the European Union.

3.3 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 (Schürmann et al., 1997).

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 $\mathrm{g}(W_{ij})$ and $\mathrm{f}(c_{ij})$ 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. With other words, A_i is the total of the activities reachable at *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 and introduced into regional science by Stewart (1947). 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 $\mathrm{g}(W_j)$ and $\mathrm{f}(c_{ij})$:

- *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 (i.e. the impedance function is linear), the accessibility indicator is total or average travel cost to a predefined set of destinations.
- *Daily accessibility*. 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.

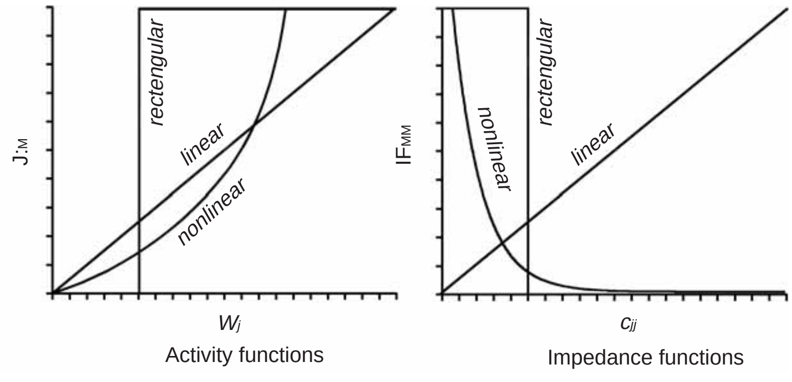


Figure 3.1
Activity and impedance functions

Table 3.2
Accessibility indicators

Type of accessibility	Activity function	Impedance function $f(c_{ij})$
Travel cost Travel cost to a set of activities	$W_j \left\vert \begin{array}{l} 1 \text{ if } W_j \ge W_{\min} \\ 0 \text{ if } W_j < W_{\min} \end{array} \right.$	c_{ij}
Daily accessibility Activities in a given travel time	W_j	$\begin{array}{l} 1 \text{ if } c_{ij} \le c_{\max} \\ 0 \text{ if } c_{ij} > c_{\max} \end{array}$
Potential Activities weighted by a function of travel cost	W_j^{α}	$\exp(-\beta c_{ij})$

- *Potential*. If the impedance function takes travel behaviour into account, i.e. the diminishing inclination to travel long distances (the impedance function is non-linear, 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 non-linear, e.g. a power function).

The different forms of rectangular, linear and non-linear functions that can be used for g(W_j) and f(c_{ij}) are shown in graphical form in Figure 3.1 (page 13).

Table 3.2 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.

3.3.1 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.

$$A_i = \sum_j g(W_j)\, c_{ij} \quad \text{with}\; g(W_j) = \begin{cases} W_j \left\vert \; 1 \text{ if } W_j \ge W_{\min} \right. \\ \qquad 0 \text{ if } W_j < W_{\min} \end{cases}$$

To make the indicator easier to compare, the accumulated generalised cost so generated is frequently divided by the number of destinations or the total of attractions g(W_j), respectively. The indicator then represents the average travel cost to the set of destinations:

$$A_i = \frac{\sum_j g(W_j)\, c_{ij}}{\sum_j g(W_j)} \quad \text{with}\; g(W_j) = \begin{cases} W_j \left\vert \; 1 \text{ if } W_j \ge W_{\min} \right. \\ \qquad 0 \text{ if } W_j < W_{\min} \end{cases}$$

In both cases the indicator expresses a *disutility*, i.e. the lower its value the higher the accessibility.

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 $W_{\min}$ of the W_j included.

There are a number of variations of travel cost indicators proposed in the literature and applied in practice that deserve to be mentioned.

- *Weighted travel speed*. If the impedance term is travel time, and the Euclidean distance or network distance between areas i and j are known, c_{ij} in the above equation can be replaced by the airline or network speed between i and j, v_{ij} (Eckey und Horn, 1992; Eckey, 1995):

  $$v_{ij} = d_{ij} / c_{ij}$$

  where d_{ij} is either Euclidean distance or the length of the minimum path between i and j through the network with travel time c_{ij}. The accessibility indicator then indicates the mean airline or network speed of all trips to reach j from i. Of course, the higher the speed, the higher the accessibility.

- *Isochrones*. If the impedance term is travel time and only one destination *j* is considered, the accessibility indicator expresses the travel time of trips to or from one area, e.g. the capital city of a country or an important port. A map of that accessibility indicator shows zones of equal travel time to or from that area and is therefore called an *isochrone* map. It goes without saying that, as accessibility indicator, travel time to only one destination is less informative than travel time to all or a large number of destinations.
- *Local indicators*. If the number of destinations is limited to one, but a different destination is selected for each origin area, e.g. the nearest urban centre, motorway exit, intercity station, freight terminal or airport, the accessibility indicator informs about the situation in the vicinity of the area but not about the wider, e.g. European, context (e.g. Lutter et al., 1992a, 1992b, 1993).
- *Topological indicators*. If only topological properties of a network are considered, indicators such as the number of nodes directly connected with a node or the number of nodes indirectly connected to it with one, two or more transfers can be defined (Dupuy, 1993; Jiang, 1993; L'Hostis, 1997; Chapelon, 1997; Joly, 1999a). If not only origins and destinations but *all* network nodes are considered, topological indicators inform about the location of a node in the network. These indicators can be informative where transfers are particularly difficult, as in air travel. In other respects topological indicators are less informative because they ignore link impedances and destinations.
- *Other network indicators*. If link impedances *are* considered, other network indicators such as the total length of all minimum paths from node *i* to all nodes *j* can be calculated. The ratio of this "network accessibility" and the total of all network accessibilities of all nodes is a dimensionless network accessibility indicator (cf. Joly, 1999b, 1999c):

$$A_i = \sum_i \sum_j c_{ij} \,/\, \sum_j c_{ij}$$

Some of these variations of travel cost accessibility indicators are presented in the second part of the report (Mathis, 2000).

3.3.2 Daily Accessibility

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 (Törnqvist, 1970). Maximum travel times of three to five hours one-way are used. Because of its association with a one-day business trip this type of accessibility is often called "daily accessibility".

$$A_i = \sum_j W_j \; f(c_{ij}) \quad \text{with } f(c_{ij}) = \begin{cases} 1 \text{ if } c_{ij} \le c_{\max} \\ 0 \text{ if } c_{ij} > c_{\max} \end{cases}$$

where $c_{\max}$ is the travel time limit. The daily accessibility indicator is equivalent to a potential accessibility (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.

Daily accessibility 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 $c_{\max}$ beyond which destinations W_j are no more considered.

3.3.3 Potential

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 non-linear. 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 non-linear. 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.

$$A_i = \sum_j W_j^{\alpha} \exp(-\beta c_{ij})$$

Earlier versions of the potential accessibility used an inverse power function reminiscent of Newton’s gravity model:

$$A_i = \sum_j \frac{W_j}{c_{ij}^{\alpha}}$$

This form of potential accessibility was proposed by Hansen as early as 1959 and is therefore called “Hansen” accessibility. Later improvements led to the empirically similar but behaviourally derived negative exponential function (Wilson, 1967).

Indicators of potential accessibility are superior to travel cost accessibility and daily accessibility in that they are founded on empirically tested 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 (see Section 3.6).

3.4 Extensions

Although the above generic accessibility indicators cover a large part of the accessibility indicators applied in practice, there are some extensions proposed in the literature which are worth to be mentioned.

Accessibility as utility

If accessibility is interpreted as the benefit accruing to the residents of an area from the opportunities that can be reached from it, that benefit can be calculated in the context of discrete choice theory as the *inclusive value* of the choice between the opportunities W_j in areas j given the c_{ij} (Neuburger, 1971; Williams, 1977; Leonardi, 1978; Ben-Akiva and Lerman, 1979):

$$A_i = \frac{1}{\beta} \ln \sum_j W_j \exp(-\beta c_{ij})$$

It is easily seen that this is a monotone increasing function of the potential accessibility presented in the previous section.

Accessibility as inverse balancing factor

Another formulation of accessibility is derived from the production-constrained spatial-interaction model

$$T_{ij} = O_i \, a_i \, D_j \exp(-\beta c_{ij})$$

where O_i are trip origins, D_j are trip destinations and the a_i are the ‘balancing factors’ used to adjust the marginal totals of the predicted trip matrix with the known trip origins:

It was already noticed early (Neuburger, 1971; Williams and Senior, 1978) that the inverse of the balancing factors

$$A_i = \frac{1}{a_i} = \sum_j D_j \exp(-\beta c_{ij})$$

is formally equivalent to the potential and can hence be interpreted as accessibility.

Nested accessibility

A further extension considers destination choice as a two-stage process where not only the opportunities at area *j* but also the opportunities that can be reached from *j* are considered in the spirit of a nested logit choice process. The resulting accessibility is (Fotheringham, 1986):

$$A_i = \sum_j A_j \, D_j \exp(-\beta c_{ij})$$

In this formulation the A_j has also been interpreted as the inverse of the second balancing factor b_j of the doubly-constrained spatial interaction model (Nijkamp and Reggiani, 1992).

Economic accessibility

Starting from a critique of the lack of theoretical content of the potential accessibility, Bröcker (1996) proposed an economically derived accessibility defined as the maximum return on production factors firms located in a region can derive given the regional input and output prices. The prices are obtained by solving a spatial computable equilibrium model of regional production and interregional and trade.

Multiscalar accessibility

It may be argued that aggregation of destinations at different distance from origin *i* by an impedance function is less informative than the explicit presentation of the spatial distribution of opportunities with respect to *i* (cf. Grasland, 1999). The accessibility of an area *i* would then be expressed as a cumulative function of opportunities sorted by distance, travel time or travel cost from *i*. By the same token, opportunities in *j* might be classified by size. Different shapes of these distributions could then be interpreted as differences in concentration or dispersion of activities around *i*.

The additional information provided by multiscalar indicators must, however, be weighed against the difficulty of presenting and comprehending multiscalar distributions for a large number of areas instead of scalar values.

3.5 Derivative Accessibility Indicators

From the three basic accessibility indicators presented in Section 3.3, an almost unlimited variety of derivative indicators can be developed (cf. Ruppert, 1975; Pirie, 1979; Handy and Niemeier, 1997; Rietveld and Bruinsma, 1998). The most important ones are discussed below.

3.5.1 Multimodal Accessibility

All three types of accessibility indicator can be calculated for any mode. On 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 only few studies calculating freight accessibility indicators.

Differences between modes are usually expressed by using different “generalised” costs. A frequently used generalised cost function is:

$$c_{ijm} = v_m t_{ijm} + c_m d_{ijm} + u_m k_{ijm}$$

where t_{ijm}, d_{ijm} and k_{ijm} are travel time, travel distance and convenience of travel from location *i* to destinations *j* by mode m, respectively, and v_m, c_m und u_m are value of time, cost per kilometre and disutility or inconvenience of mode *m*, respectively. 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

$$c_{ij} = -\frac{1}{\lambda} \ln \sum \exp\left(-\lambda c_{ijm}\right)$$

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 (Williams, 1977). The similarity of this function with the “inclusive value” of the utility accessibility in Section 3.4 is obvious. 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 daily accessibility exist.

3.5.2 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.

3.5.3 Intra-Area Accessibility

Intermodality is also an issue when calculating intra-area accessibility. Most accessibility studies so far have 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 account of. Yet the ease of getting from home or office to the nearest station of the high-speed rail network or the next international airport may be more important for the accessibility of a location than the speed of the long-distance connection from there.

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, increase 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. Bröcker (1989) and Frost and Spence (1995) pointed to the pitfalls of these approaches and proposed more robust yet still approximate solutions.

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.

3.6 Cohesion Indicators

Cohesion indicators are used to describe the distribution of accessibility across areas. Cohesion indicators are macro-analytical indicators combining the indicators of individual areas into one measure of spatial concentration. Differences in the cohesion indicators of two spatial distributions of accessibility reveal whether one distribution is more equitable or more polarised than the other. Changes in cohesion indicators over time indicate whether transport infrastructure projects or transport policies have contributed or are likely to contribute to reducing or increasing existing disparities in accessibility between areas, i.e. whether there is convergence or divergence in accessibility.

A comprehensive list of cohesion indicators is given in Bökemann et al. (1997). Two frequently applied cohesion indicators are the coefficient of variation and the Gini coefficient. They will be explained below using accessibility as an example.

- *The coefficient of variation*. The coefficient of variation is the standard deviation of area indicator values expressed in percent of the average of all areas:

  $$V = \frac{\sqrt{\sum_r (\bar{X} - X_r)^2 / n}}{\bar{X}} 100$$

  The coefficient of variation informs about the degree of homogeneity or polarisation of a spatial distribution. The greater the coefficient of variation, the more polarised is the distribution. A coefficient of variation of zero indicates that all areas have the same indicator values. The different sizes of areas can be accounted for by treating each area as a collection of individuals having the same indicator values. The coefficient of variation can be used to compare two accessibility scenarios with respect to cohesion or equity or two points in time of one scenario with respect to whether convergence or divergence in accessibility occurs.
- *The Gini coefficient*. The Lorenz curve compares a rank-ordered cumulative distribution of indicator values of areas with a distribution in which all areas have the same indicator values. This is done graphically by sorting areas by increasing indicator value and drawing their cumulative distribution against a cumulative equal distribution (an upward sloping straight line). The surface between the two cumulative distributions indicates the degree of polarisation of the distribution of

indicator values of areas. The Gini coefficient calculates the ratio between that area of that surface and the area of the triangle under the upward sloping line of the equal distribution. The equation for the Gini coefficient is

$$G = 1 + 1/n - 2/(n^2 \overline{X}) \sum_r r\, X_r$$

where X_r are indicator values of areas sorted in decreasing order. The equation is used to measure the inequality in indicator values between areas, with X_r being the indicator value of area *r*, $\overline{X}$ the average indicator value of all areas, and *n* the number of areas. A Gini coefficient of zero indicates that the distribution is equal-valued, i.e. that all areas have the same indicator values. A Gini coefficient close to one indicates that the distribution of indicator values is highly polarised, i.e. few areas have very high indicator values and all other areas very low values. The different sizes of areas can be accounted for by treating each area as a collection of individuals having the same indicator values.

The Gini coefficient can be used to compare the inequality in accessibility between areas for two different years. A growing Gini coefficient indicates that inequality in accessibility between areas has increased, a declining coefficient indicates that disparities have been reduced. Similarly the Gini coefficient can be used to compare two scenarios of transport infrastructure projects or transport policy. A larger Gini coefficient indicates that a scenario leads to greater disparities, a lower Gini coefficient indicates that it leads to more cohesion between areas.

A serious deficiency of both indicators, the coefficient of variation and the Gini coefficient, is that they indicate *relative* differences between two spatial distributions. However, it will become evident (in Chapter 4) that relative differences tend to indicate a tendency of convergence where in fact divergence has occurred. A simple thought experiment is sufficient to demonstrate this.

Imagine that in a certain period the accessibility of all areas, however measured, is increased by an equal margin of ten percent. Both coefficient of variation and Gini coefficient will report that the spatial distribution of accessibility has not changed, and indeed it has not changed in relative terms, as the relative shares of accessibility have remained the same. If, however, the distribution of accessibility at the outset was highly peaked, with the ratio between the highest and the lowest area accessibility in the range of twelve to one, the already most accessible regions will gain in accessibility twelve times as much as the least accessible areas. So the gap between the accessibility of the areas has in fact become wider, something the two cohesion indicators failed to report.

Even worse, the result of the cohesion analysis heavily depends on the type of accessibility indicators applied. Again a simple thought experiment will demonstrate this.

Imagine this time that the travel speeds on all transport links in Europe are increased by 20 percent. Table 3.3 shows the likely result in terms of convergence or divergence in accessibility for different types of accessibility indicator:

Table 3.3
Likely cohesion effects of increasing all travel speeds

Accessibility indicator	Formula	Cohesion indicator	
		absolute	relative
Travel cost	$A_i = \sum_j W_j c_{ij} / \sum_j W_j$	convergence	no change
Daily accessibility	$A_i = \sum_j W_j$	divergence	convergence
Potential	$A_i = \sum_j W_j \exp(-\beta c_{ij})$	divergence	convergence
Utility	$A_i = \frac{1}{\beta} \ln \sum_j W_j \exp(-\beta c_{ij})$	uncertain	convergence

The likely cohesion effects to be expected are:

- In the case of *travel cost accessibility*, the most remote areas will experience the largest absolute reductions in travel time, which is equivalent to a convergence of accessibility. Due to the linear structure of the accessibility formula, however, the relative distribution of travel times will remain exactly the same.
- In the case of *daily accessibility*, the central areas are likely to extend their contact areas by a larger margin because more large cities can be reached within the specified time limit. The peripheral areas, however, may benefit more in relative terms because their enlarged contact areas are likely to include medium-sized cities that could not be reached before. So there is likely to be absolute divergence and relative convergence.
- In the case of *potential accessibility*, the largest absolute gains in accessibility will be concentrated in the most central and already most accessible areas, i.e. the existing disparities in accessibility will increase. In relative terms, however, peripheral areas will benefit more from better access to large central agglomerations, whereas central areas will benefit little from better access to low-density peripheral areas, so relative convergence is likely to occur.
- In the case of the *logarithmic transformation of potential accessibility* (see Section 3.4), the absolute gains in accessibility of the peripheral areas will be less pronounced and relative convergence will become more likely. This result is of particular interest if indeed this accessibility indicator is the best representation of economic benefit.

These theoretical results are based on certain generalisations about the spatial distribution of large and small cities and the existing transport infrastructure in Europe and may therefore need to be modified for specific spatial contexts, i.e. for individual countries. It would be desirable to conduct a thorough empirical examination of the issue of cohesion indicators in the form of a systematic comparison of the consequences of the choice of different accessibility and cohesion indicators, spatial resolutions and network representations on the identification of convergence or divergence in accessibility in Europe.

Until such examination, however, great care should be taken when interpreting cohesion indicators, not only of accessibility. As the cohesion indicators most commonly used in research for the European Commission, standard deviation and coefficient of variation, are biased towards convergence where in fact divergence may have occurred, policy conclusions drawn from these indicators should be made with particular caution (see Chapter 9).

4 Existing Accessibility Indicators

There is a large variety of approaches to measuring accessibility in the geographic and economic literature. However, there are only few attempts to classify and compare accessibility indicators in a systematic way. Most of the studies have proposed and demonstrated a specific approach to measuring differences or changes in accessibility in a particular spatial context or year or period.

4.1 Existing Indicators

Early accessibility studies considered the endowment of an area with transport infrastructure expressed by such measures as total length of motorways, number of railway stations as indicator of accessibility (e.g. Biehl, 1986 1991). While this kind of indicator may contain valuable information about the area itself, it fails to recognise that many destinations of interest may lie outside the area. This kind of indicator will therefore not be considered here.

The accessibility indicators examined distinguish between destinations in the city or regions itself and destinations in other cities and regions and take into account that the latter are more distant. The effort needed to overcome that distance is measured as spatial impedance. Spatial impedance is calculated in units of distance, time or money or a combination of the latter two in terms of generalised cost.

Because of their fundamentally different approach and interpretation, accessibility indicators based on Euclidean distance and accessibility indicators based on network impedance will be dealt with in separate sections.

4.1.1 Euclidean Distance

This type of accessibility indicator uses geographical or Euclidean distance between areas as spatial impedance (see Section 3.2.3). 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. The mean length of internal trips in the origin area is estimated as a function of its size.

4.1.1.1 Distance

Grasland (1999) calculated the mean Euclidean distance to the population of Europe using data from the UNEP-GRID database of world population in 1990 for a grid of cells of 1° latitude and longitude (see Figure 4.1, page 22) according to the formula

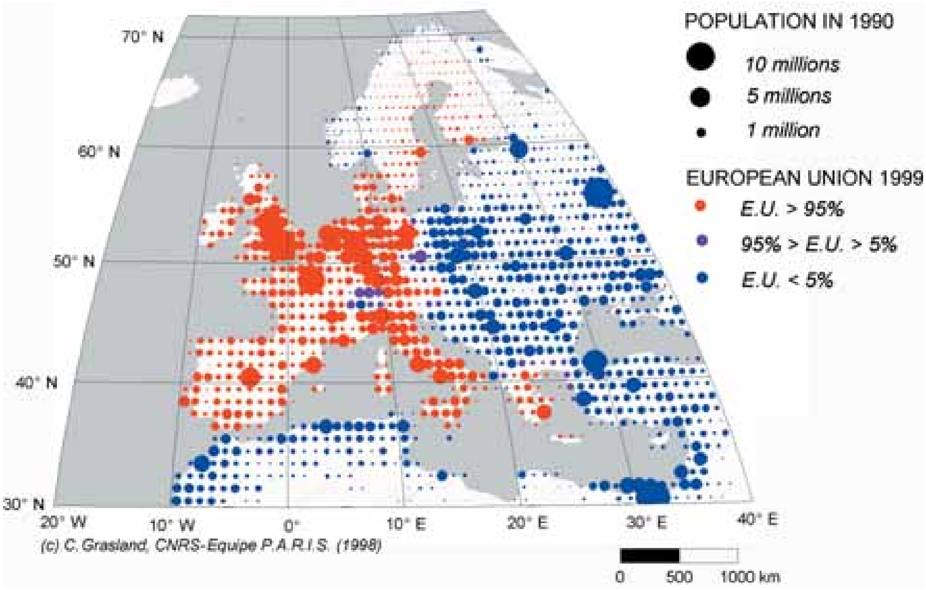
$$A_i = \sum_j P_j \, d_{ij} \, / \sum_j P_j$$

where P_j is population in raster cell j and d_{ij} is Euclidean distance between raster cells i and j. The result is shown in Figure 4.2 (page 22) with an interpolation used to produce a smooth accessibility surface.

According to this criterion, the centre of gravity of the EU population is located in France, near Valmy at 49° N and 5° W, with a mean distance to the population of the EU of 740 km. The map demonstrates that many places outside of the EU are closer to its population than places located inside its territory. Cities such as Porto, Sevilla, Palermo and Stockholm (located in the EU) have more or less the same accessibility (1,500 km) as Algier, Tunis, Tirana, Kaliningrad or Olso (located outside the EU).

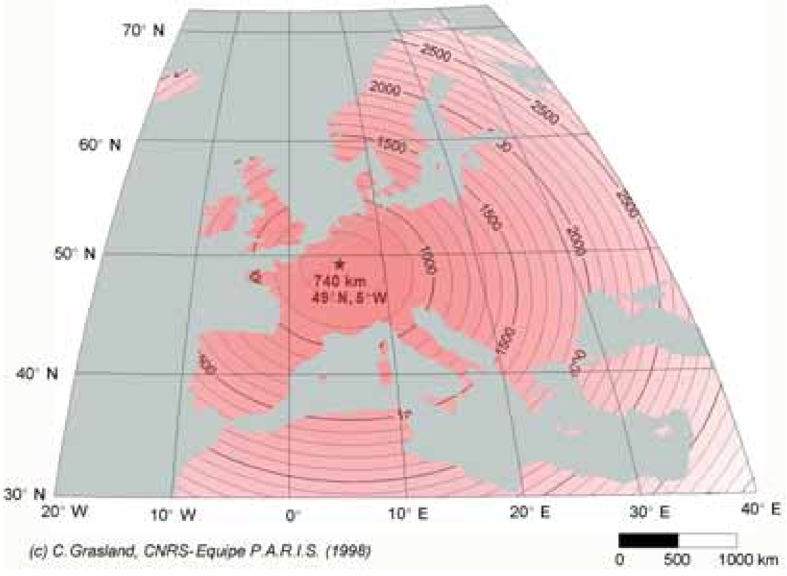
This type of accessibility indicator might be of interest to actors who want to be in contact with the whole population of the EU, such as large multinational firms. However, they would probably prefer an indicator measuring distance to economic activity, and they would certainly be more interested in a measure of accessibility based on actual travel time or cost using existing transport networks (see Section 4.1.2).

Figure 4.1
Grid repartition of population in Europe



Source: UNEP – GRID

Figure 4.2
Mean distance to the population of the EU in 1990



Source: Grasland, 1999

4.1.1.2 Potential

An application of Euclidean distance to potential analysis is the work by Grasland (1991) and Boursier et al. (1993) using again the UNEP-GRID database (see Figure 4.1) to calculate European population potentials based on the Gaussian neighbourhood function

$$A_i = \sum_j P_j \exp\left(\frac{\ln 0.5}{R^2}\; d_{ij}^2\right)$$

where P_j is population in raster cell j and d_{ij} is the Euclidean distance between raster cells i and j as above. R is the 'span' of the neighbourhood function defined as the distance (in km) where the neighbourhood probability is 0.5.

Figure 4.3 demonstrates how this kind of indicator can be applied to illustrate the spatial integration taking place through the opening of the borders to eastern Europe and, in the future, the enlargement of the EU. The top two maps present the familiar image of the population potential of the EU member states in 1990. The two maps in the centre show the population potential of neighbouring non-EU countries (including Switzerland). With R = 100 km, the most

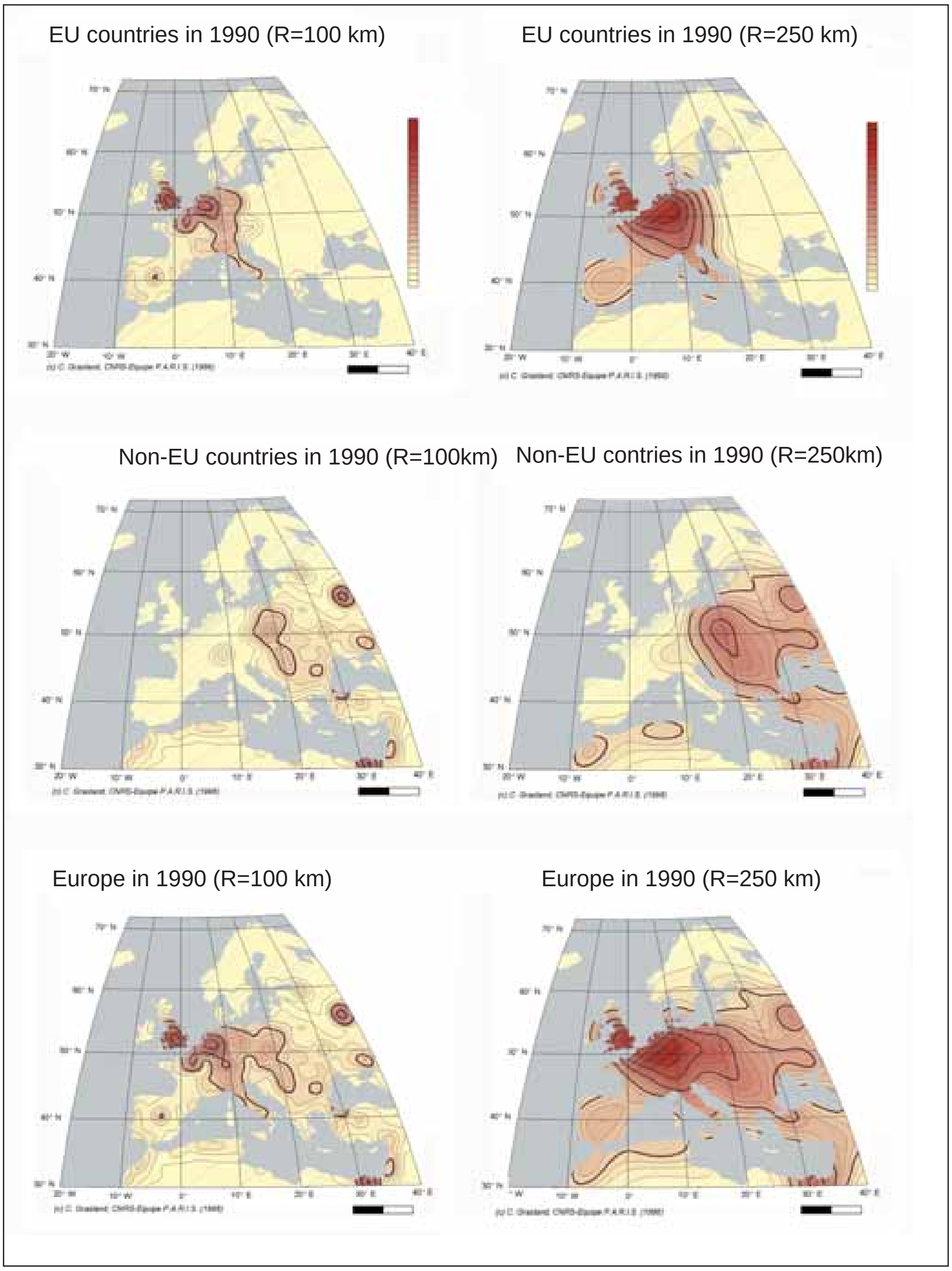


Figure 4.3
Population potential of EU countries (top), non-EU countries (centre) and all Europe (bottom), with neighbourhood functions R = 100 km (left) and R = 250 km (right)

Source: Grasland, 1999

important concentrations are located in Russia (Moscow, St. Petersburg), Ukraina, Egypt, Turkey, and east-central Europe (Silesia). With *R* = 250 km, the main concentrations of population are located in east-central Europe with higher values than in Russia, where local concentrations of population are surrounded by wide low-density areas. The two maps at the bottom show the population potential of all of Europe, i.e. if no border barriers are assumed.

If the two maps at the bottom are compared with the two maps at the top, it becomes apparent how the population potential shifts to the east to take account of the influence of countries located in southern and eastern Europe. The map on the left with *R* = 100 km well illustrates the “Blue Banana” (RECLUS, 1989) and a less prominent second “banana” in eastern Europe. However, the map on the right with *R* = 250 km shows that the major concentration of population continues to be in north-west Europe. If the gradient of density is taken as criterion of delimitation, the sphere of influence of the population concentration of north-west Europe includes all east-central Europe and a large part of Ukraina and Turkey.

4.1.2 Network Impedance

This type of accessibility indicator uses the length of minimum paths between areas over transport network(s) as spatial impedance. 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 access links. The mean length or travel time or cost of the access links and of the internal trips in the origin area is estimated as a function of its size.

4.1.2.1 Travel Cost

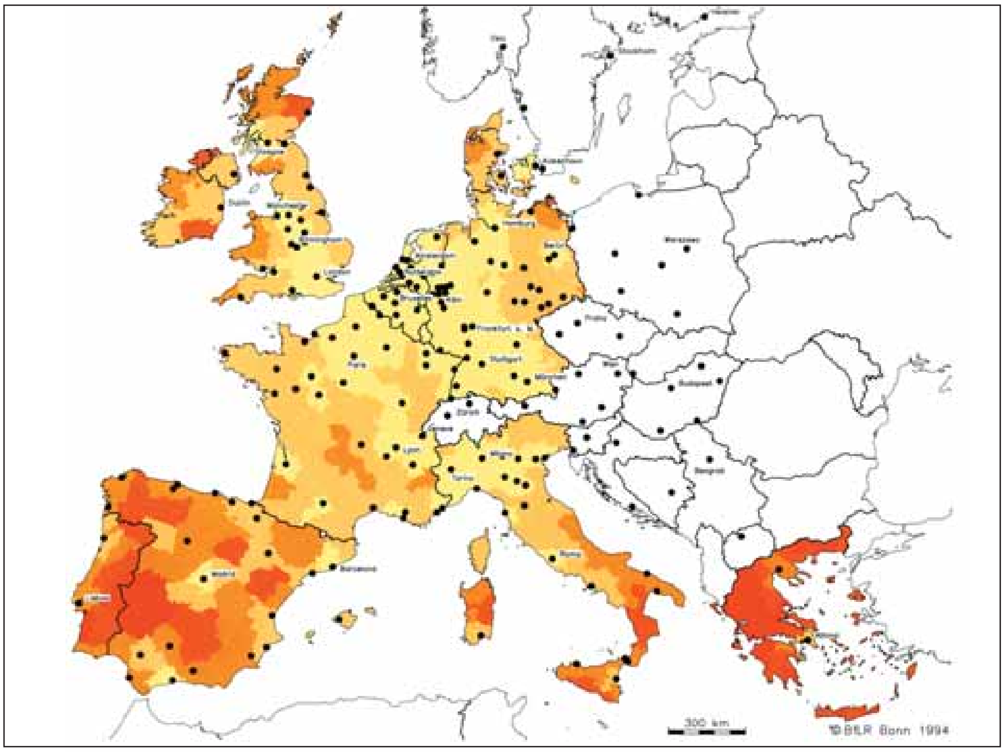
Total or average travel cost to a specified set of destinations has received increasing recognition as accessibility indicator in recent studies because of its straightforward interpretability.

The Bundesforschungsanstalt für Landeskunde und Raumordnung (Lutter et al., 1992a, 1993) in a study for DG Regional Policy 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 fastest mode (road, rail, air) to 194 economic centres in Europe. The selection of centres was based on RECLUS (1989) and Zumkeller and Herry (1992).

Figure 4.4 shows the resulting map with the familiar pattern of highly accessible regions in north-west Europe, the Rhône-Alpes region in France, the Rhine valley, southern Germany and northern Italy, but also islands of high accessibility around airport regions in south Europe with frequent flights. The peripheral regions include the whole of Greece (except Athens), nearly all Portugal and Spain, most regions in southern Italy, Ireland, Scotland and the north of England, but also parts of western France, Denmark and east Germany. Figure 4.5 shows a similar measure expressing regional accessibility to the three nearest economic centres. Here mostly road and rail are used, and the distribution of accessibility is much more differentiated, depending on the location and spacing of the centres: where the economic centres are located far apart from each other, accessibility is low. These and similar analyses were conducted taking account of planned infrastructure projects known at that time. The results with and without planned infrastructure are summarised by country in of Figure 4.6. It can be seen that the largest gains in accessibility were expected for the peripheral countries Greece, Portugal and Ireland, a confirmation of the hypothesis voiced in Section 3.6 that travel cost accessibility indicators tend to report convergence in accessibility.

Figure 4.4
Mean travel time to 194 economic centres in 1991

🟨 < 5 h
🟧 5 – 6 h
🟧 6 – 7 h
🟥 7 – 8 h
🟥 > 8 h



Source: Lutter et al., 1993

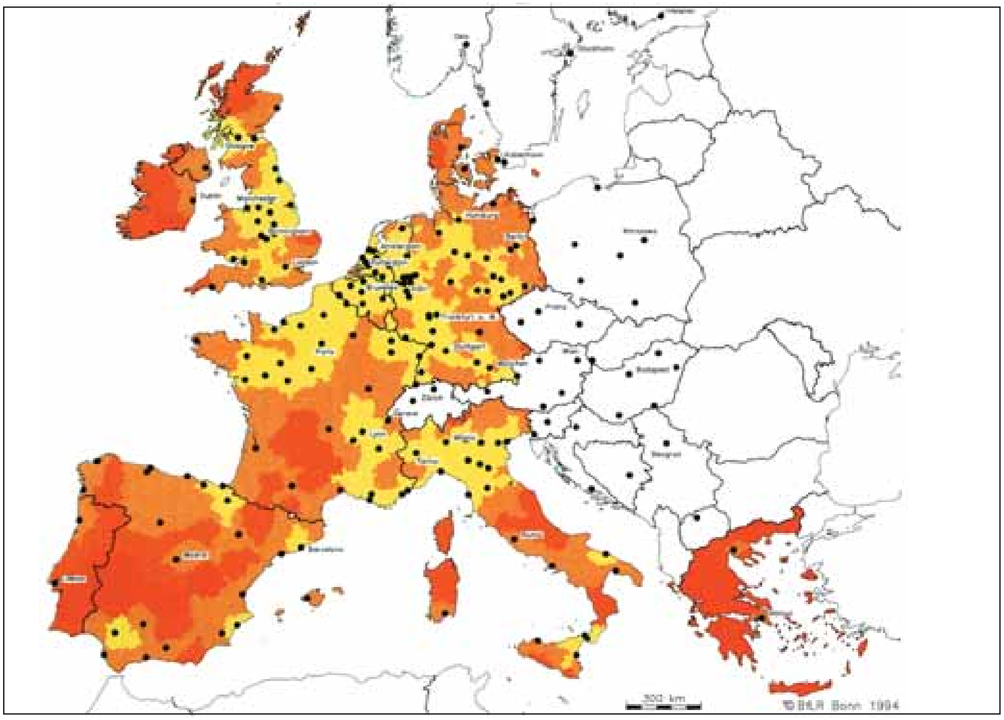


Figure 4.5
Mean travel time to the three nearest economic centres in 1991

🟨 < 1 h
🟧 1 – 2 h
🟥 2 – 3 h
🟥 3 – 4 h
🟥 > 4 h

Source: Lutter et al., 1993

In a parallel study Lutter et al. (1992b) extended the analysis down to the level of 8,588 municipalities in the (old) Federal Republic of Germany. Indicators calculated included car travel times to the nearest motorway exit, intercity station, airport, urban centre and employment centre, lorry travel times to the nearest road-rail freight terminal, and rail travel times to eleven economic centres, both for 1990 and for the expected transport infrastructure in 2000.

Similar accessibility indicators were developed for the 545 counties in the reunited Germany by Eckey (Eckey and Horn, 1992; Eckey, 1995) in order to show the effects of the road and rail projects implemented after the unification of Germany. Besides mean travel time to all counties weighted by population, also travel time to the nearest urban centre was calculated. In addition, Eckey also calculated mean travel speed both as airline and network speed (see Section 3.3.1).

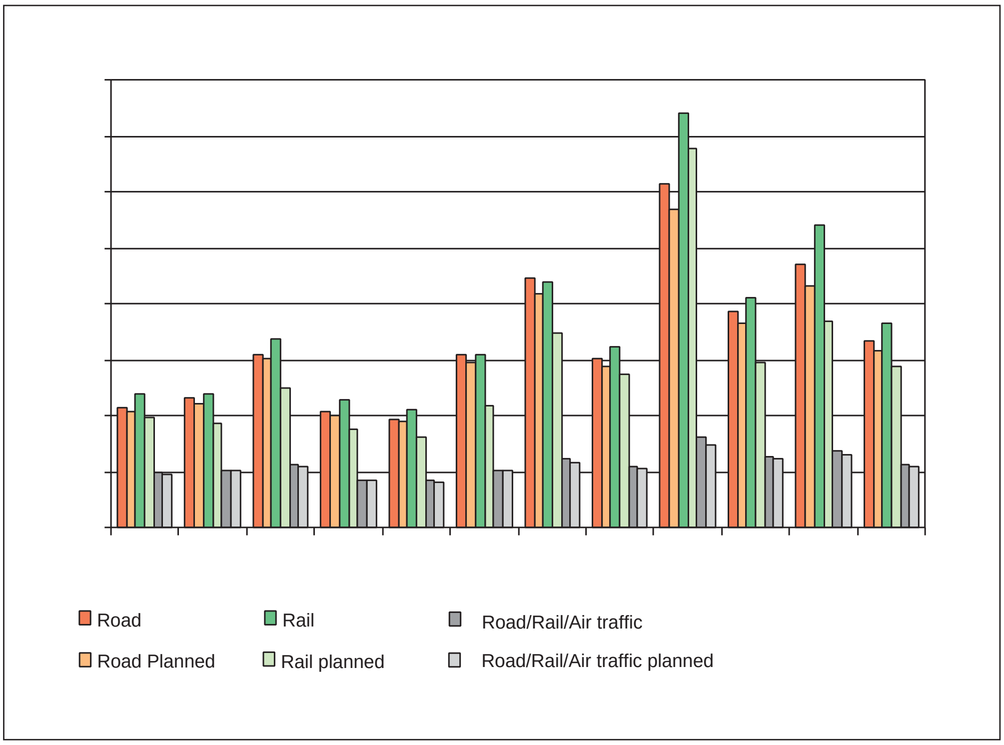
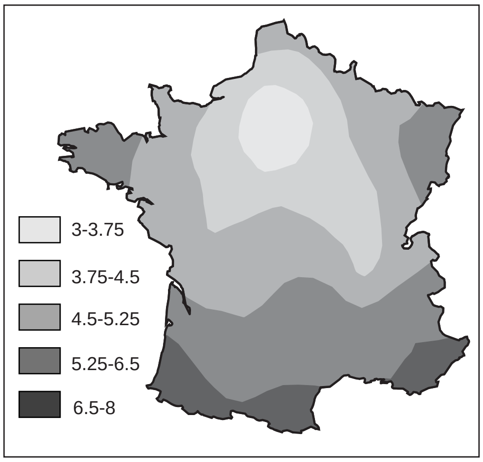


Figure 4.6
Mean travel time to 194 economic centres in 1991

Source: Lutter et al., 1993

In a very similar spirit is the work of Cauvin and colleagues at the University of Strasbourg. In a pioneering early study Cauvin et al. (1987) analysed travel conditions in pre-industrial France using data about mail delivery times between 42 cities in France in 1770. The study showed isochrone maps for selected cities as well as a map of global accessibility indicating for each city the mean of mail delivery times in days to all other cities. Figure 4.7 shows the map of global accessibility with strong spatial interpolation.

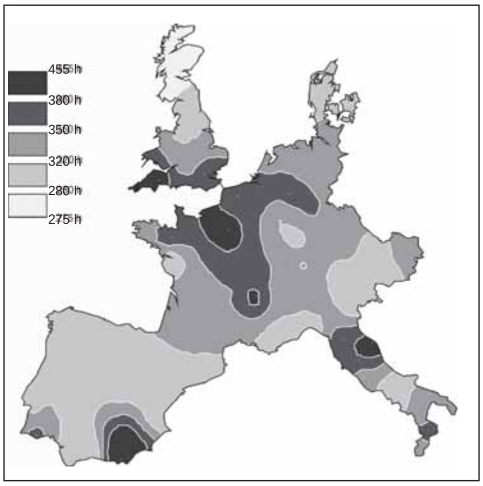
Figure 4.7
Average mail delivery times (days) to 42 cities in France in 1770



Source: Cauvin et al., 1987

In another study Cauvin et al. (1989) used concepts of time geography (Törnqvist, 1970) to construct an accessibility measure based on the usable length of stay at a destination during a business trip in Europe by air. However, unlike Törnqvist and his followers (see Section 4.1.2.2), they did not ask how many cities a traveller can reach in a given time. Instead they pre-defined a set of 53 cities in Europe and asked how much useful time at the destination, i.e. how much time between 8 and 19 hours, the traveller would have available in each city between the first flight out and the last flight in. The study is remarkable because of its detailed consideration of the time components of air travel including access, waiting and transfer times at origin city, origin airport, transfer airport (if any), destination airport and destination city. The results of the study are summarised in Figure 4.8 showing the total of useful time at the 54 potential destinations.

Figure 4.8
Useful time at destination (hours) in air travel 1987



Source: Cauvin et al., 1989

In a more recent study, Cauvin et al. (1993) analysed rail travel times between 55 cities in Europe in 1987–1988 and in 2015 based on information about future high-speed train services in Europe provided by the French National Railways SNCF. As in the earlier study on pre-industrial France, the results were presented in isochrone maps for selected cities as well as in the form of a global accessibility indicator calculated, for each city, as the unweighted average of the travel times to all other cities, both for 1987–1988 and for 2015.

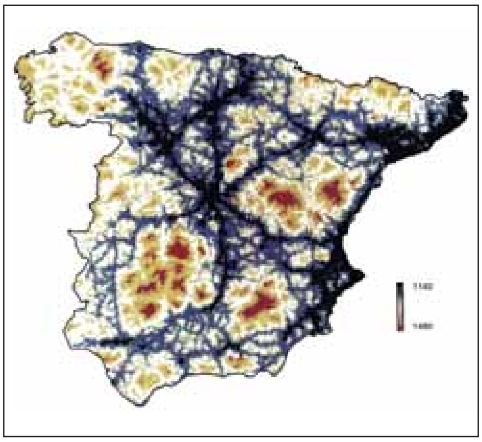
Calvo et al. (1993) developed a system of accessibility indicators based on a repartition of Spain into some 36,000 square raster cells of 5 km width. The population of the 8,060 municipalities was allocated to the raster cells based on assumptions about the decrease of population density with distance from the centres of the municipalities. The accessibility indicators were calculated for each of the 36,000 raster cells as both origins and destinations. Both travel cost and potential indicators were calculated (see Section 4.1.2.3). One of the travel cost indicators used was the total of all minimum-path network distances from origin cell *i* to all destination cells *j* weighted by a "route factor", i.e. divided by the total of all Euclidean distances to the same destinations:

$$A_i = \sum_j c_{ij} \Big/ \sum_j d_{ij}$$

where c_{ij} is the minimum-path distance through the network and d_{ij} Euclidean distance between origin cell *i* and destination cell *j*. This indicator can be interpreted as a measure of network efficiency only which does not take account of the spatial distribution of population or economic activity.

Figure 4.9 shows the spatial distribution of this indicator for the road network in Spain in 1994. It is interesting to see that, although no population data were used, nevertheless the major urban centres become visible –

Figure 4.9
Network accessibility weighted by route factor 1994



Source: Calvo et al., 1993

because they coincide with the areas of highest network density. Also the corridors of high accessibility between the major urban centres are clearly articulated.

In the UTS (Union Territorial Strategies) study, Chatelus and Ulied (1995) developed several accessibility indicators for the evaluation of trans-European networks at the level of NUTS-2 regions in the EU plus Norway. One of them, the FreR(M) indicator, measured the average cost to reach a market area of size *M* by lorry

$$A_i = \min \sum_{j\in \mathbf{Z}} P_j \, c_{ij} \qquad \text{with} \sum_{j\in \mathbf{Z}} P_j \geq M$$

where P_j is population at destination *j* and c_{ij} is generalised road transport cost including cost of the driver's time, cost per kilometre and a fixed cost component. The map in Figure 4.10 shows the spatial

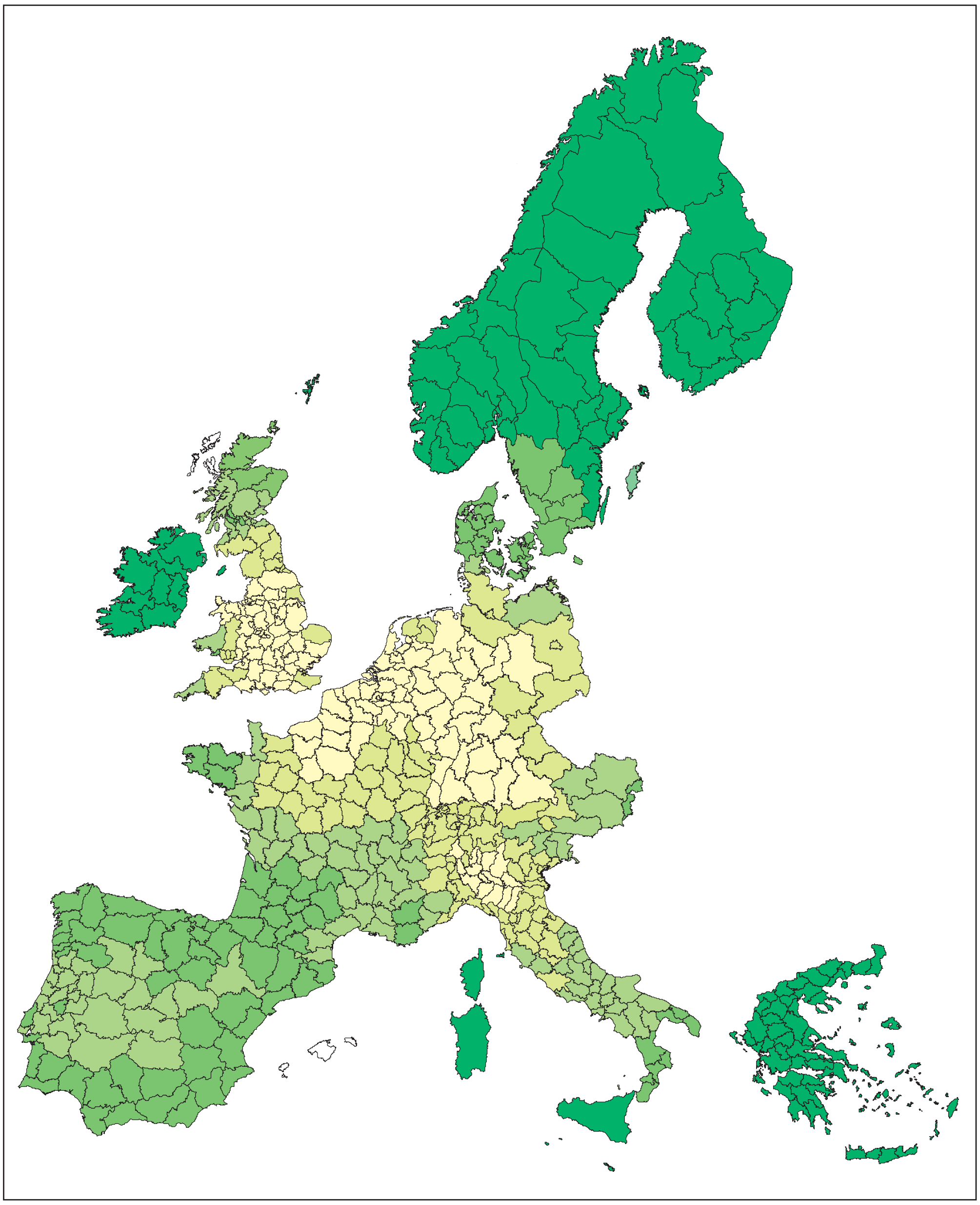


Figure 4.10
Average cost to reach a market area of 30 million people in French Francs

🟨 513 to 1060.79
🟨 1060.79 to 1554.81
🟩 1554.81 to 2090.02
🟩 2090.02 to 3923.74
🟩 3923.74 to 12909.02

Source: Chatelus and Ulied, 1995

distribution of the FreR(M) indicator calculated for a market area of 30 million people.

Two more accessibility indicators developed in the UTS study, the CON(T) indicator for passenger travel and another indicator for freight transport, the FreC(T) indicator, will be presented in Section 4.1.2.2.

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 (maximum 30 minutes for Paris). 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). The map of road accessibility in Figure 4.11 shows average road travel times in 1992 with the highest accessibility concentrated around Paris.

Figure 4.12 shows the absolute changes in average road travel times between 1992 and 2002 under the assumption that the road infrastructure investments of the TEN Outline Plan are implemented. The greatest transport cost savings occur in peripheral regions such as the British Isles, the Iberian Peninsula and Greece, which again confirms the bias of travel cost accessibility indicators towards convergence. The accessibility of the United Kingdom and Ireland is substantially improved because in 1992 the Channel Tunnel was not yet opened.

In a more recent study Gutiérrez et al. (1998) applied an accessibility indicator similar to the one used by Eckey and Horn (1992) expressing mean airline speed of travel of trips from origin *i* to all destinations *j* to the road and rail networks in Spain:

$$A_i = \sum_j \frac{c_{ij}}{d_{ij}} W_j \Bigg/ \sum_j W_j$$

where c_{ij} is network impedance and d_{ij} Euclidean distance between *i* and *j*, and W_j is the weight of destinations, in this case total income of the population at *j*. Gutiérrez et al. argue that this measure is more useful for assessing transport infrastructure investments than other accessibility measures because it neutralises the effect of pure geographic location.

Average travel time to selected destinations was also used by Gattuso and Chindemi (1998) in a study of freight movements through the port of Gioia Tauro in Calabria. Guzzo (1998) explored various indicators of unweighted and weighted travel time and travel speed in a study on the impacts of future trans-European networks. Senn (1996) developed accessibility indices based on the average difference between route length and airline distance between twenty Italian regions. Cascetta and Biggiero (1997) calculated accessibility indicators A_i of location *i* as the logsum of the utility v_{ij} of trips to destinations *j*:

$$A_i = \ln \sum_{\mathrm{j}} \exp(v_{ij})$$

Borgia and Cappelli (1994) applied a multimodal accessibility indicator of Italian regions defined as the logsum of the net benefits of modal accessibilities (cf. Section 3.4). The net benefit of a mode was measured as the negative exponential of travel time to seven major cities minus the monetary cost of travel (Pagliara, 1999).

One of the most recent applications of travel cost accessibility indicators is the study for the Austrian Conference on Regional Planning (ÖROK) by the Austrian Institute of Spatial Planning (ÖIR, 1999). The study is the culmination of more than twenty years of accessibility research in Austria resulting in one of the most spatially disaggregate models of its kind in Europe with more than 12,000 links of the road network and all rail and bus time tables manually coded, including local trams and buses as well as walkways to stops. The size of settlements for which accessibility can be calculated goes down to 300 inhabitants, i.e. far below the municipality level. In the study, accessibility was defined as average travel time to the centres of the Austrian system of central places, both by road and by public transport. The study was used to analyse the impacts of planned transport infrastructure investment scenarios and to classify regions as “central”, “peripheral” and “extremely peripheral”. Figure 4.13 (page 30) shows examples of accessibility maps for the existing road and rail networks.

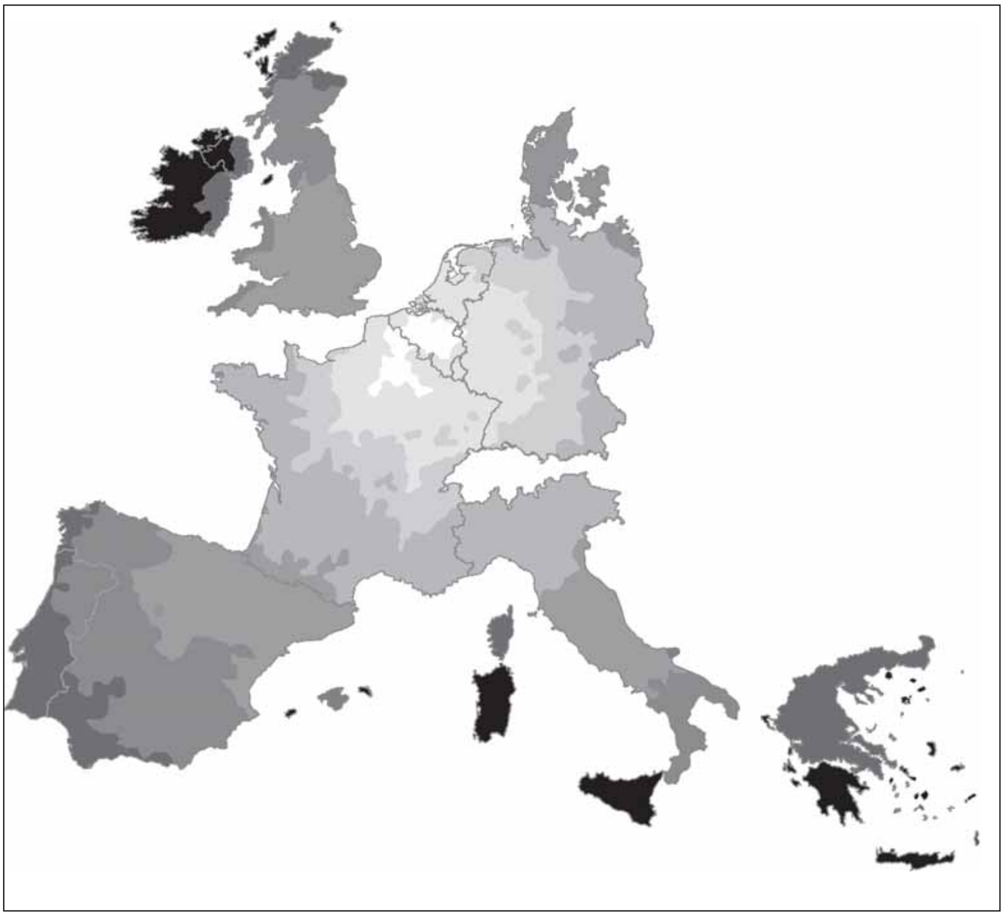


Figure 4.11
Road travel time to 94 economic centres in 1992

Source: Gutiérrez and Urbano, 1996

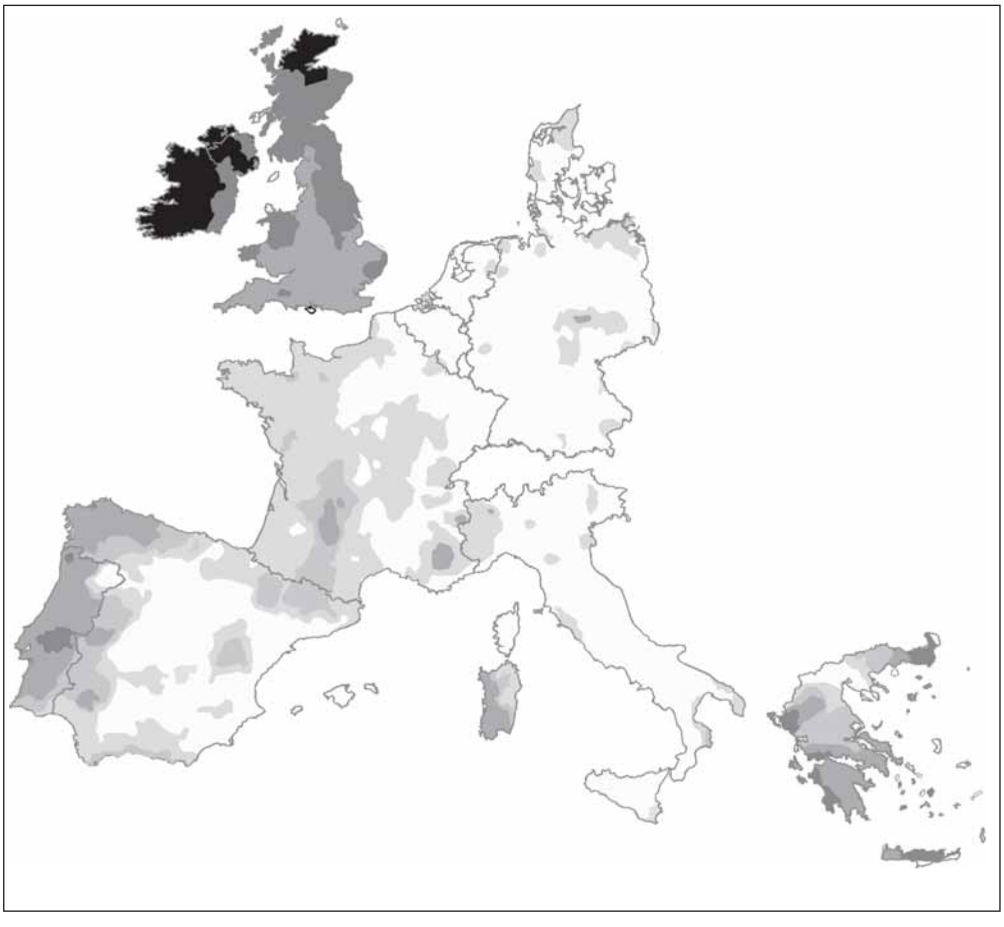
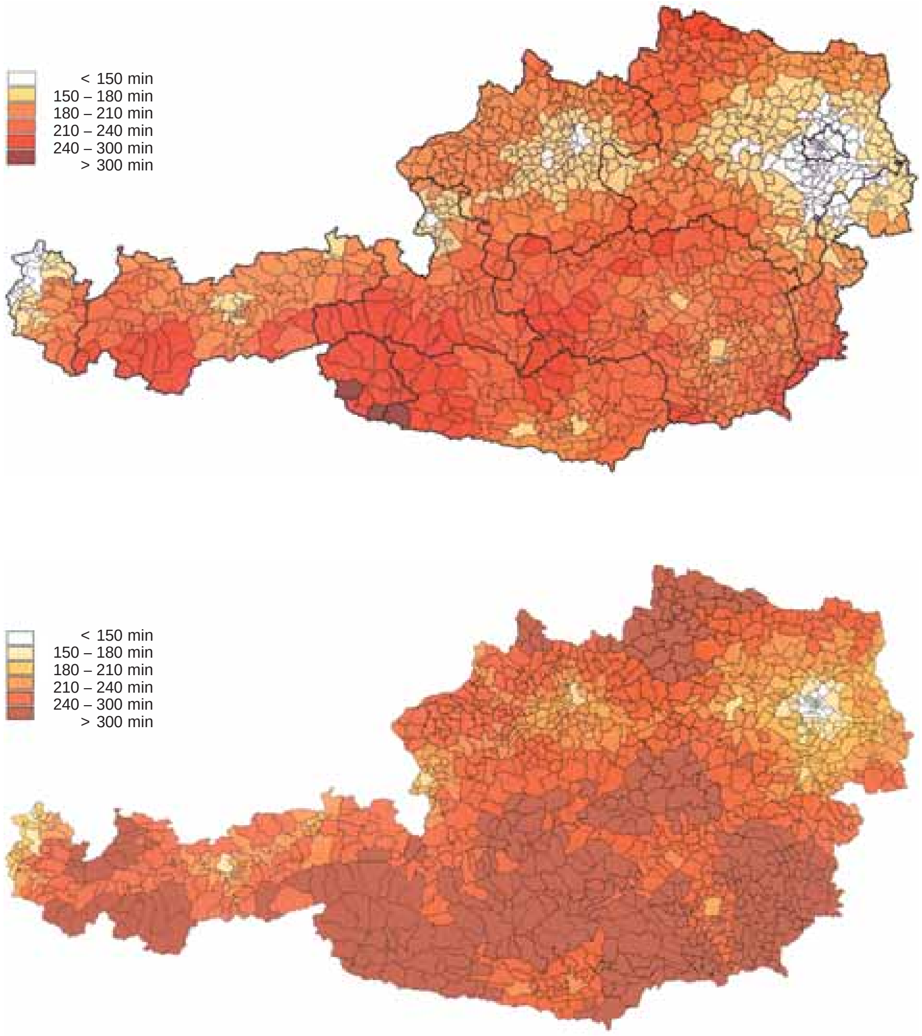


Figure 4.12
Change in road travel time 1992–2002

Source: Gutiérrez and Urbano, 1996

Figure 4.13
Weighted average travel time of 1,205 travel analysis zones to 55 central places in Austria and neighbouring countries by car (top) and rail (bottom) in 1997



Source: ÖIR, 1999

Finally, the ICON index (MCRIT, 1999) is presented as an example of a local travel cost indicator (cf. Section 3.3.1). The ICON index evaluates the quality of access to the nearest nodes of long-distance transport networks weighted by importance and level of service:

$$A_i = \sum_n p_n \left(t_{in}^a \frac{t_n^x - t_n^a}{1 + \gamma \exp\left(-\beta \frac{S_n^x - U_n}{S_n^x - U_0} \right)} \right)$$

where t_n^a is the travel time from origin i to the nearest node of network n with level of service S_n^x and utility U_n, and p_n and p_n^w are network-specific weights and t_n^x the S_n^x and are target values of access time and level of service, respectively. Figure 4.14 shows the spatial distribution of the ICON index in south-west Europe.

The ICON index shares with other local indicators the disadvantage that it considers only local conditions and fails to take account of network impedance. On the other hand it calls attention to the fact that many accessibility indicators ignore the quality of local access to long-distance networks. It would be desirable to in the future develop indicators taking account of both aspects of accessibility.

4.1.2.2 Daily Accessibility

As indicated in Section 3.3.2, the concept of daily accessibility was developed by Törnqvist, who as early as 1970 developed the notion of “contact networks” based on the hypothesis that the number of interactions with other cities by visits such as business trips would be a good indicator of the position of a city in the urban hierarchy.

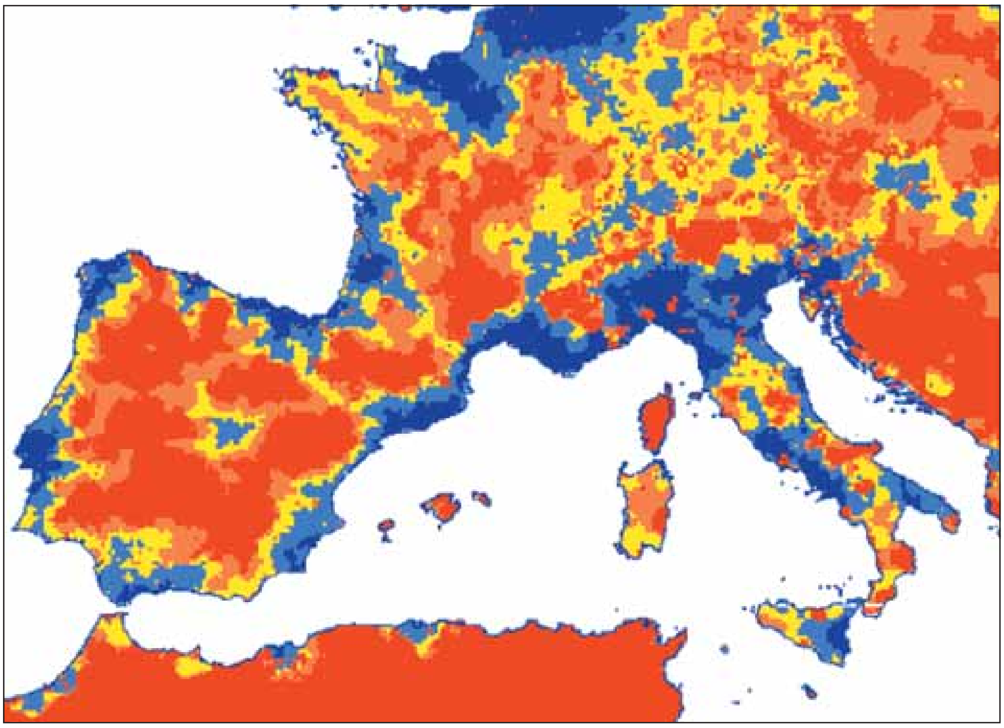


Figure 4.14
The ICON index in south-west Europe

Source: MCRIT, 1999

Figure 4.15 illustrates the results of a more recent application of this method to cities in Europe (Cederlund et al., 1991; Erlandsson and Törnqvist, 1993). The sizes of the circles on the maps correspond to 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 map impressively reproduces the “Blue Banana” (RECLUS, 1989) and highlights the peripherality of large parts of the

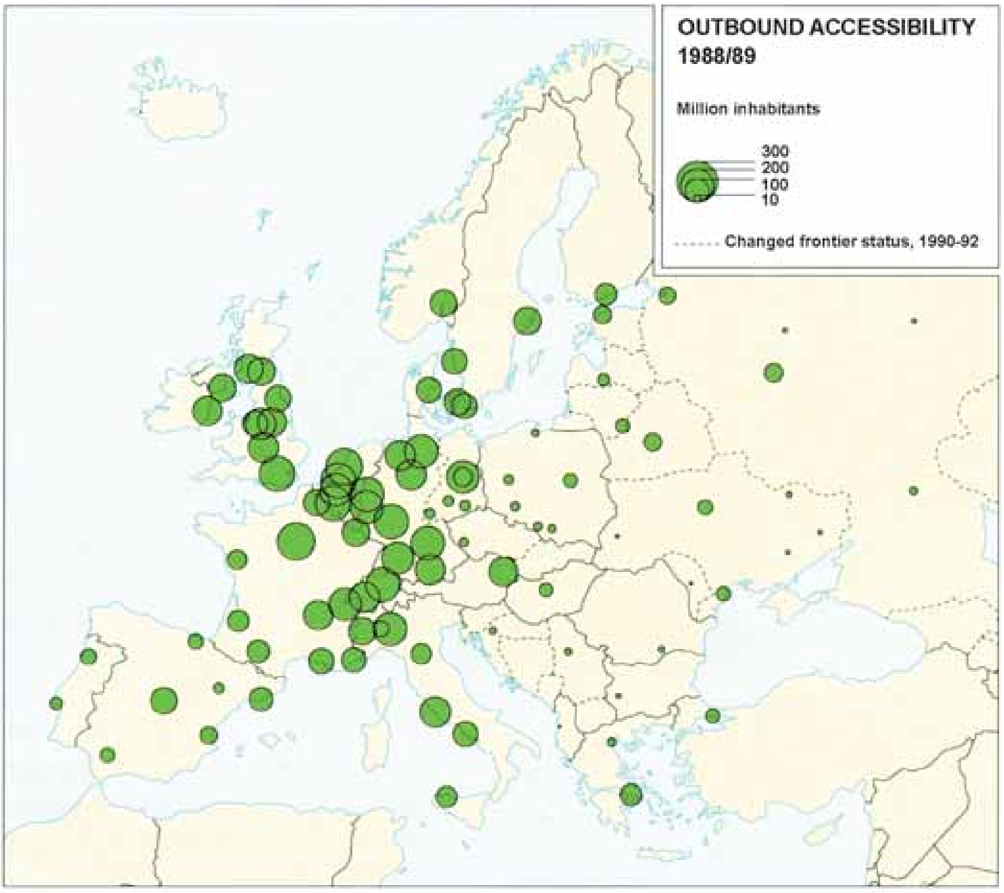


Figure 4.15
Outbound accessibility

Source:
Erlandsson and Törnqvist, 1993

Mediterranean and the Nordic and east European countries.

In the accessibility study of the Bundesforschungsanstalt für Landeskunde und Raumordnung for DG Regional Policy mentioned in the previous section (Lutter et al., 1993) daily accessibility was calculated in terms of the number of people that can be reached in three hours by the fastest mode. Modes considered included road, rail and air with and without planned infrastructure investments (new motorways, high-speed rail lines and more frequent flight connections).

Figure 4.16 summarises the resulting accessibility indicators by country highlighting the central location and population density of the Benelux countries (Lutter et al., 1993). The transport infrastructure investments underlying this analysis are the same as the ones presented in Figure 4.6 in the previous section, in which the peripheral countries Ireland, Portugal and Greece showed the largest gains in accessibility. Here the opposite occurs: the largest gain in daily accessibility are concentrated in the central areas with the highest previous accessibility, which again confirms the hypothesis that convergence or divergence in accessibility is largely a matter of the accessibility indicator chosen and the cohesion indicator applied (absolute or relative).

Also three hours was the time limit set for the *CON(T)* accessibility indicator used in the UTS study (Chatelus and Ulied, 1995). The indicator accumulated population of NUTS-2 regions of EUR15 plus Norway and Switzerland reachable within a maximum travel time $t_{\max}$

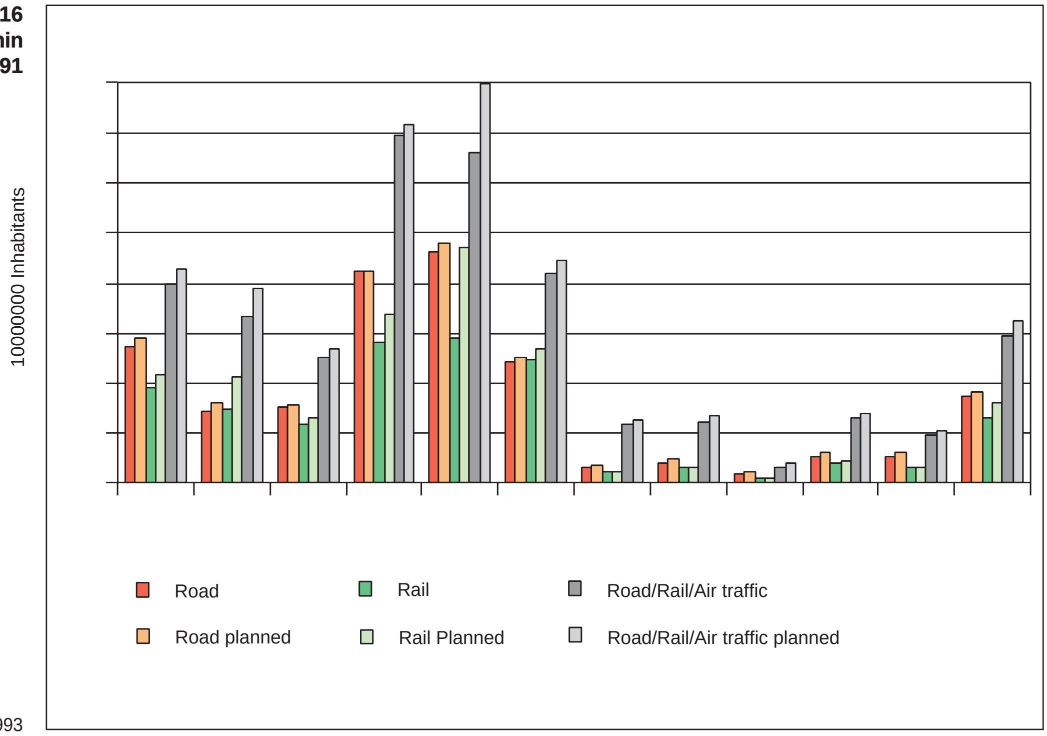
$$A_i = \sum_{j \in \mathbf{Z}} P_j \qquad \text{with } j \in \mathbf{Z} \text{ if } t_{ij} \le t_{\max}$$

where P_j is population of destination j and t_{ij} travel time between origin i and destination j 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 the criteria competitiveness, cohesion and sustainability as follows:

- *Competitiveness*. It was assumed that an area becomes more competitive if its CON(T) index increases in comparison to the European average.
- *Cohesion*. It was assumed that an area becomes better integrated into Europe if its CON(T) index grows compared to the previous time period.
- *Sustainability*. It was assumed that Europe becomes more sustainable if the share of the CON(T) index by rail increases.

Figure 4.16
Population reached within three hours in 1991



Source: Lutter et al., 1993

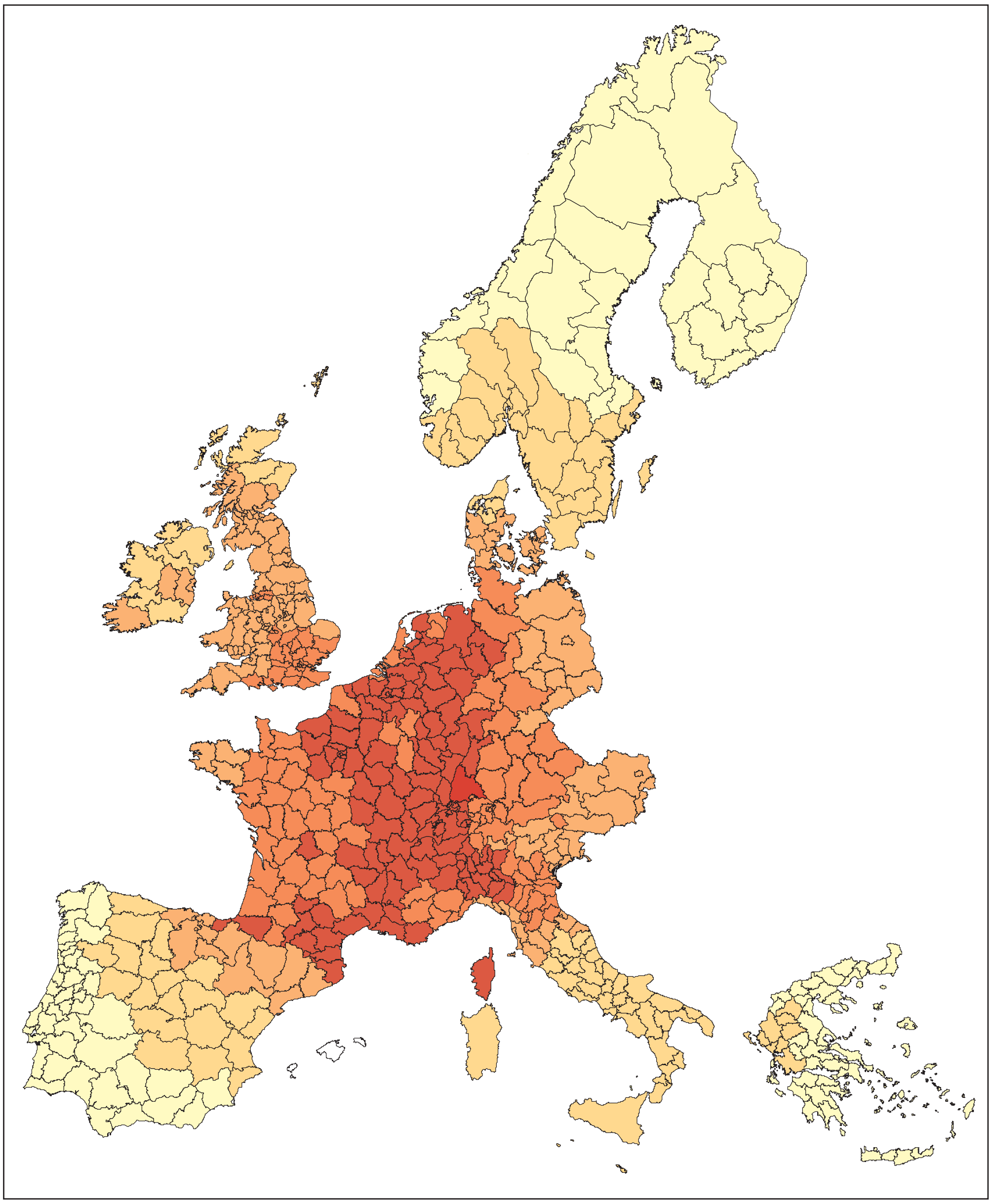


Figure 4.17
Market area reached in three days (Thousands of inhabitants)

Source: Chatelus and Ulied, 1995

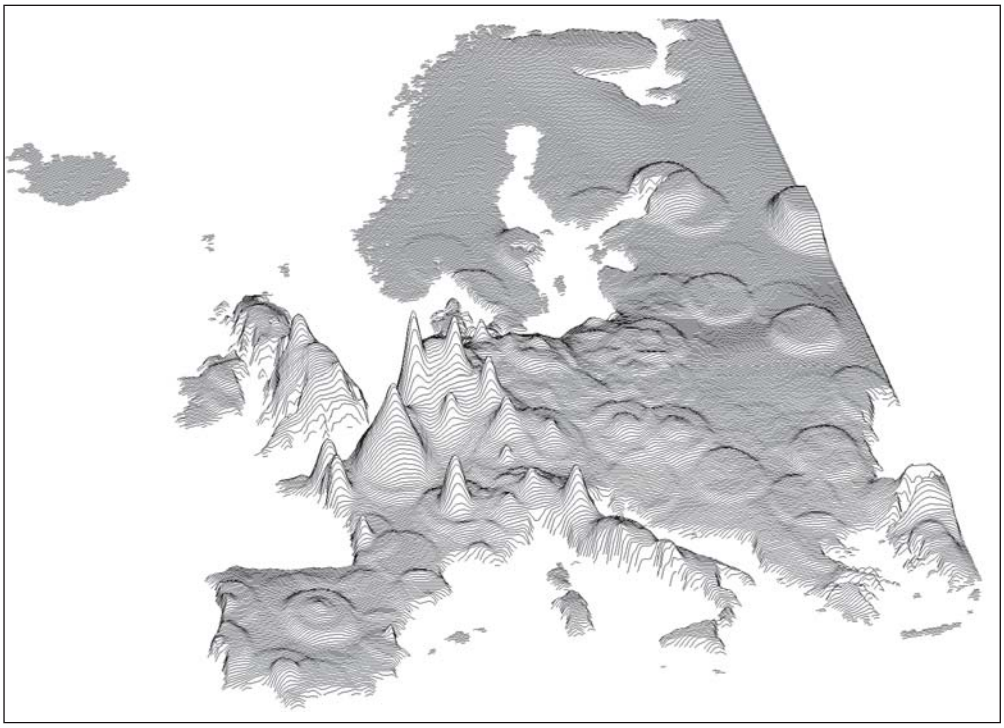
In the same study the *FreR(T)* index, a freight accessibility indicator expressing the size of the market that can be reached in a certain travel time was developed. The indicator accumulates the population that can be reached in one, two or three days by the fastest connection using road, rail or combined traffic with driving time restrictions for lorry drivers observed. The equation is identical to the one above for the CON(T) index but t_{max} was set to one, two or three days. Figure 4.17 shows the market area that can be reached in three days (Chatelus and Ulied, 1995), once more highlighting the enormous gap in accessibility between central and peripheral regions.

Spiekermann and Wegener developed three-dimensional surfaces of daily road and rail accessibility for Europe using raster-based GIS technology (Spiekermann and Wegener, 1994a, 1996; Schürmann et al., 1997; Vickerman et al., 1999). The quasi-homogenous accessibility surface was 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.

Figures 4.18 shows as an example daily accessibility by rail in 1993. Five hours were selected as maximum one-way travel time. In the three-dimensional representation the height of the "mountains" is proportional to the number of people reached from each raster cell in five hours. It is clear that rail accessibility is heavily node-oriented; the peaks of the accessibility surface correspond to major population centres and railway interchanges. However, the three-dimensional representation illustrates that the accessibility quickly decreases with distance from these nodes and that there are interstitial 'grey zones' of low accessibility even in highly accessible central regions.

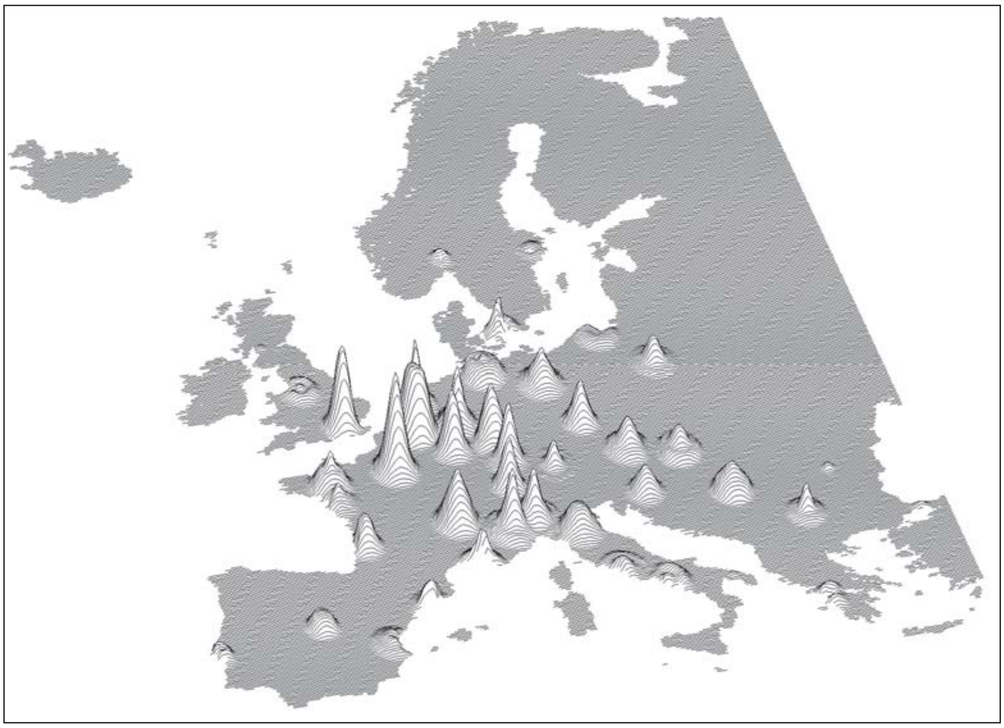
Figure 4.19 shows the growth in daily accessibility due to the increase in travel speeds by the construction of new high-

Figure 4.18
Daily accessibility by rail in 1993



Source:
Spiekermann and Wegener, 1994a

Figure 4.19
Absolute change in daily accessibility by rail 1993–2010



Source:
Spiekermann and Wegener, 1994a

speed rail lines and the upgrading of existing lines according to the TEN Outline Plan of the European Union, i.e. the absolute difference between situation in 1993 and the situation in 2010. As to be expected, the winners are the major cities and railway nodes in the central areas of Europe, whereas the peripheral regions gain only little. This result may be compared with the map in Figure 4.12 where clearly the peripheral regions seem to be the winners. It is important to note that these different outcomes are not caused by the different modes analysed but by the different accessibility indicators applied.

4.1.2.3 Potential

The most popular type of accessibility indicator found in the literature continues to be potential accessibility (see Section 3.3.3)

Keeble et al. (1982, 1988) analysed the centrality of economic centres in Europe using a gravity potential (see Section 3.3) with regional GDP as destination activity; the resulting centrality contours are shown in Figure 4.20. The figure clearly shows two central areas of high accessibility in Europe: one between London and northern Italy and one between Paris and Berlin.

Bruinsma and Rietveld (1992) calculated potential accessibility of European cities with respect to population. The resulting map, in which the sizes of the circles indicate not population but accessibility of cities, is shown in Figure 4.21 (page 36). Not surprisingly, it closely resembles the contour map by Keeble et al. of Figure 4.20 and so demonstrates the spatial correlation between economic and population centres.

Using the same raster-based representation of space as for the calculation of travel cost accessibility (see Section 4.1.2.1 and Figure 4.9), Calvo et al. (1993) calculated also potential accessibility with the following gravity model:

$$A_i = P_i + \sum_j \frac{P_j}{c_{ij}^2} \Big/ \sum_j P_j$$

where P_i is population of origin cell i as the 'self-potential', P_j population of destination cells j and c_{ij} minimum-path travel times

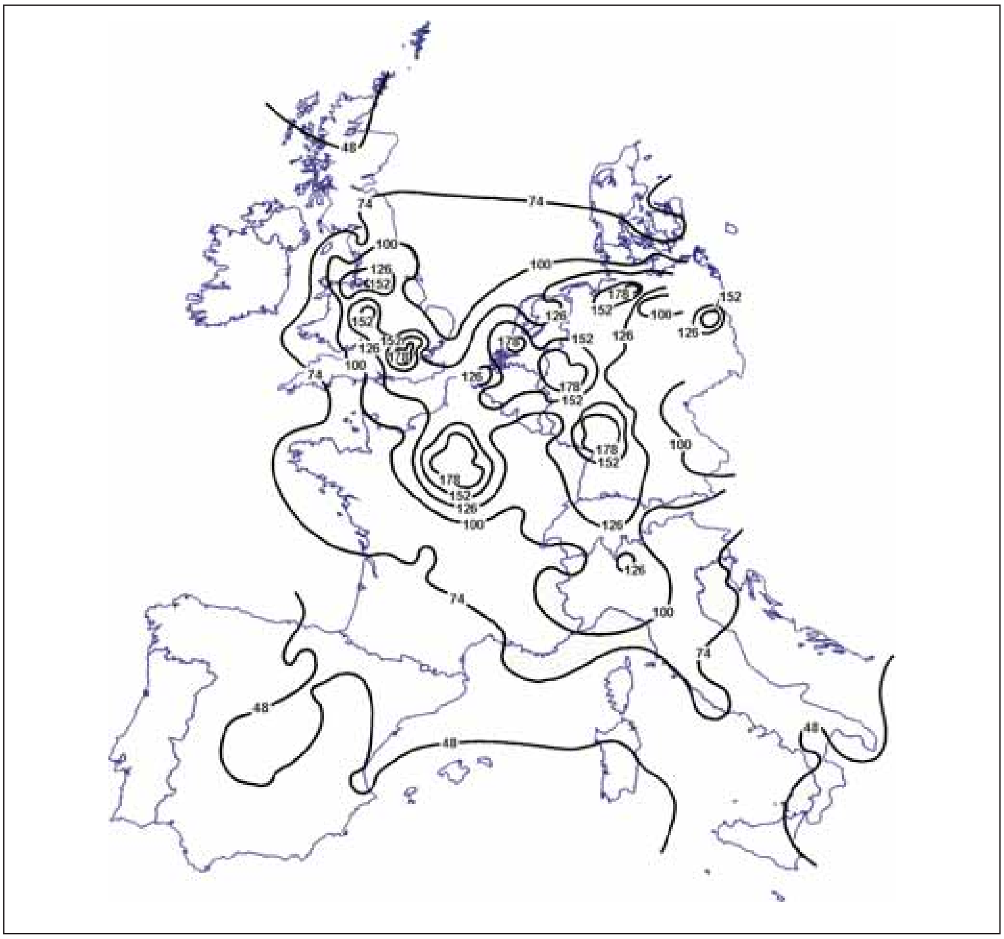


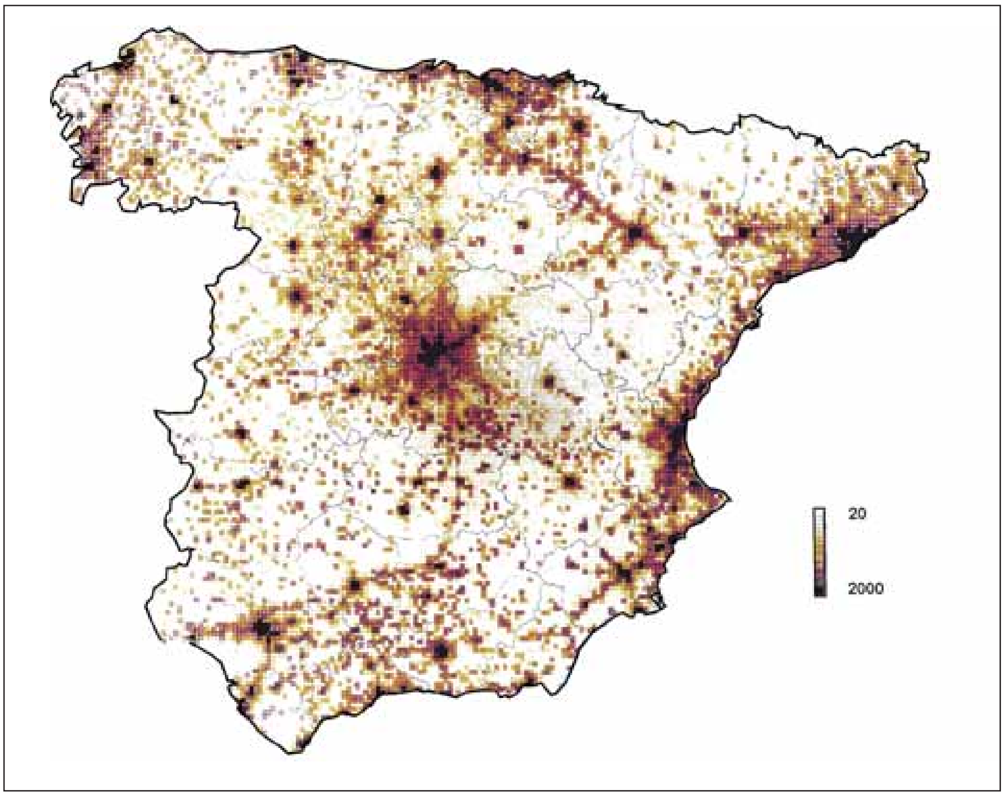
Figure 4.20
Economic potential in Europe

Source: Keeble et al., 1988

Figure 4.21
Population potential of European cities

Source:
Bruinsma and Rietveld, 1992

Figure 4.22
Population potential with road network of 1994 in Spain



Source: Calvo et al., 1993

by road in 1994. Figure 4.22 illustrates the result. Due to the high-resolution of the spatial representation, the high-density, high-accessibility corridors fanning out from the major agglomerations are clearly articulated as well as the vast interstitial areas of low accessibility between the metropolitan areas.

In a study of rail accessibility in Italy Bibby and Capineri (1997) used population of the more than 8,000 municipalities in Italy weighted by per-capita income as destination activity M_j:

$$A_i = \sum_j \frac{M_j}{t_{ij}}$$

where t_{ij} is rail travel time including access, waiting, in-vehicle, transfer and egress times. The study used digital timetable information of the Italian railways to calculate average travel times of the three fastest train connections between each pair of cities in Italy arriving not later than 11.00 h. Figure 4.23 shows the potentials of more than 8,000 municipalities indicating the strong dominance of the major urban areas.

Potential accessibility indicators were calculated for the planned high-speed rail network in Germany by Steinbach and Zumkeller (1992) as well as in the study by Gattuso and Chindemi (1998) on freight movements through the port of Gioia Tauro, Calabria, Italy.

In studies for the Highlands and Islands European Partnership and for DG Regional Policy of the European Commission, Copus (1997, 1998, 1999) developed “peripherality indicators” for NUTS-2 and NUTS-3 regions based on road-based potential measures. Figure 4.24 (page 38) shows the economic potential using GDP as the destination variable and Figure 4.25 (page 38) the peripherality index derived from it as the inverse standardised to the interval between zero (most central) and one hundred (most peripheral).

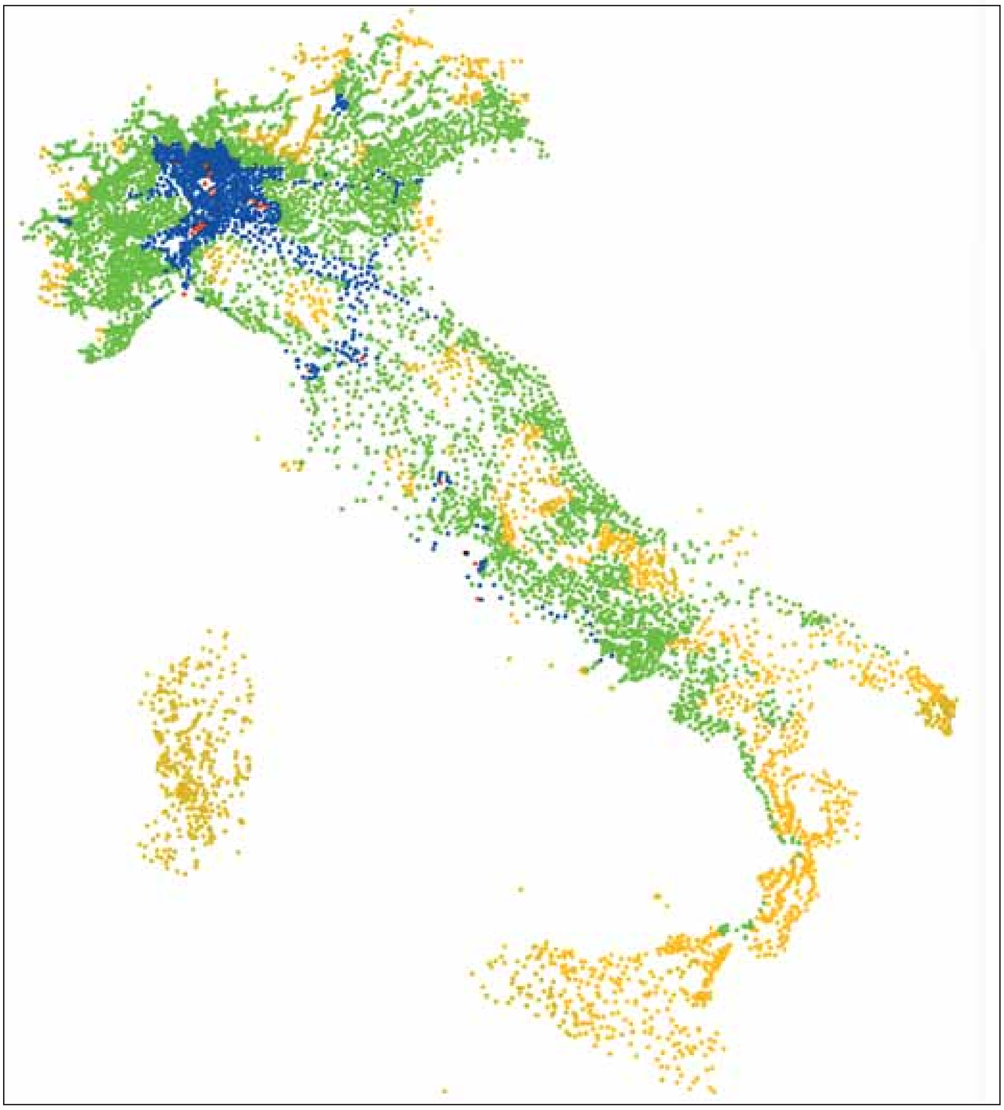


Figure 4.23
Population potential of municipalities in Italy

Milano = 100 %

● < 10 %
● 10 - 20 %
● 20 - 40 %
● 40 - 60 %
● 60 - 95 %
● > 95 %

Source: Bibby and Capineri, 1997

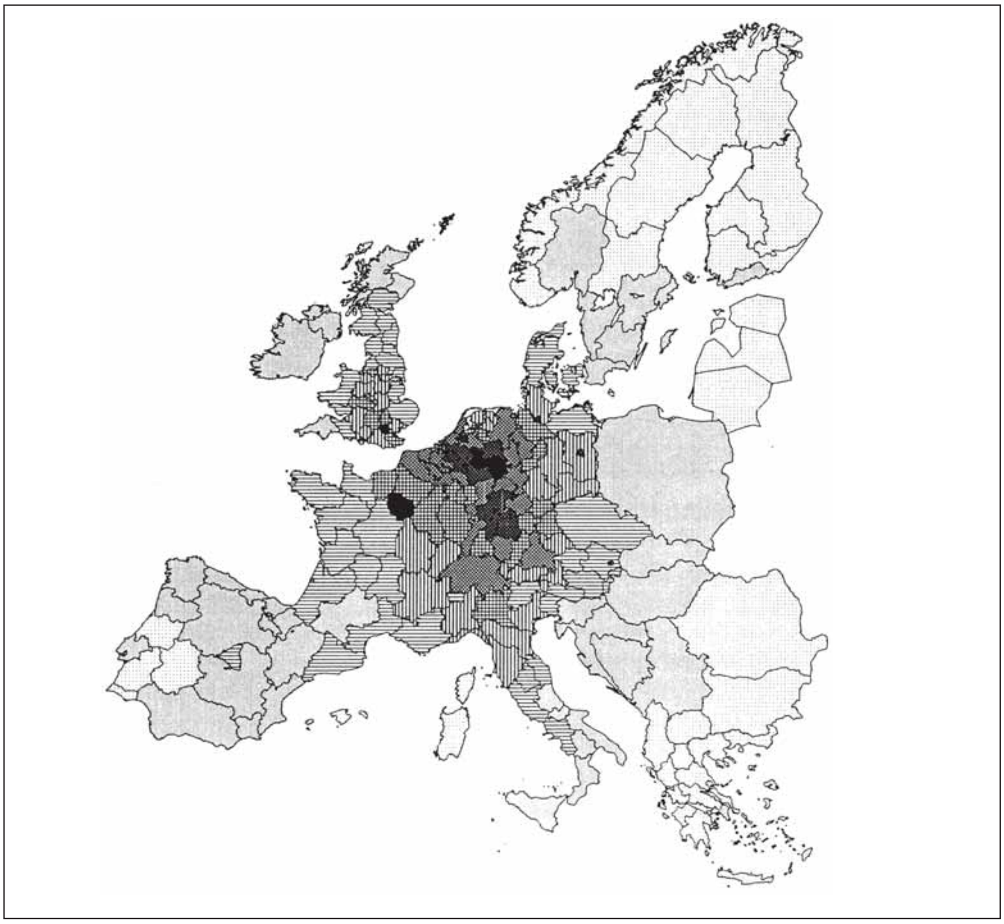


Figure 4.24
Economic potential (GDP in ECU) in 1994

Source: Copus, 1997

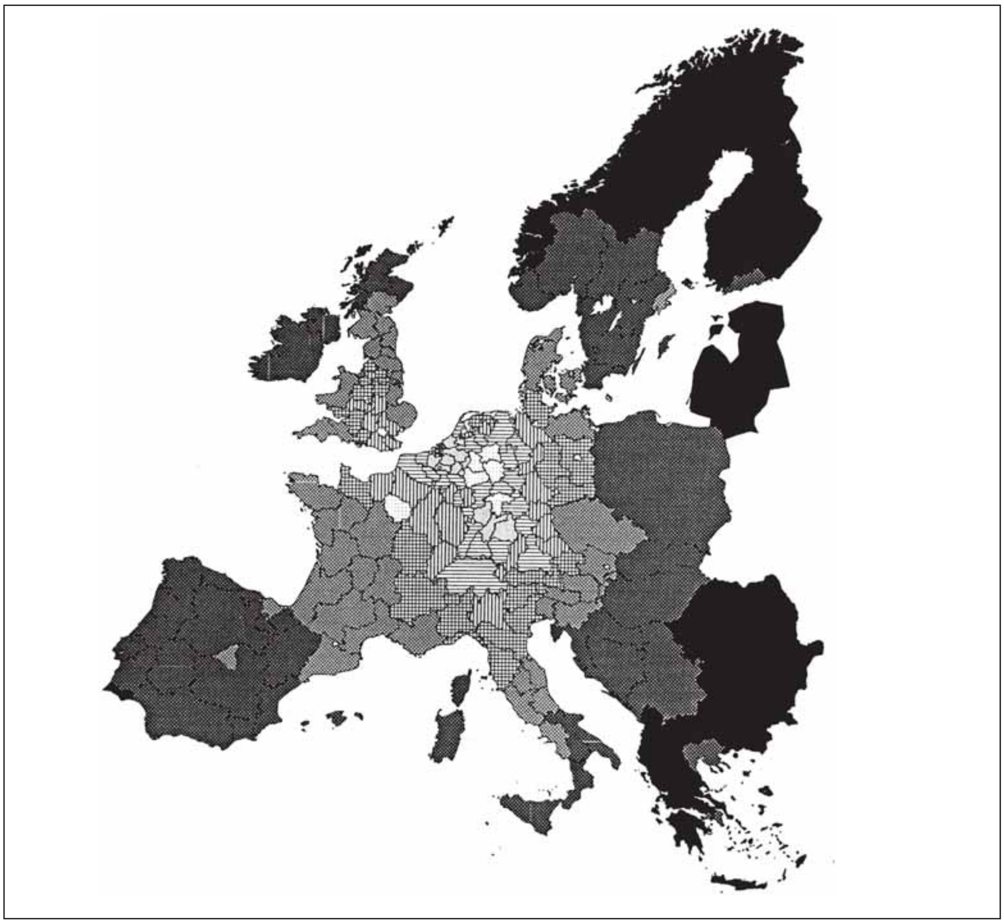


Figure 4.25
Peripherality index (GDP in ECU) 1994

Source: Copus, 1997

The final example shows three-dimensional accessibility surfaces of potential rail accessibility constructed by Spiekermann and Wegener with the same technology as the ones of daily accessibility shown in Figures 4.18 and 4.19 (Spiekermann and Wegener, 1994a, 1996; Schürman et al., 1997; Vickerman et al., 1999). Figure 4.26 shows accessibility by rail in Europe in the year 1996, and Figure 4.27 shows absolute growth in accessibility until 2010 due to the high-speed rail TEN Outline Plan. It can again be seen that, in contrast to the results achieved with travel cost accessibility indicators, potential indicators tend to predict that the already highly accessible central regions will benefit most from the TEN programme, i.e. predict divergence in accessibility rather than convergence.

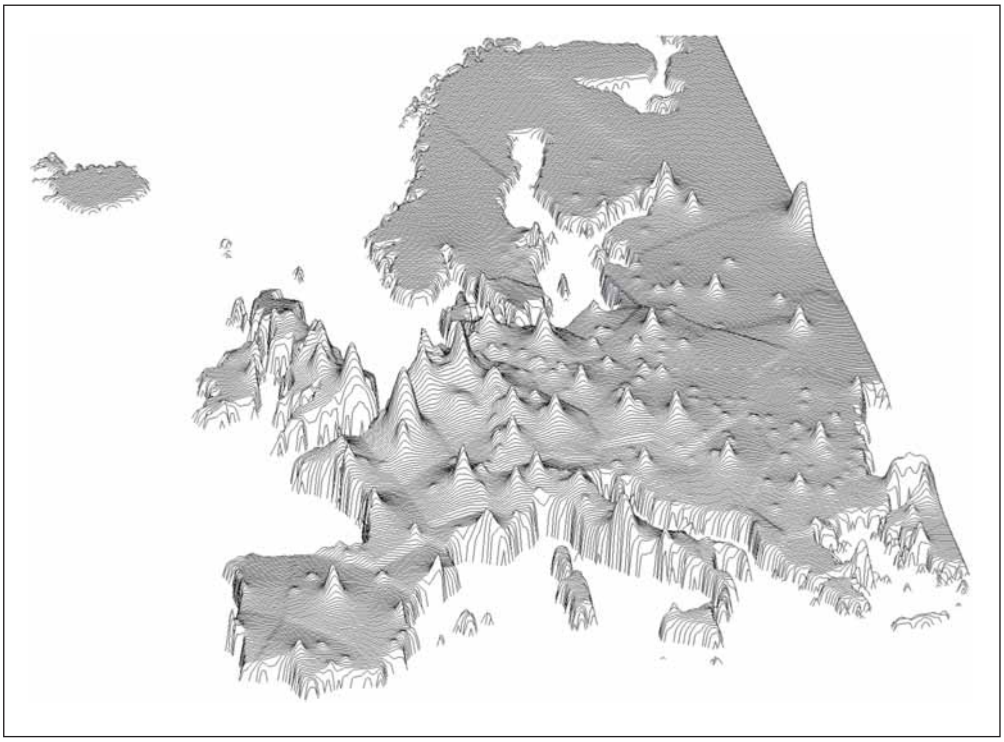


Figure 4.26
Potential accessibility by rail in 1993

Source:
Spiekermann and Wegener, 1994a

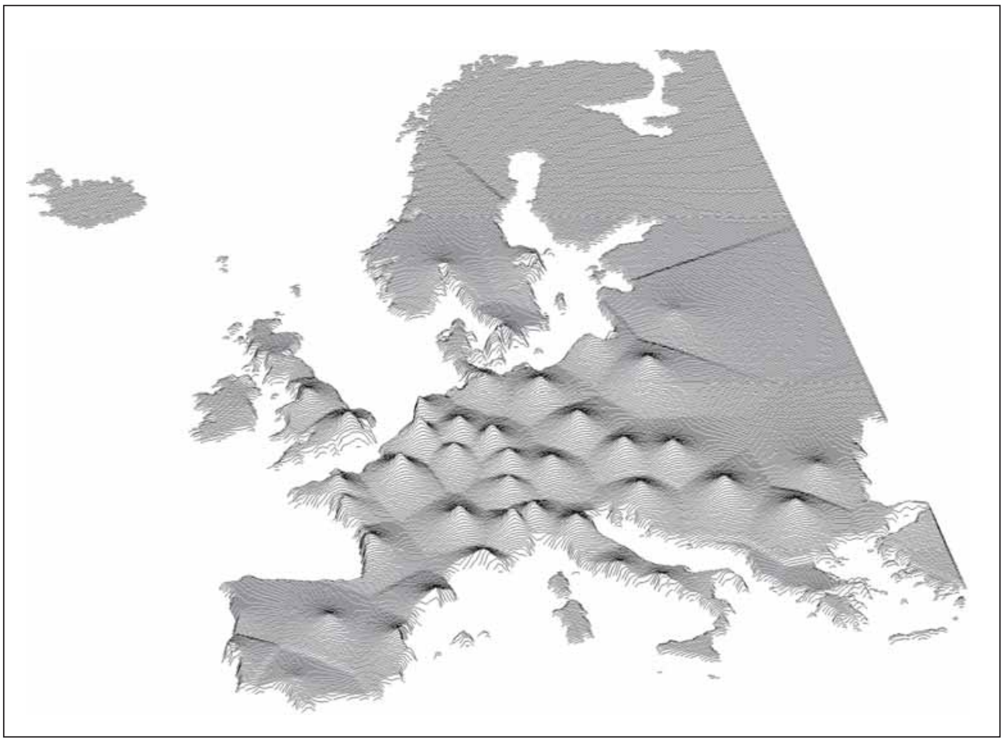


Figure 4.27
Absolute change in potential accessibility by rail 1993–2010

Source:
Spiekermann and Wegener, 1994a

4.2 Comparative Studies of Accessibility

Bruinsma and Rietveld (1996a, 1996b) reviewed the state of the art in developing indicators of accessibility and compared indicators of accessibility in Europe calculated in recent studies. In the theoretical part of their study they list eleven types of accessibility indicators:

– acc1	access to network
– acc2	distance to the nearest network node
– acc3	number of direct connections
– acc4	number of lines arriving at node
– acc5	travel cost to one other node
– acc6	average travel cost to all nodes
– acc7	expected value of utility of visit to all nodes
– acc8	potential accessibility
– acc9	number of people reachable with a certain travel cost
– acc10	inverse of balancing factor in spatial interaction model
– acc11	accessibility assessed by expert judgement

It is obvious that indicators acc1 to acc5 belong to the “simple” indicators (see Section 2.4) and that acc6, acc9 and acc8 correspond to the travel cost accessibility, daily accessibility and potential accessibility discussed in Section 3.3.

In the empirical part of their study Bruinsma and Rietveld compared accessibility indicators calculated by seven groups of authors:

- *Erlandsson and Lindell* (1993): daily accessibility (acc9) by fastest mode (cf. Figure 4.3),
- *Bruinsma and Rietveld* (1993): potential accessibility (acc8) by fastest mode (cf. Figure 4.5).
- *Spiekermann and Wegener* (1996): daily accessibility (acc9) and potential accessibility (acc8) by rail based on raster cells,
- *Gutiérrez et al.* (1996): travel cost accessibility (acc6) by rail (cf. Figure 4.2),
- *Cattan* (1992): travel cost accessibility (acc6) of rail and air traffic,
- *RECLUS* (1989): distance to nearest airport or port (acc2),
- *Healey & Baker* (1994): expert judgement (acc11).

The result of their analysis was that within a given travel mode the correlation between the accessibility indicators examined is rather high despite significant differences in implementation. They concluded therefore that if one is mainly interested in the rank order of cities with respect to accessibility, the choice of indicator is of less importance than the choice of modes considered. However, if one is interested in inequalities in accessibility between cities or regions, the way the indicators are implemented appears to have a much larger impact.

Schürmann et al. (1997) compared different variants of accessibility indicators such as weighted and unweighted average travel time to cities of different sizes by road and rail, daily accessibility and potential accessibility without a network, by road and by rail for different years, daily accessibility v. potential accessibility and population potential v. economic potential for 201 regions of the European region at the NUTS-2 level. They concluded that travel cost accessibility is not very sensitive to changes in the transport network, the choice of destination activity or the level of spatial aggregation, that daily accessibility is rather sensitive to changes in the transport system and reveals much larger differences between central and peripheral regions, and that potential accessibility ranges somewhere in between the two other accessibility indicators.

5 Choice of Indicators

The review of indicators of geographical position (see Chapter 4) has resulted in a large number of indicators, in particular of accessibility indicators. However, for policy-oriented analysis, a manageable set of generally accepted, robust and feasible indicators is required. On the other hand, it would be dangerous to prematurely settle on a too narrow set of established indicators, because this would preclude the utilisation of more complex indicators when studying specific issues and would also discourage future innovation in research.

The Working Group therefore followed a two-level approach: On the one hand it made a suggestion for a limited set of reference indicators of geographical position, which are readily available and well established, for immediate use and practical illustration. On the other hand, it compiled a larger, more open list of specific indicators, which deserve further attention and examination with respect to their discriminatory power (differentiation between areas), explanatory power (predicting area development) and policy relevance (EU objectives). Both selections are tentative and do not preclude the later inclusion of other indicators still to be developed.

Before choosing indicators for the two lists, the Working Group had to find answers to a number of questions which were not specified in its terms of reference:

(1) *For what purpose are indicators to be developed?* The term “spatial differentiation” used in the Call for Tender (see above) seemed to be too narrow. It became increasingly clear that the Commission hoped to use the indicators also for *targeting policies*, i.e. for identifying areas which are suitable or eligible for specific EU policies, such as receiving subsidies from the Structural Funds. By the same token the indicators should be suitable for being used in *policy analysis*, i.e. for ex-post analysis of the impacts of such policies, e.g. whether the areas benefiting from the policies achieved the intended targets for which they were selected. Finally, from a scientific point of view, indicators may be selected for their explanatory power, i.e. because they are suitable for being used for *predicting other indicators* which cannot be easily measured. The Working Group decided that, if possible, the indicators selected should serve all four purposes: spatial differentiation, targeting policies, policy analysis and predicting other indicators.

(2) *For which areas are indicators to be developed?* The Call for Tender referred to “regions, cities and corridors” but failed to specify the intended spatial scope and spatial resolution of the analysis. Was only the territory of the present European Union to be covered or also future accession countries? How about studies covering only one country or parts of a country? In the case of regions, what size of regions in terms of the *Nomenclature d’Unités Territoriales Statistiques* (NUTS) levels 0, 1, 2, 3 , 4 or 5? In the case of cities, only major cities or all cities? And what is a corridor: a set of regions or cities along a major transport line? The Working Group decided to confine itself in the present phase to NUTS-3 regions cities in the present EU and to leave the consideration of other European regions and smaller areas for later research.

(3) *How many indicators are to be developed?* From a dissemination point of view a limited number of well established, clearly defined and “officially certified” reference indicators seems to be preferable. Only if the number of indicators is small and their calculation transparent and unambiguously defined, can they be applied in a wide range of contexts and different points in time and yet produce well understood and comparable results. From a scientific point of view, however, the number of indicators should be large in order to respond to different situations and policy questions and reflect advances in scientific theory and method, computing resources, data availability and changing policy issues. The Working Group decided to adopt a two-level approach: to recommend a limited set of *reference indicators* and at the same time keep its options open for a larger, potentially unlimited set of *specific indicators*.

(4) *How are the indicators to be selected?* Depending on the purpose for which the indicators are to be used, different selection criteria may be used. If spatial differentiation is the main purpose, indicators should be selected by their discriminatory power in terms of explained statistical variance. This criterion implies

that indicators should, ideally, be orthogonal, or statistically independent, of one another. If, however, targeting policies or policy analysis are the main purpose, policy relevance should be the main selection criterion. This criterion may conflict with the requirement of statistical independence because indicators that in the past have been highly correlated may be addressed by different policies in the future. Finally, if predicting other indicators is the main purpose, explanatory power should be the selection criterion, and this may conflict with all of the above criteria. The Working Group decided to search for indicators that satisfied all three criteria, discriminatory power, policy relevance and explanatory power, if necessary at the expense of statistical independence.

In the first subsection of the chapter, the policy objectives and policy fields for which the indicators are to be used are identified by reference to the European Spatial Development Perspective (ESDP). Based on this analysis, the proposed reference indicators and a list of possible specific indicators are presented and their choice explained.

5.1 Objectives of the ESDP

In the final conclusions issued at the Potsdam conference of EU Ministers responsible for spatial planning in May 1999, the objectives of spatial policies were defined (ESDP, 1999):

"The aim of spatial development policies is to work towards a balanced and sustainable development of the territory of the European Union."

Article 2 of the Maastricht Treaty states as the goals of the European Union the promotion of harmonious and balanced economic development, stable, non-inflationary and sustainable growth, convergence of economic performance, high levels of employment and social security, improvement of the quality of life and economic and social coherence and solidarity between the Member States.

These objectives were taken up in the European Spatial Development Perspective (ESDP) in the "triangle of objectives" linking the three goals economic and social cohesion, conservation of natural resources and cultural heritage, and a more balanced competitiveness of the European territory (ESDP, 1999, 10). Spatial development policies should promote sustainable development of the EU through a "balanced spatial structure" by "development of a balanced and polycentric urban system and a new urban-rural relationship", "securing parity of access to infrastructure and knowledge" and "sustainable development, prudent management and protection of nature and cultural heritage" (ESDP, 1999, 11).

These objectives are to be observed in all EU policies which have a spatial impact, in particular policies in the fields of

- Community Competition Policy,
- Trans-European Networks (TEN),
- Structural Funds,
- Common Agricultural Policy (CAP),
- Environment Policy,
- Research, Technology and Development (RTD),
- Loan activities of the European Investment Bank.

5.1.1 Cohesion

A prominent role for the achievement of these goals play the trans-European networks in the fields of transport, communications and energy (TEN). Already Article 129b of the Maastricht Treaty linked the TEN to the objectives of Article 7a (free traffic of goods, persons, services and capital) and Article 130a (promotion of economic and social cohesion). In particular the trans-European transport networks were to link landlocked and peripheral areas with the central areas of the Union. These objectives were confirmed in the ESDP (1999, 14). The trans-European transport networks (TETN) are the most relevant in spatial development policy and in financial terms. The TETN absorb more than 80 % of the total TEN budget. A large part of the investments in TETN is currently concentrated on high-speed railway lines, often connecting major conurbations. Cities close to high-speed transport stops and with a comparatively poor connection until now are likely to benefit most from these investments. In addition, in areas with a high volume of long-distance road traffic, high-speed lines may offer an incentive to shift increasing shares of traffic to the railways, thus helping to relieve road congestion and improve the environment. Indeed, rising traffic levels, in particular on road and air networks, are threatening the competitiveness of some central areas in the EU. A multitude of different initiatives are also required in long-distance traffic, in particular by increasing the shift to rail, inland waterways and coastal and maritime transport.

Also the Structural Funds, in particular the European Regional Development Fund (ERDF), follow the objective of economic and social cohesion (as measured by traditional macroeconomic indicators). The First Report on Economic and Social Cohesion concluded that disparities between Member States have tended to decrease, but that at the same time regional concentration of economic activities is increasing. This is related to the lack of mechanisms for spatial co-ordination. The latter could substantially contribute to a more balanced distribution of economic activities. For this reason, increasingly, spatial typologies are being used to frame the interventions of the Funds (for example, urban areas), in addition to traditional subsidising (ESDP; 1999, 16).

5.1.2 Peripherality

In the ESDP document, improvements in accessibility are given a high priority as a policy target: “Good accessibility of European regions improves not only their competitive position but also the competitiveness of Europe as a whole.” (ESDP 1999, 69) “The creation of several dynamic zones of global economic integration, well distributed throughout the EU territory and comprising a network of internationally accessible metropolitan regions and their linked hinterland (towns, cities and rural areas of varying sizes), will play a key role in improving spatial balance in Europe” (ESDP, 1999, 20). However, it is admitted that “it is not possible to achieve the same degree of accessibility between all regions of the EU” (ESDP, 1999, 36).

This goal-setting reflects the assertion that improvements in accessibility have positive implications for regional (economic) development. Unfortunately, there is no unicausal and straightforward link between these two phenomena, and thus the question remains *a priori* open: upgrading a region’s accessibility provides actors in that particular region with improved possibilities to reach destinations outside, but at the same time, they also meet increasing competition from outside. The net effect on regional development remains an empirical issue.

Accessibility indicators can be used to analyse peripherality in several ways: regions can be classified into central and peripheral regions, impacts of different policy measures such as transport investments can be evaluated, or impacts of accessibility on regional development can be analysed.

All these issues have been discussed in the economic and geographic literature, but the existing empirical evidence does not provide a full coverage of the issues bearing relevance to the analysis of geographical position in the ESPON Study Programme.

A periphery can be defined as a region with low accessibility. However, this is far from being the whole story; peripherality is a contextual category loaded with numerous meanings, and in addition to accessibility, many other criteria are used to delineate centres and peripheries in regional research (see for instance Eskelinen and Snickars, 1995). Notwithstanding this qualification, accessibility is clearly a key criterion of geographical peripherality, and also of major importance in defining economic peripherality, as location (either as pure geographical position or in relation to transport networks) is indisputably a conditioning factor for the competitiveness of regions.

The ranking of regions in terms of accessibility depends on the indicator used (see Table 3.1). The choice of the mode of transport or of a combination of modes is a key issue in this context. In empirical terms, for example it is of interest to what extent accessibility to population by road of peripheral regions differs from their accessibility to population by air? Most analyses of accessibility have focused on differences between regions with high accessibility, and peripheries have remained an undifferentiated residual. There is a need to pay more attention to the internal differences and distinctive features of peripheral regions in empirical analyses.

Empirical comparisons of accessibility indicators support the intuitively obvious view that Euclidean distance to the geographical core of the EU does not suffice to explain interregional differences. The location of regions with respect to national centres and to the economic core region of Europe has had an impact on their roles in the interregional and international division of labour and on their network infrastructures. There is also a feedback here: existing infrastructures tend to maintain the different roles of regions. This suggests several research problems. In different peripheries of Europe different solutions to the problem of low accessibility have evolved or have been constructed by means of strategic policy initiatives mainly in a national context. For instance, Finland and Sweden have successfully coped with their peripherality by a raw-material based production structure, regional division of labour and regionally differentiated infrastructure capacity. In fact, the need to develop specific solutions might have contributed to the creation of competitive advantage in certain fields of infrastructure technologies, for instance in the area of ice-breakers and mobile communication networks.

In recent years the role of transnational policies has grown in importance in the EU. Changes in competitive conditions set new requirements for infrastructure capacity and accessibility. Competitive advantage is more than earlier based on man-made, not natural resources, which emphasises the significance of fast passenger transport and information transmission. Even if these challenges are a result of globalisation, the possibility to find solutions is also strongly influenced by local conditions, e.g., the possibility to strengthen the resources of a certain region or centre by improving accessibility in the local daily region.

In this situation, accessibility indicators are important for evaluations of different policy programmes, such as the trans-European networks. Other potential areas of evaluation studies include, for instance, the implications for accessibility of institutional changes in border regions. The results of the survey of accessibility indicators in this report can be used for dividing the regions of the EU into centres and peripheries (actually this division is a continuum), for comparing the divisions resulting from using different indicators and for evaluating the likely impacts of various policy measures on the differences in accessibility between central and peripheral regions.

5.2 Selection Criteria

Scientific policy analysis plays an important role in providing rational and accountable criteria for targeting spatial policies and allocating funds by developing, testing and applying indicators for the classification and assessment of areas (cities, regions or corridors) with respect to the achievement (or lack of achievement) of policy goals. The Potsdam document lists policy fields in which such information is required (ESDP, 1999, 18-19):

– "*Delimitation of areas eligible for financial support and determination of assistance rates.* These areas determine the interventions of spatial structural policies as well as the possibility of national financial aids with a regional purpose; such as, for example, the eligible areas under the regional fund.

– *Improvement of infrastructures.* Certain Community policies intervene by financing infrastructures which exert a direct impact on the territory. This is the case, for example, with the trans-European networks, in particular in the transport and energy sectors, both in their linear (e.g. motorways, high-voltage lines) and location-related infrastructure aspects (e.g. centres for freight transport, power stations).

– *Using spatial categories.* A number of Community policies make use of spatial categories, for example in the implementation of legal provisions in the field of environmental protection (…), in the allocation of specific aids (e.g. mountain regions, whose agriculture is also supported by a specific directive; and islands according to Article 130 a of the Amsterdam Treaty), or in the definition of certain items in the 5th Framework Programme for Research, Technology and Development.

– *Development of functional synergies.* Within the framework of some Community policies, spatial elements are taken into account to establish functional interdependencies and to emphasise synergies. (…) Regional policy attempts to promote regional innovation strategies in line with local needs (…).

– *Integrated spatial development approaches.* (…) A number of Community activities try to develop integrated and multisectoral approaches with a strong spatial dimension. This is true of the Community initiative on transnational co-operation in the field of spatial development (INTERREG II C) (…)."

In this context the research on indicators of geographical position has to be seen. The indicators to be developed should be suitable to support the rational discussion about the direction and volume of Community action and Community support in the light of the achievement of the Community objectives listed above. The indicators should be policy-relevant in the sense that they are suitable for

- differentiating areas (cities, regions and corridors) with respect to the achievement or non-achievement of the objectives,
- defining areas that are eligible to receive funding and promising with respect to achieving the stated goals and
- being used in ex-ante and ex-post evaluations and in models for explaining and forecasting the likely effects of policies under comparable conditions.

In addition, the indicators had to satisfy the following practical requirements:

- The indicators had to be available for NUTS-3 regions, or it had to be possible to calculate them from available NUTS-3 region data and available European network data.
- The indicators had to be scalar values, i.e. indicators consisting of a distribution of values were not considered.
- The indicators should be as simple and easy to explain and to reproduce as possible. Complex indicators should only be proposed where simple indicators are not sufficient.

These criteria were the basis for the selection of the following two sets of reference and specific indicators. Below, the two sets of indicators will be presented.

5.3 Reference Indicators

The first set of indicators consists of readily available and well established indicators for immediate use and practical illustration. The selected reference indicators are summarised in Table 5.1.

Geographical indicators

The most straightforward indicators of geographical position are geographical latitude and longitude. As latitude and longitude have only little meaning by themselves, they are combined here into one scalar indicator, Euclidean distance from the centre of gravity of population in the European Union.

Physical indicators

Elevation above sea level distinguishes between mountainous and flatland areas. The indicator proposed here is mean elevation averaged over the area. The length of seashores expressed as percent of the total perimeter of the area discriminates between coastal and landlocked areas. The climate of an area is indicated by mean annual sunshine.

Table 5.1
Reference indicators of geographical position

Indicator	Comments
Geographical latitude and longitude	Geographical latitude and longitude are combined into one scalar indicator, Euclidean distance from the centre of gravity of population in the European Union.
Mean elevation above sea level	Elevation above sea level distinguishes between mountainous and flatland areas.
Length of seashores	The length of seashores discriminates between coastal and landlocked areas.
Mean annual sunshine	The climate of an area is represented by mean annual sunshine radiation.
Major and secondary language	Linguistic identity is expressed by the major and the secondary language spoken in the area.
Accessibility by road to population	Accessibility by road to population is an indicator of the size of market potential for suppliers of goods and services.
Accessibility by rail to population	Accessibility by rail to population is an indicator of the size of market potential for suppliers of services.
Accessibility by air to GDP	Accessibility by air to GDP is an indicator of the size of market potential for suppliers of high-level business services.

Cultural Indicators

Cultural identity may be based on ethnicity, language, religion or specific traditions in economy, life style or the arts. Of all potential cultural indicators, language is selected as the most significant and clear-cut indicator. Linguistic identity is expressed by the major language spoken in the area, complemented by the second-important language in two-language regions, such a Cataluña or Pais Vasco.

Accessibility indicators

The selection of accessibility indicators is particularly difficult because of the vast number of indicators and methods of calculation proposed in the literature. Only the most common and most established accessibility indicators can be selected as reference indicators.

These most frequently applied and most extensively tested accessibility indicators are potential indicators. The potential of an area is the total of the destinations in other areas that can be reached from the area discounted by a negative function of the effort to reach them (see Chapter 3).

Three kinds of potential accessibility indicator are suggested. The first two measure accessibility to population, the last one accessibility to economic activity (expressed by gross domestic product, or GDP). Accessibility to population is an indicator for the size of market areas for suppliers of goods and services; accessibility to GDP an indicator of the size of market areas for suppliers of high-level business services.

5.4 Specific Indicators

The reference indicators of geographical position can be calculated quickly from readily available area and network data and can be expected to produce reliable and policy-relevant results for studying a broad range of policy questions. However, they do not do justice to the most advanced state of the art in geography and related disciplines with respect to the development of more sophisticated and more complex indicators, in particular accessibility indicators, addressing more specific research and policy issues. In this section therefore specific indicators are listed, which deserve further attention and examination with respect to their discriminatory or explanatory power or policy relevance.

The list of specific indicators presented in Table 5.2 is even more open than the list of reference indicators presented in Table 5.1, because future research and advanced possibilities of data organisation (in geographic information systems) and computation (with more powerful computers) will open up new approaches to measuring geographical position and because future policy issues are likely to require new and innovative answers.

All specific indicators are accessibility indicators. Therefore the list of indicators in Table 5.2 is organised by the dimensions of accessibility identified in Table 3.1.

Many of the indicators contained in Table 5.2 have been calculated, tested and mapped by research laboratories in EU member states (see Chapter 4) and can be re-calculated to allow a systematic comparison with the results of the reference indicators with respect to their advantages and disadvantages in terms of data requirements, ease of calculation, discriminatory and explanatory power and policy relevance.

Further possible refinements of the accessibility indicators indicated in Table 5.2 should be examined, such as accessibility indicators taking account of time table information and transfers in rail and air line networks, multi- and intermodality in both passenger and freight networks and political, economic and cultural barriers, or accessibility indicators for different types of actors and users. In all cases the added value of the increased complexity in terms of discriminatory power, explanatory power and policy relevance should be assessed. Yet, even this list is far from being complete. Other, not listed possible extensions of the methodology would address specific issues such as the structure of networks (levels, mesh size, saturation, bottlenecks), their vulnerability against natural hazards (floods, earth quakes) or human actions (strikes, demonstrations or sabotage), their dynamics, evolution and obsolescence, or temporal constraints such as congestion in holiday periods or at weekends, the impacts of social or environmental regulations or the psychological impacts of heavy goods vehicles on certain areas. Also multiscalar accessibility indicators, such as the cumulative distribution by distance of accessible destinations by Grasland (1999) should be explored.

In addition, innovative approaches to visualising geographical position should be further pursued. In this context, the three-dimensional methods of *chronocartes* developed by Mathis et al. (1999a), the accessibility reliefs developed by Schürmann et al. (1997) and anamorphose maps of time-space (time-space maps) developed by Cauvin (1994) and Spiekermann and Wegener (1994b) deserve particular attention.

Table 5.2
Specific indicators of geographical position

Dimension	Specific indicators
Origins	Accessibility from the point of view of different income groups Accessibility from the point of view of different economic sectors Accessibility from the point of view of tourists
Destinations	Accessibility to ‘soft’ location factors Accessibility to tourist attractions
Spatial impedance	Accessibility in terms of Euclidean distance Accessibility in terms of distance, travel cost or travel time Accessibility in terms of convenience, reliability or safety Accessibility with different network representations Accessibility by rail based on time table information Accessibility of destination beyond a certain size Accessibility of destinations up to a certain distance Accessibility with higher weights for large destinations
Constraints	Accessibility with and without certain links (e.g. tunnels) Accessibility by road taking account of road gradients Accessibility by road taking account of road congestion
Barriers	Accessibility taking account of border delays to non-EU countries Accessibility taking account of language and cultural barriers
Types of transport	Accessibility for goods transport by road and/or rail Accessibility for goods transport via ports and road/rail
Modes	Accessibility by road with and without motorways Accessibility by rail with and without high-speed rail Accessibility by inland waterways Multimodal accessibility (e.g. by fastest mode) Intermodal travel accessibility (e.g. rail-and-fly, fly-and-drive) Intermodal goods transport accessibility (logistic chains) Absolute/relative accessibility differences between (sub-)modes
Spatial scale	Accessibility of NUTS-4 or NUTS-5 regions Accessibility of major (all) cities Accessibility of raster cells Accessibility to all cities of a country Mean accessibility to all cities by country Mean travel speed by city or country Accessibility from a country to the rest of Europe Accessibility within a corridor or group of cities Accessibility taking account of intraregional access
Equity	Comparisons of accessibility of rich and poor regions Comparisons of accessibility of central and peripheral regions Comparisons of accessibility of urban and rural regions Comparisons of accessibility of nodal and interstitial regions Comparison of accessibility of peripheral regions
Dynamics	Comparisons between accessibility indicators over time Analysis of convergence/divergence of accessibility over time

6 Presentation of Indicators

Space restrictions permit to illustrate only the proposed reference indicators of geographical position. Examples of some of the specific indicators are presented in Part 2 of the report (Mathis, 2000).

6.1 Reference Indicators

The eight proposed reference indicators of geographical position are represented in eight maps each showing one indicator for NUTS-3 regions.

- *Euclidean distance to the centre of gravity of population*. Figure 6.1 (page 50) presents an interpretation of geographical indicators. They are used here to calculate Euclidean distances between points. The points are the centroids of the NUTS-3 regions, i.e. idealised locations representative of the spatial distribution of population and economic activities in the regions. In the example the centroids are the central points of the most important cities in the regions. Euclidean distance to the centre of gravity of the population of the EU is the simplest way to show peripherality. It can be seen that the centre of gravity of population of the EU is near the city of Reims in eastern France.
- *Mean elevation above sea level*. Figure 6.2 (page 51) shows mean elevation above sea level of NUTS-3 regions in m. The distinction between the flatlands in north-west Europe, the areas of medium height on the Iberian peninsula, the north of Sweden, the south-east of France, central Italy and Greece and the Alpine areas in France, Italy and Austria are clearly distinguished.
- *Length of seashores*. Figure 6.3 (page 52) shows the length of seashores expressed as percent of the total perimeter of the NUTS-3 regions. Spatial resolution affects this indicator, i.e. at a high resolution a rocky coastline with many inlets and projections results in a higher percentage than at a lower resolution.
- *Mean annual sunshine*. Figure 6.4 (page 53) shows the climate indicator expressed in terms of mean annual sunshine radiation in kWh/m^2 taken from a map in Palz and Greif (1995).
- *Major and secondary language*. Figure 6.5 (page 54) groups regions by major and secondary language. The division of Europe in countries or regions with mainly Romanic and Germanic languages is clearly expressed, as well as the linguistic isolation of Finland and Greece.
- *Accessibility*. Figures 6.6 to 6.8 show accessibility indicators by road (Figure 6.6, page 55), rail (Figure 6.7, page 56) and air (Figure 6.8, page 57). All indicators are of the potential type. The indicators were calculated for the centroids, i.e. the locations of the major cities in the NUTS-3 regions. Population and GDP of the destination regions were disaggregated to 10x10-km raster cells (see Schürmann et al., 1997). Barrier effects are considered in the form of average waiting times at borders outside and to and from the EU. The maps of population potential by road (Figure 6.6) and rail (Figure 6.7) are similar, with the areas of highest accessibility concentrated in the Benelux countries and western Germany, though rail accessibility is somewhat more peaked around major rail stations. Because of the consideration of waiting times at external borders, they are more similar to the population potential in terms of Euclidean distance calculated by Grasland for the EU only (cf. Figure 4.3, top) than to the potential calculated by Grasland for the whole of Europe without border delays (cf. Figure 4.3, bottom). The economic potential by air (Figure 6.8) is strongly concentrated around airports, yet as these are dispersed across the continent, the airplane links even peripheral regions to the European core.

The indicator values calculated for the 1,020 NUTS-3 regions can be downloaded for further analysis from http://www.nordregio.se/spespn/spesp101.htm. Some preliminary analyses are presented in Section 6.2.

Figure 6.1
Euclidean distance to the centre of gravity of population in Europe in km

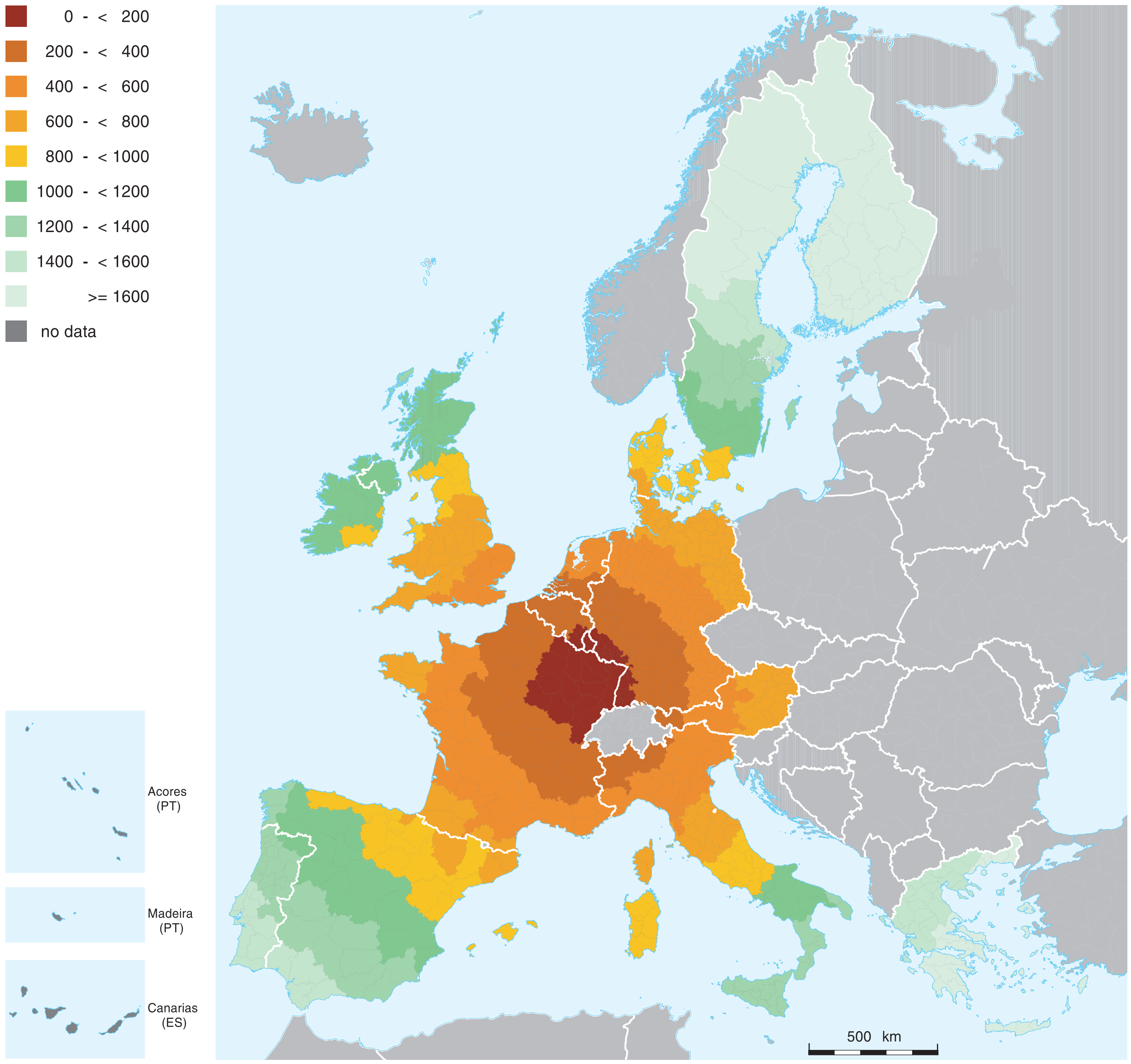


Figure 6.2
Mean elevation above sea level in m

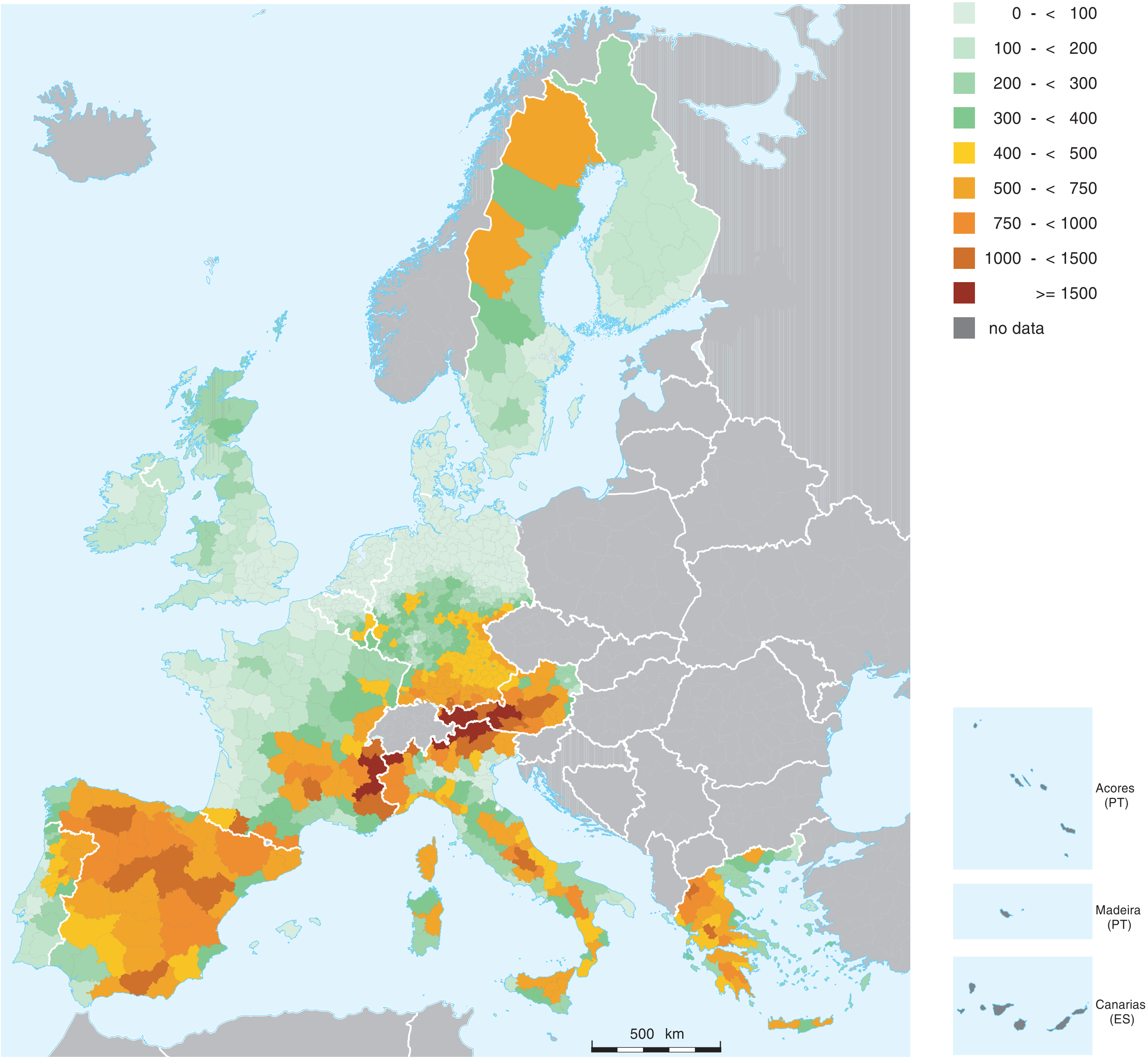


Figure 6.3
Length of seashores in % of region perimeter

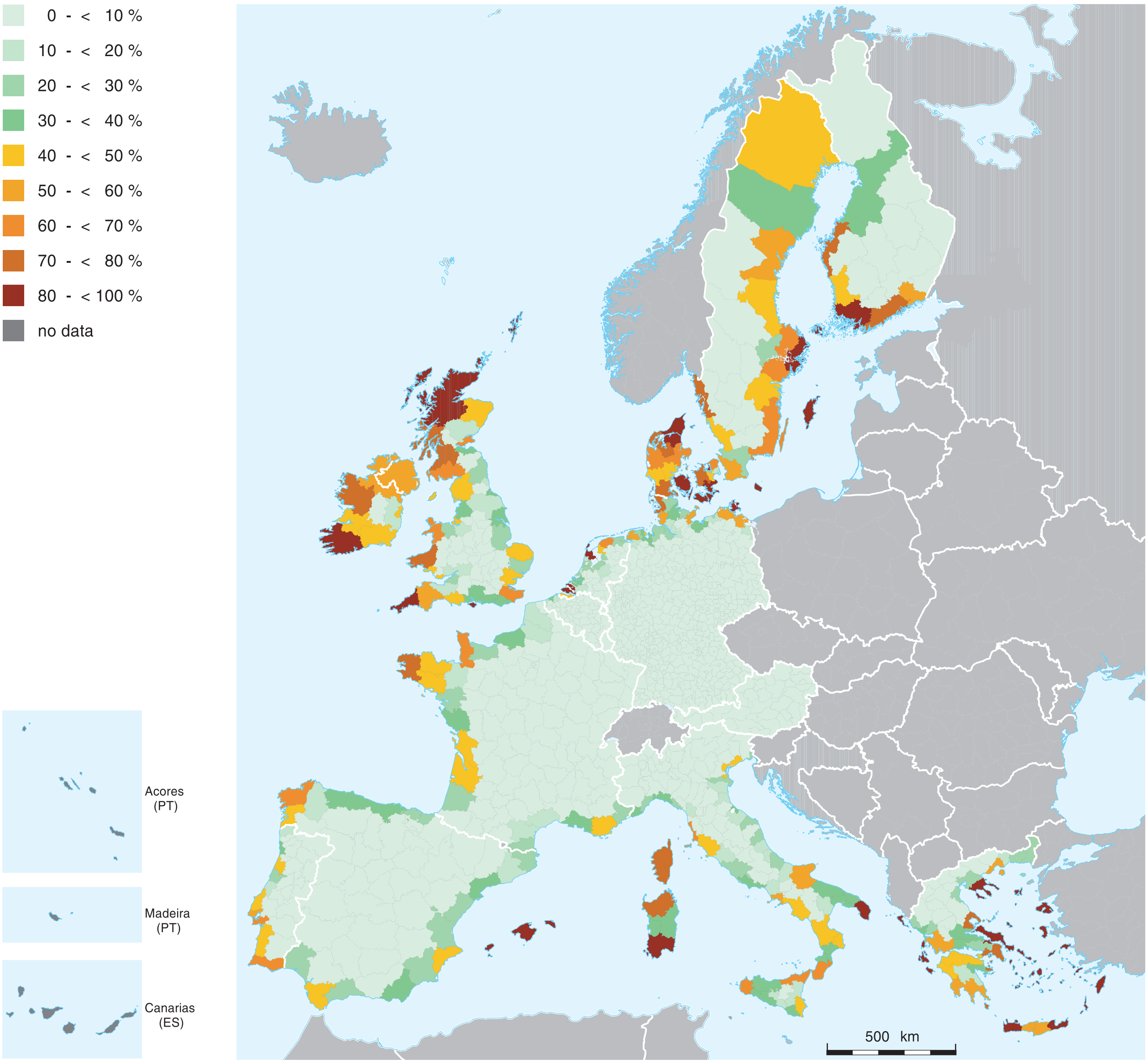


Figure 6.4
Mean annual sunshine radiation in kWh/m^2 (after Palz and Greif, 1995)

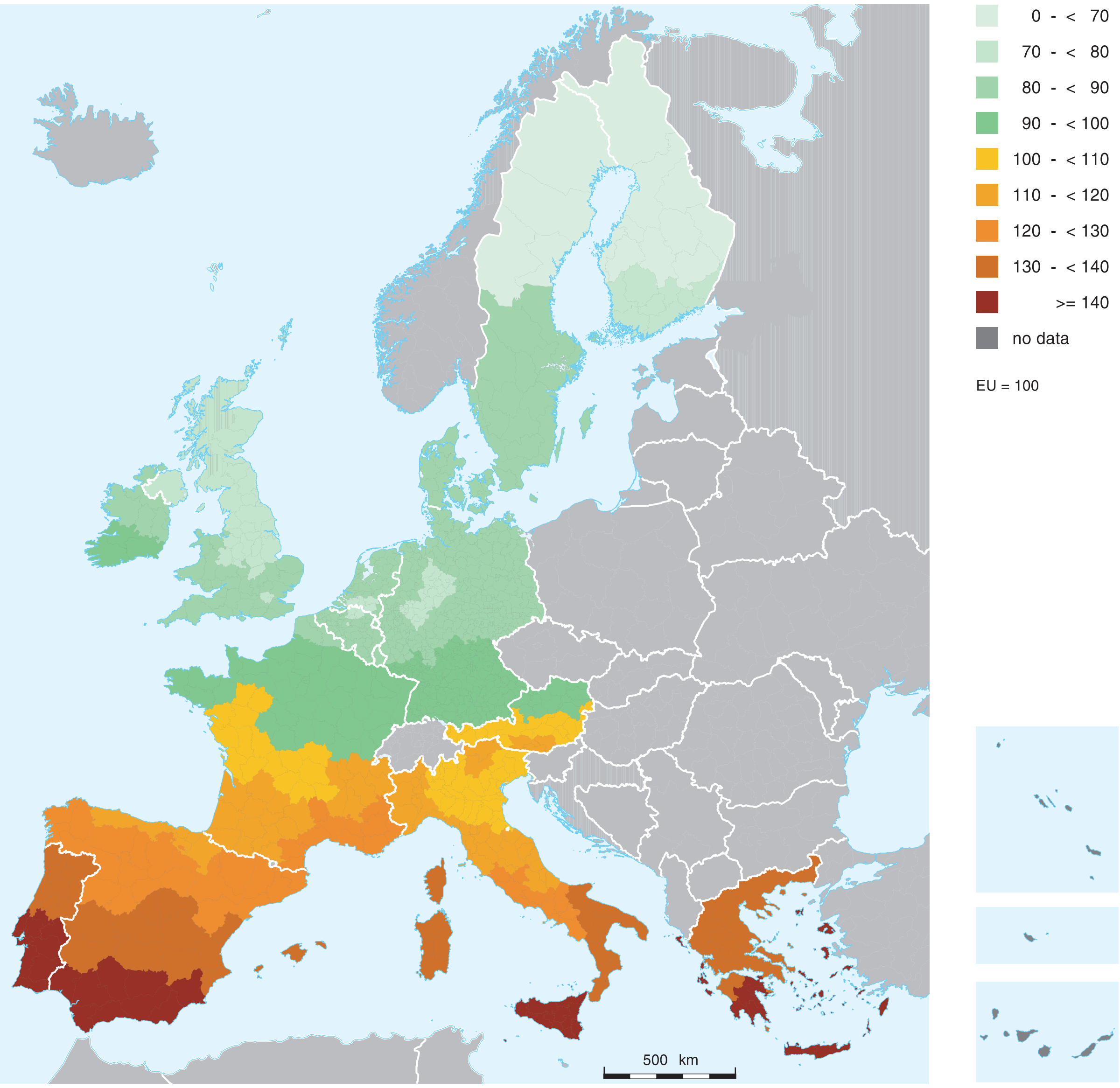


Figure 6.5
Major and secondary language

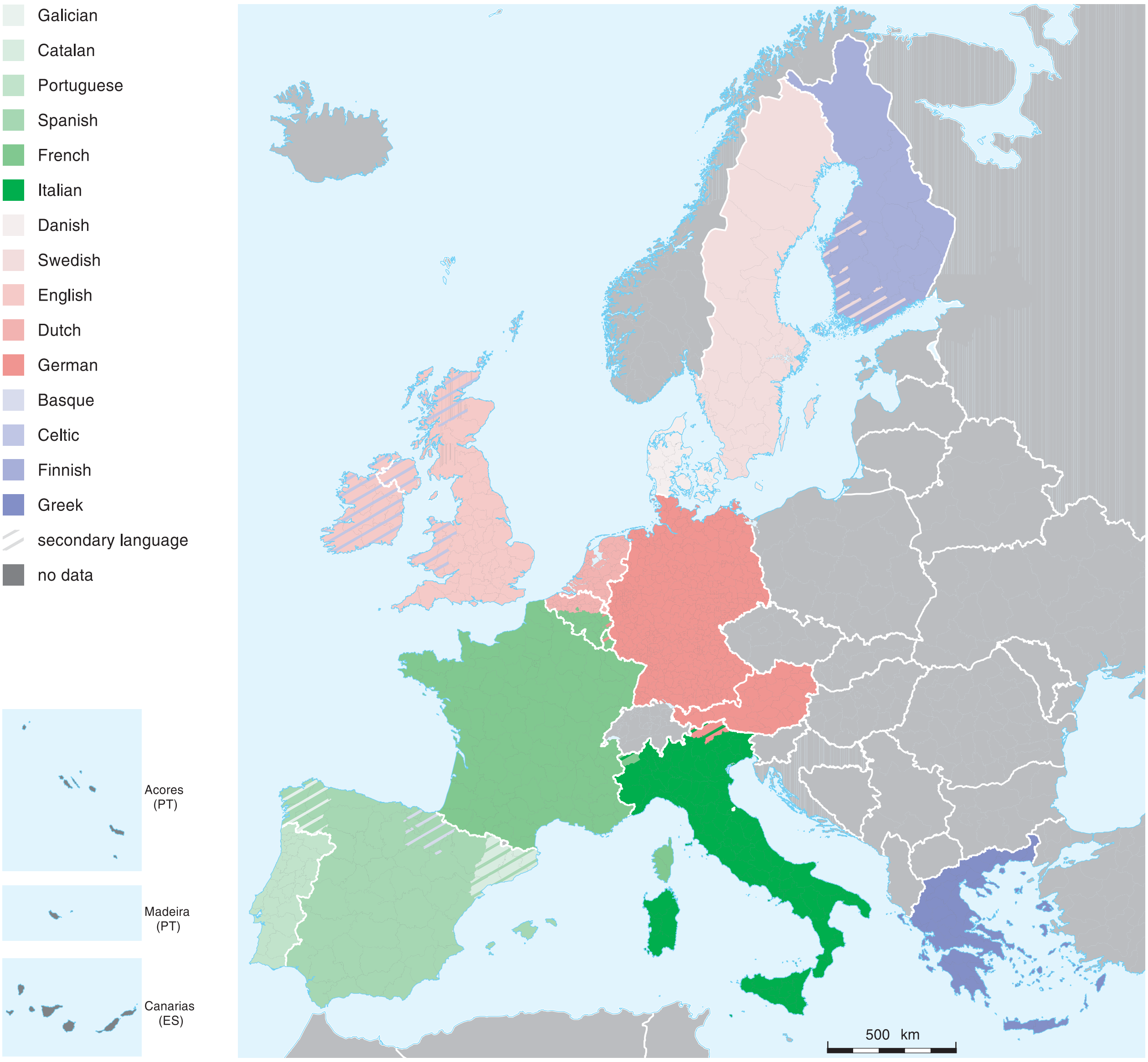


Figure 6.6
Population potential (Accessibility by road to population in 1996)

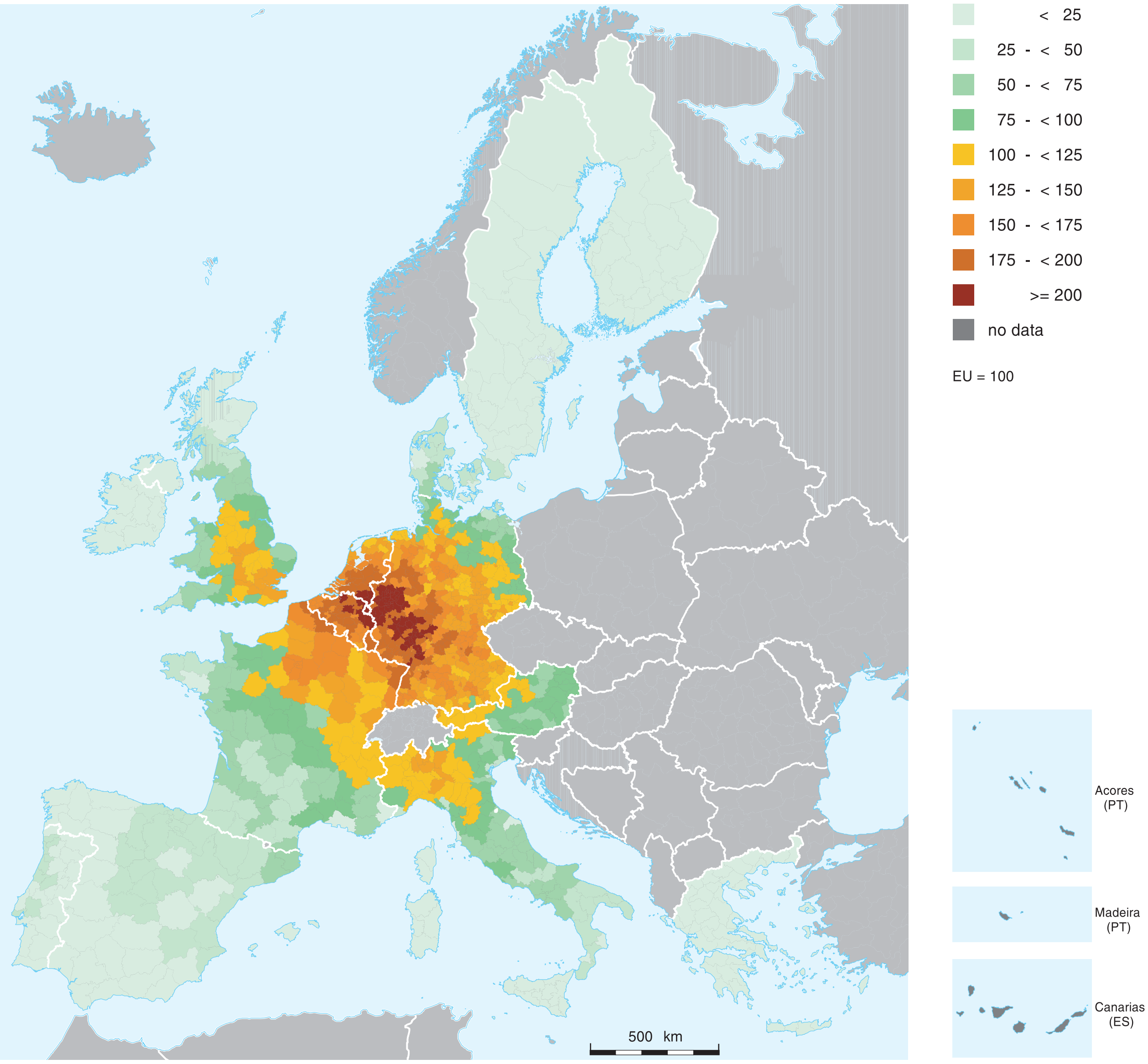


Figure 6.7
Population potential (Accessibility by rail to population 1996)

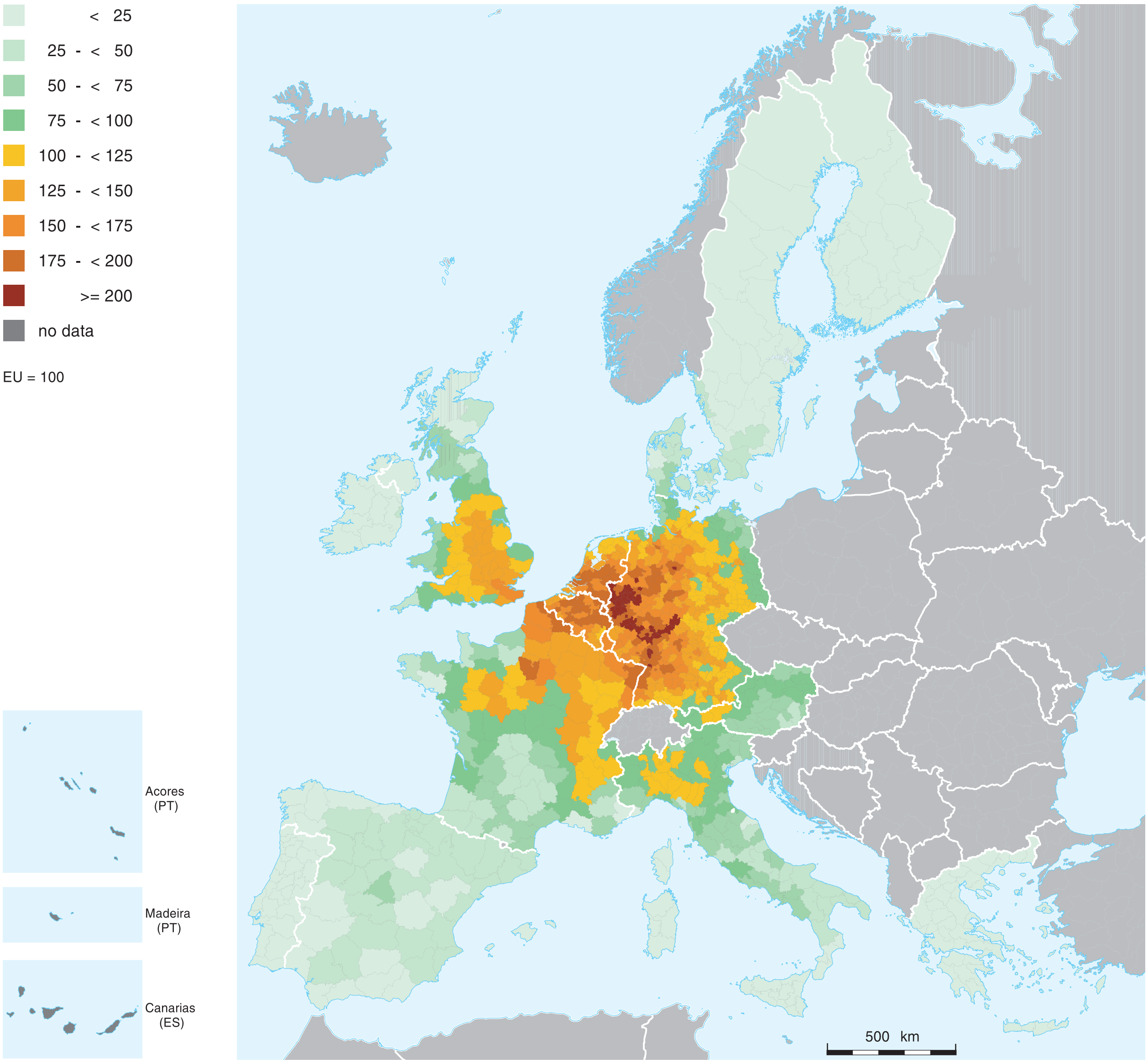
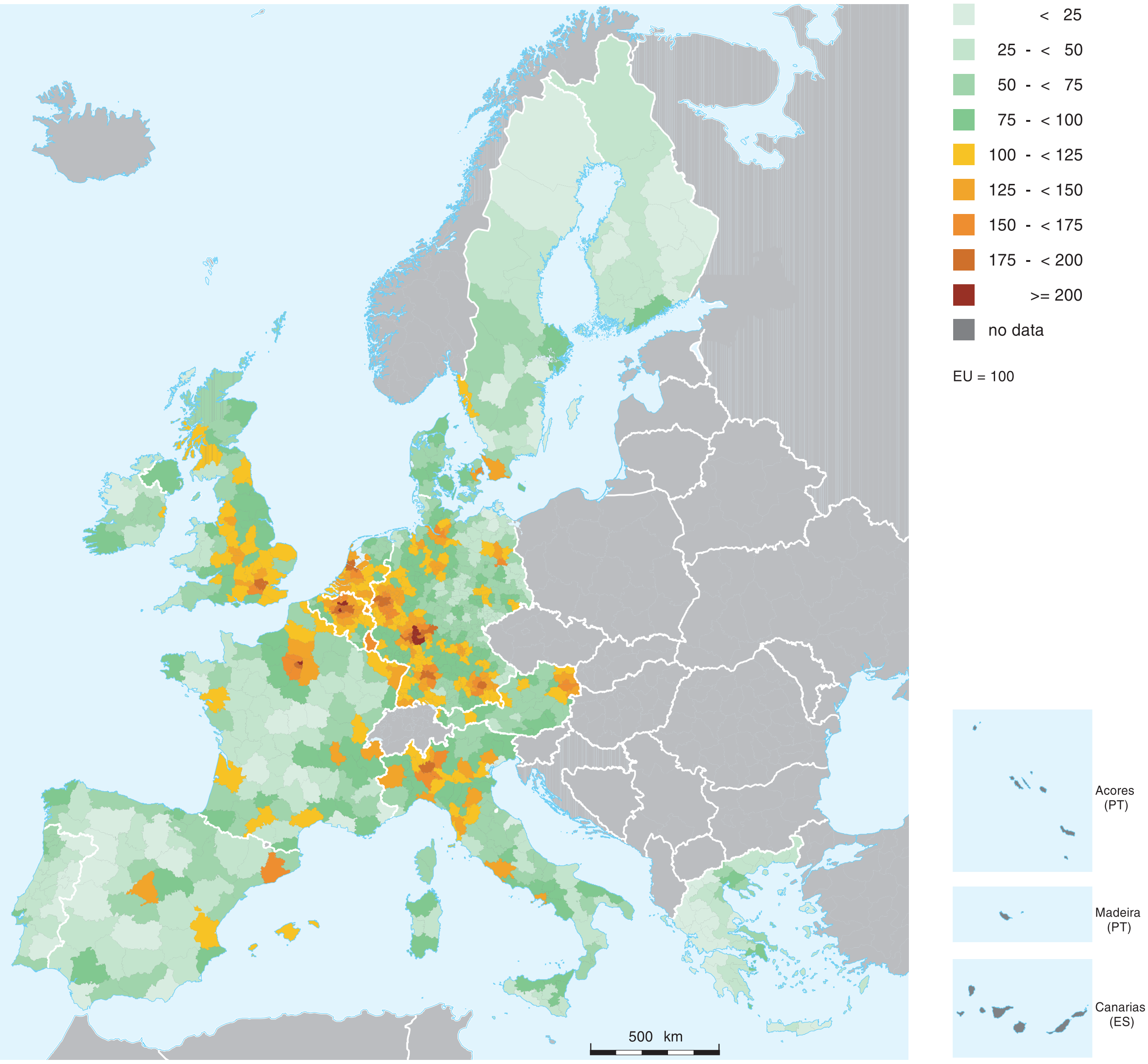


Figure 6.8
Economic potential (Accessibility by air to GDP in 1996)



6.2 Analysis of Reference Indicators

After presenting the eight reference indicators of geographical position, first results of an experimental analysis of distributional issues arising from them will be presented. This analysis does not exhaust the full range of possibilities to analyse these indicators. In addition it must be remembered that geographical position is only one of seven groups of indicators studied in ESPON. A more comprehensive analysis taking account of all seven sets of indicators is presented in Weber et al. (1999).

The units of analysis are the 1,020 NUTS-3 regions of the European Union without the French overseas regions and the Spanish and Portuguese islands in the Atlantic. Two kinds of analyses were performed. First, the three accessibility indicators were analysed with respect to the cohesion indicators discussed in Section 3.6. Second, a simple cluster analysis using different subsets of the reference indicators was performed.

6.2.1 Cohesion Analysis

The analysis of cohesion was restricted to the three accessibility indicators because they are the only indicators of geographical position for which future values that differ from the present values can be calculated because they are the only ones that can be changed by policy.

The analysis was performed with road, rail and air potential accessibility of the 1,020 NUTS-3 regions between 1981 and 2016. The 1996 values are the indicator values presented in Figures 6.6 to 6.8. The accessibility values for other years were calculated using road and rail networks generated for 1981, 1986, 1991, 2001, 2006, 2011 and 2016 and the airline network of 1996 in the EU 4th RTD Framework SASI project (Fürst et al., 1999). Historical network states were compiled from various sources. Future network states were forecast according to the TEN Outline Plan (European Commission, 1998). For accessibility by air no backcasting or forecasting was possible because of lack of data. For all years NUTS-3 population (in the case of road and rail) and GDP (in the case of air) of 1996 were used as destination weights. Between the above years, accessibility values were linearly interpolated.

Figure 6.9 shows the development of the coefficient of variation of accessibility of NUTS-3 regions between 1981 and 2016. For accessibility by air only the 1996 value is shown. It is clearly apparent that using this indicator accessibility by road and rail become less polarised. This is to be expected because, as it was argued in Section 3.6, the coefficient of variation considers *relative* rather than *absolute* change. It can also be seen that accessibility by rail seems to be slightly more evenly distributed than accessibility by road, whereas accessibility by air is much more spatially homogenous than by the two surface modes.

Figure 6.9
Coefficient of variation of accessibility of NUTS-3 regions, 1981–2016

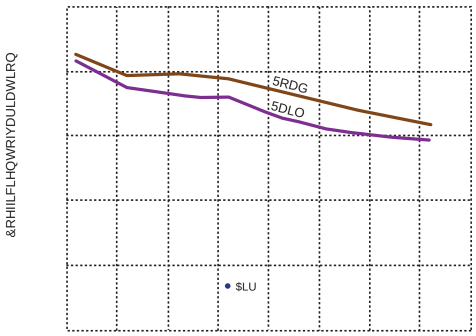
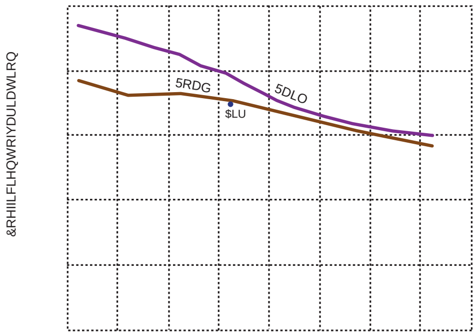


Figure 6.10 shows what happens when the NUTS-3 regions are weighted by their population (or GDP in the case of air). Now accessibility by rail is more polarised because larger urban areas are better connected to rail than smaller cities, whereas road accessibility is more evenly distributed. Accessibility by air is much more polarised, which can be explained by the fact that only the largest agglomerations

Figure 6.10
Coefficient of variation of accessibility of NUTS-3 regions weighted by population, 1981–2016



have good air connections. Despite of this shift, the overwhelming trend is spatial convergence.

The same data were also analysed with the Gini coefficient and presented in the form of Lorenz curves. As explained in Section 3.6, the Lorenz curve compares a rank-ordered cumulative distribution of area values with a distribution in which all areas have the same indicator values. This is done graphically by sorting areas by increasing indicator value and drawing their cumulative distribution against a cumulative equal distribution (an upward sloping line). The Gini coefficient calculates the ratio between that area and the triangle under the upward sloping line of the equal distribution.

Figure 6.11 compares four pairs of distributions. The two Lorenz curves at the top compare accessibility by road and by rail (left) and accessibility by road and by air (right) in 1996. The two curves at the bottom compare accessibility by road in 1996 and 2016 (left) and accessibility by rail in 1996 and 2016 (right). The numbers attached to the curves are the associated Gini coefficients (in percent). It can be seen that the Gini indicator reveals only small differences between the distributions, only accessibility by air is significantly more evenly distributed than accessibility by road (as in Figure 6.9). Over time there is convergence of accessibility.

Figure 6.12 shows the same comparisons with the NUTS-3 regions weighted by population (or GDP in the case of air). Not surprisingly, the spatial disparities increase substantially (i.e. the area under the diagonal becomes larger) because the larger urban areas are also the more accessible. However, over time the differences between the accessibilities become smaller, though only slightly.

These results are disappointing in the light of the massive investment in transport infrastructure assumed in the analysis. The reason for the little response of the two indicators is, as has been argued already in Section 3.6, that the two indicators measure *relative* rather than *absolute* differences between distributions.

In summary it can be said that the most frequently used indicators of spatial cohesion, the coefficient of variation and the Gini coefficient, are insensitive to overall improvements of accessibility and, are biased towards convergence.

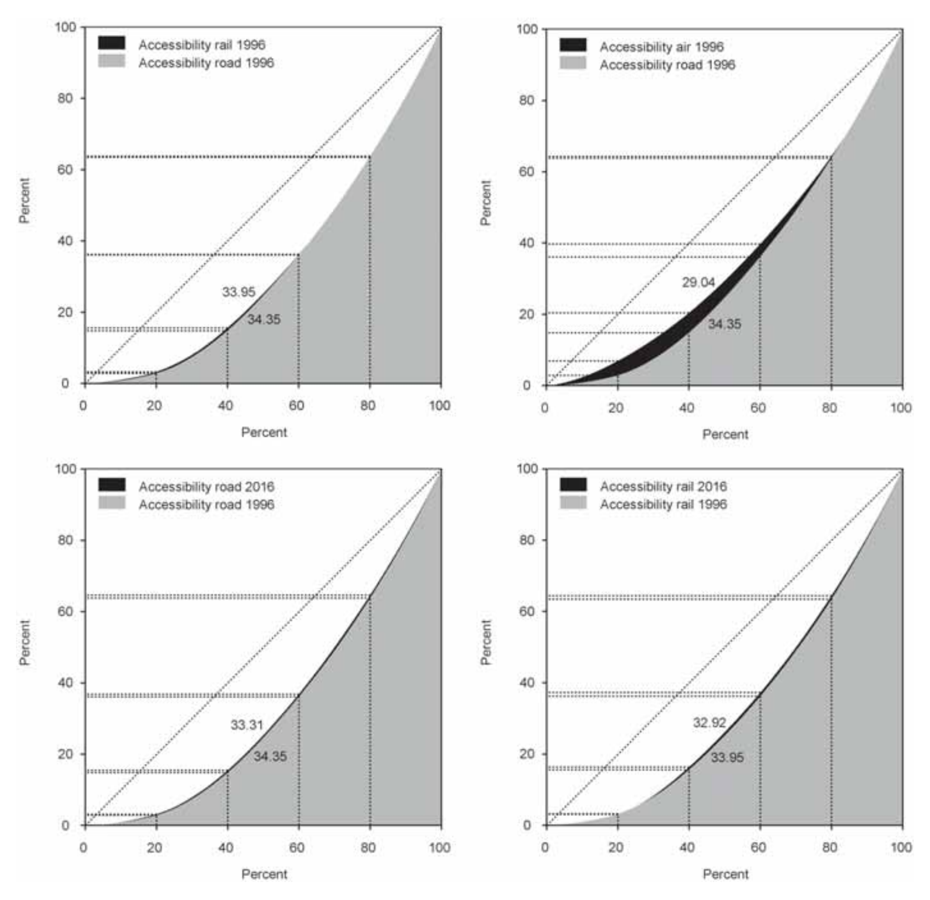
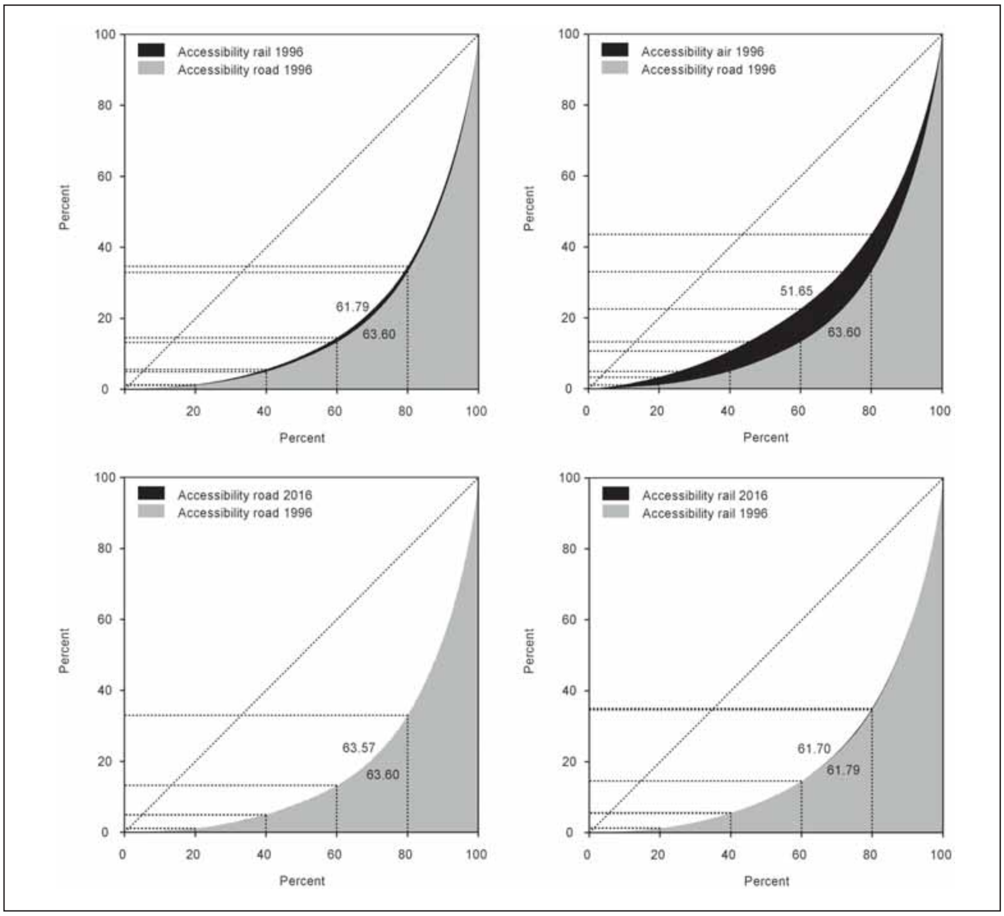


Figure 6.11
Lorenz curves of accessibility of NUTS-3 regions, 1981–2016

Figure 6.12
Lorenz curves of accessibility of weighted NUTS-3 regions, 1981–2016



A more realistic picture emerges if not relative but absolute differences are compared. The maps in Figures 6.13 and 6.14 (pages 61 and 62) compare accessibility by road and by rail in 1996 and 2016, respectively. It can be seen that in 1996 in most parts of Europe accessibility by rail was significantly lower than accessibility by road. However, in 2016, the situation has almost reversed except in Portugal, Greece and Sicily. Now, because of the planned substantial investment in TEN rail infrastructure, in most regions accessibility by rail is superior to accessibility by road. As Figures 6.9 to 6.12 have shown, neither the coefficient of variation nor the Gini coefficient was able to express these massive changes.

The importance of distinguishing between absolute and relative differences becomes even more obvious if the cohesion effects of trans-European transport investments over time are analysed. Figures 6.15 and 6.16 (pages 63 and 64) show the absolute changes of accessibility of NUTS-3 regions by road and by rail, respectively, between 1996 and 2016. In absolute terms, the already highly accessible central regions gain most, i.e. the gap in accessibility between the central and peripheral regions becomes larger – and not smaller as Figures 6.9 to 6.12 suggest.

In contrast to this, the maps in Figures 6.17 and 6.18 (pages 65 and 66) show relative changes in accessibility. The result is virtually reversed: now the peripheral regions seem to gain! However, it must be kept in mind that these gains are in relation to their very small starting values and are many times overshadowed by the much larger gains of the central regions.

The conclusion from these comparisons is that extreme care needs to be taken with respect to the accessibility indicator used and the cohesion indicator applied before meaningful and reliable assessment about the cohesion effects of transport infrastructure investments can be made. The examples suggest that any attempt to compress the distributional effects of spatial policies into one single indicator value is fraught with difficulties. Reasonably designed maps showing the spatial distribution of absolute differences between two distributions, however, seem to offer meaningful and reliable information about spatial convergence and spatial divergence.

Figure 6.13
Rail accessibility in 1996 in % of road accessibility in 1996

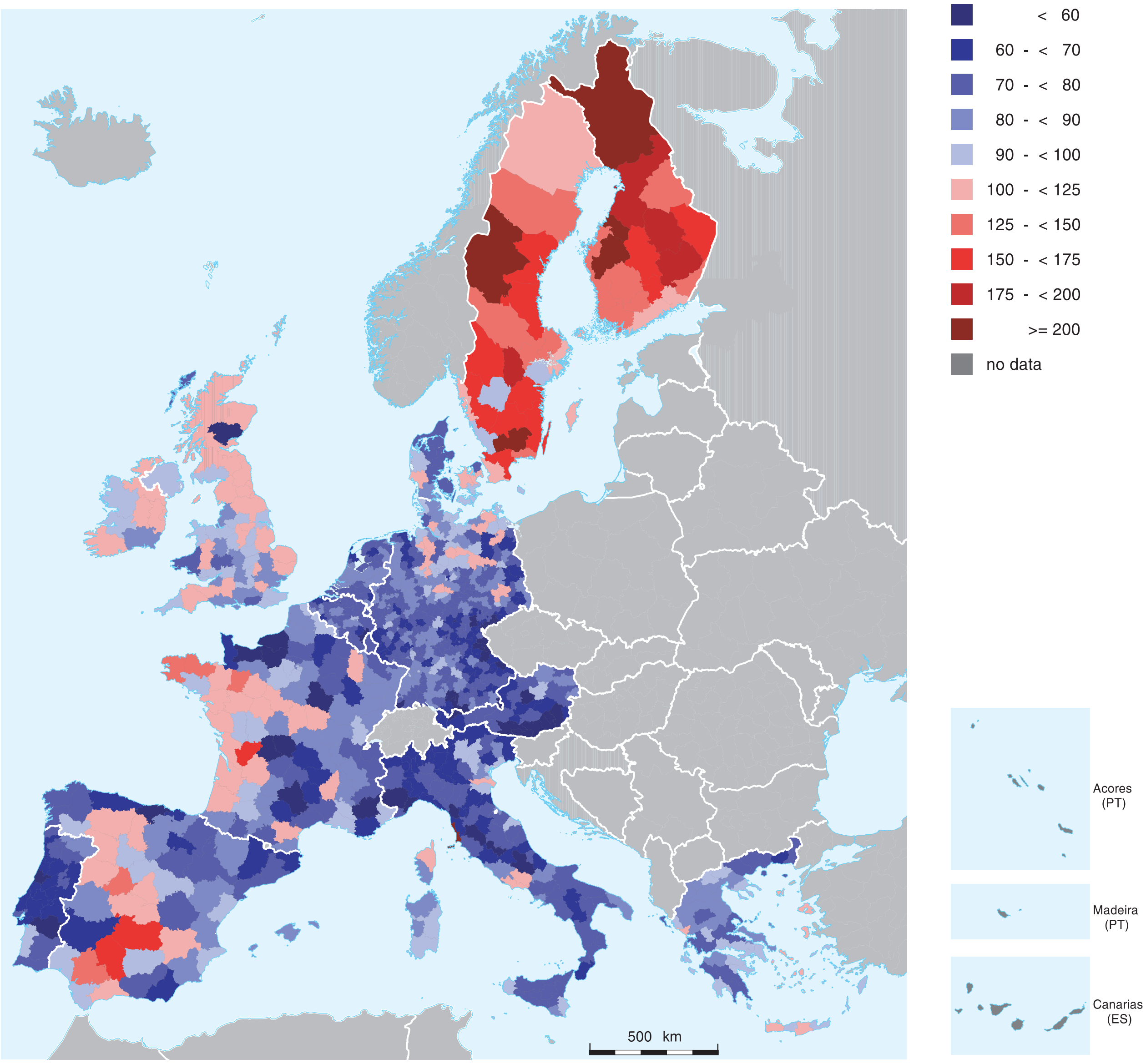


Figure 6.14

Rail accessibility in 2016 in % of road accessibility in 2016

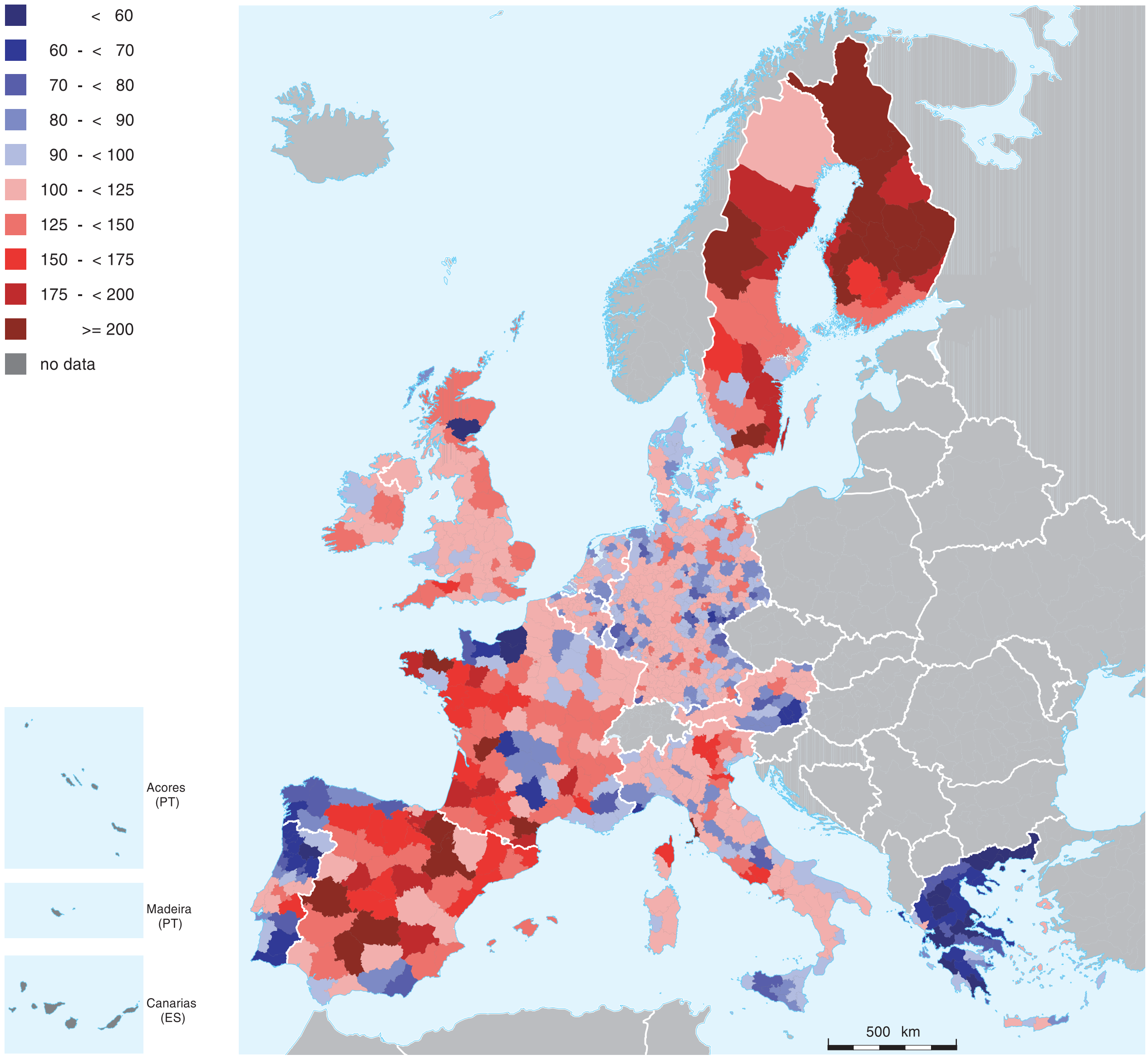


Figure 6.15
Road accessibility 1996–2016: absolute change in %

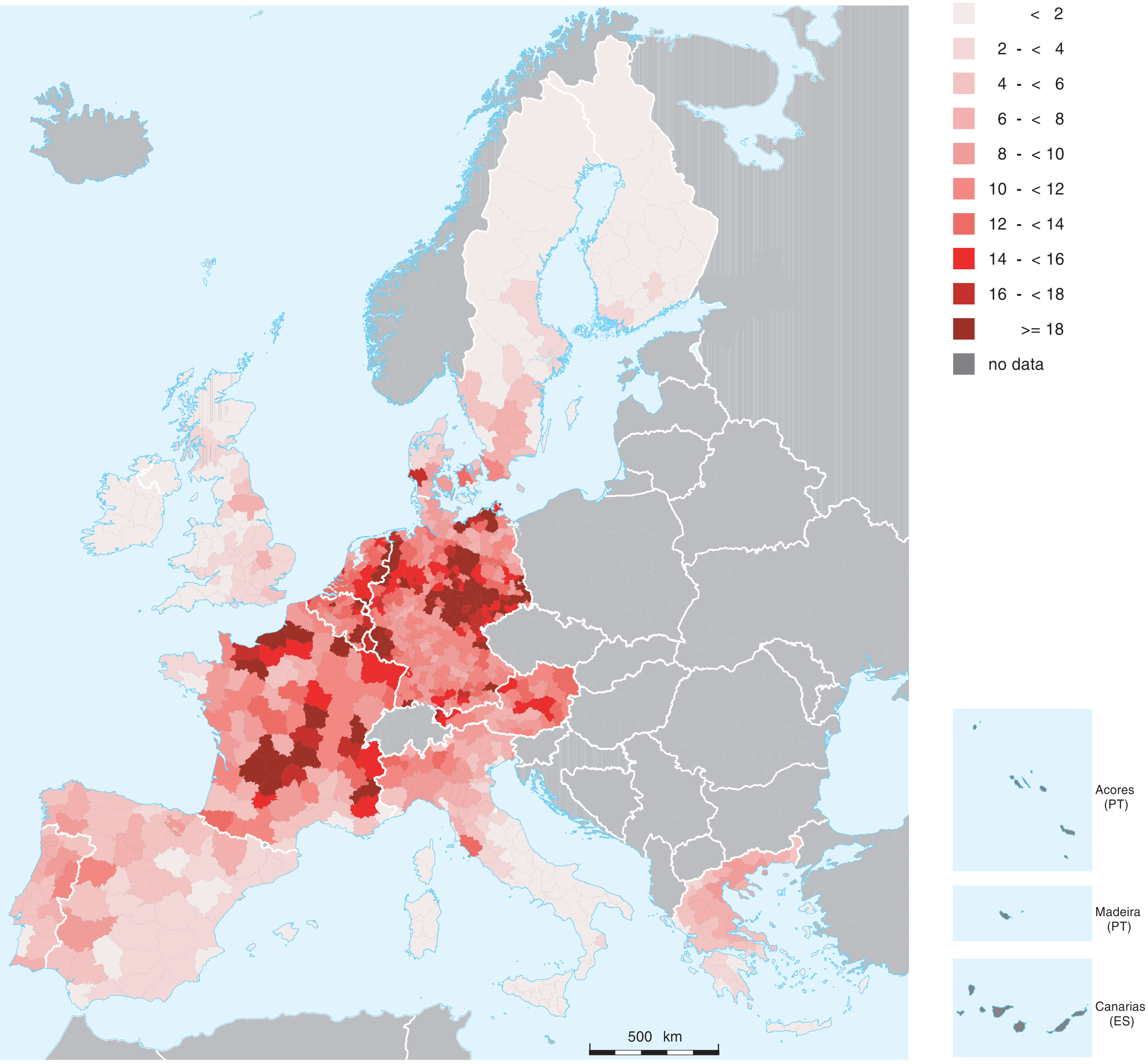


Figure 6.16
Rail accessibility 1996–2016: absolute change in %

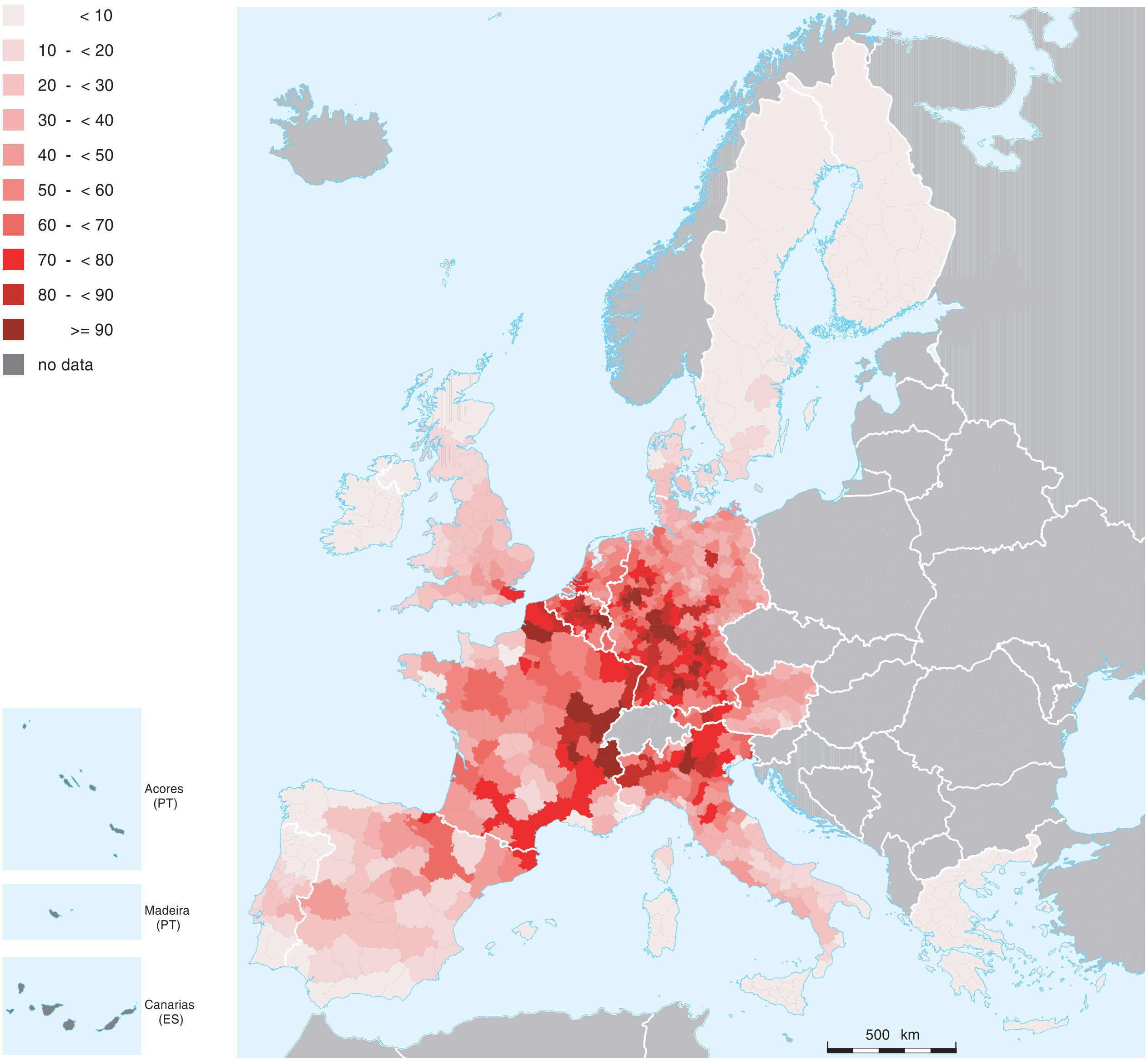


Figure 6.17
Road accessibility 1996–2016: relative change in %

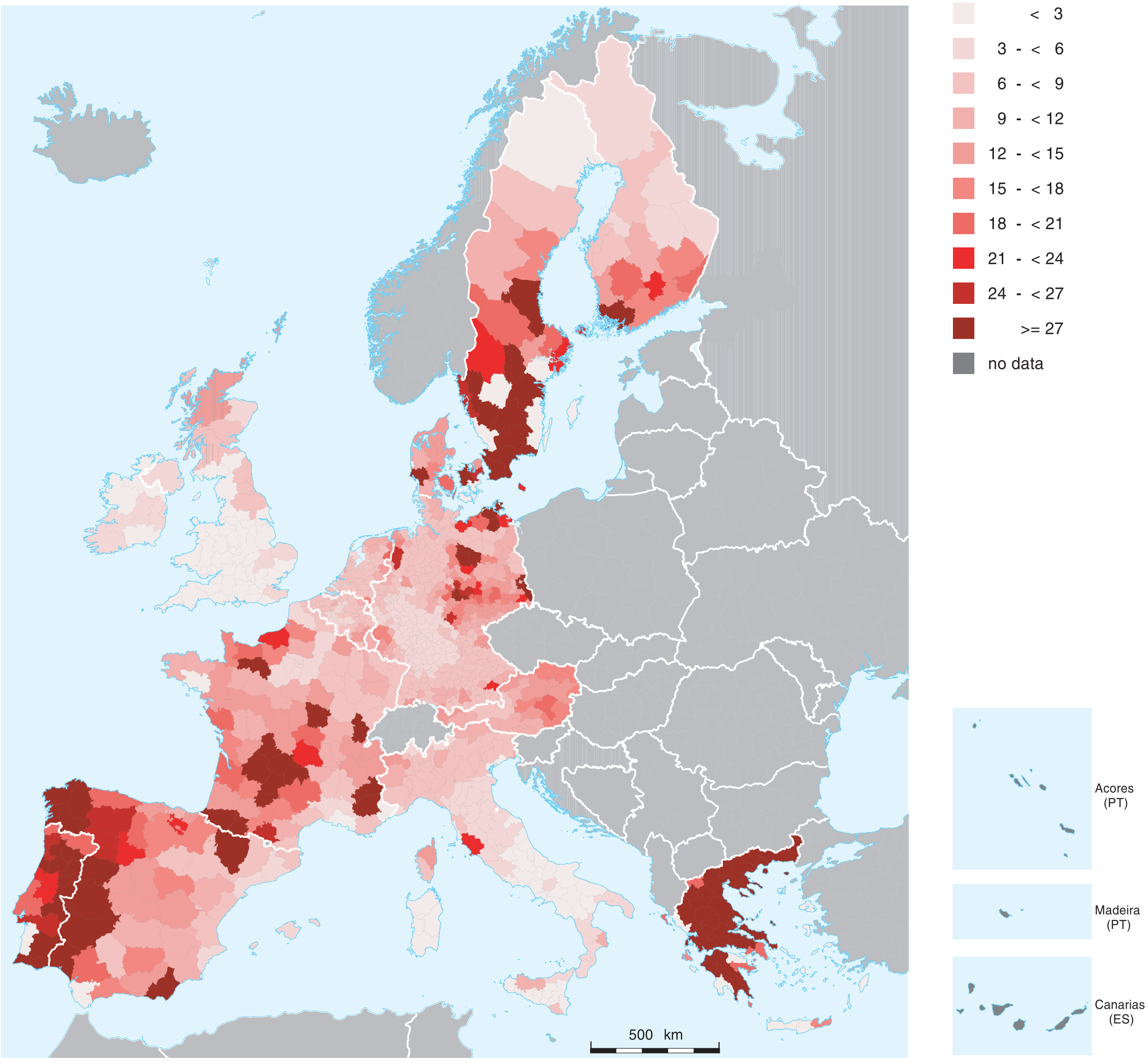
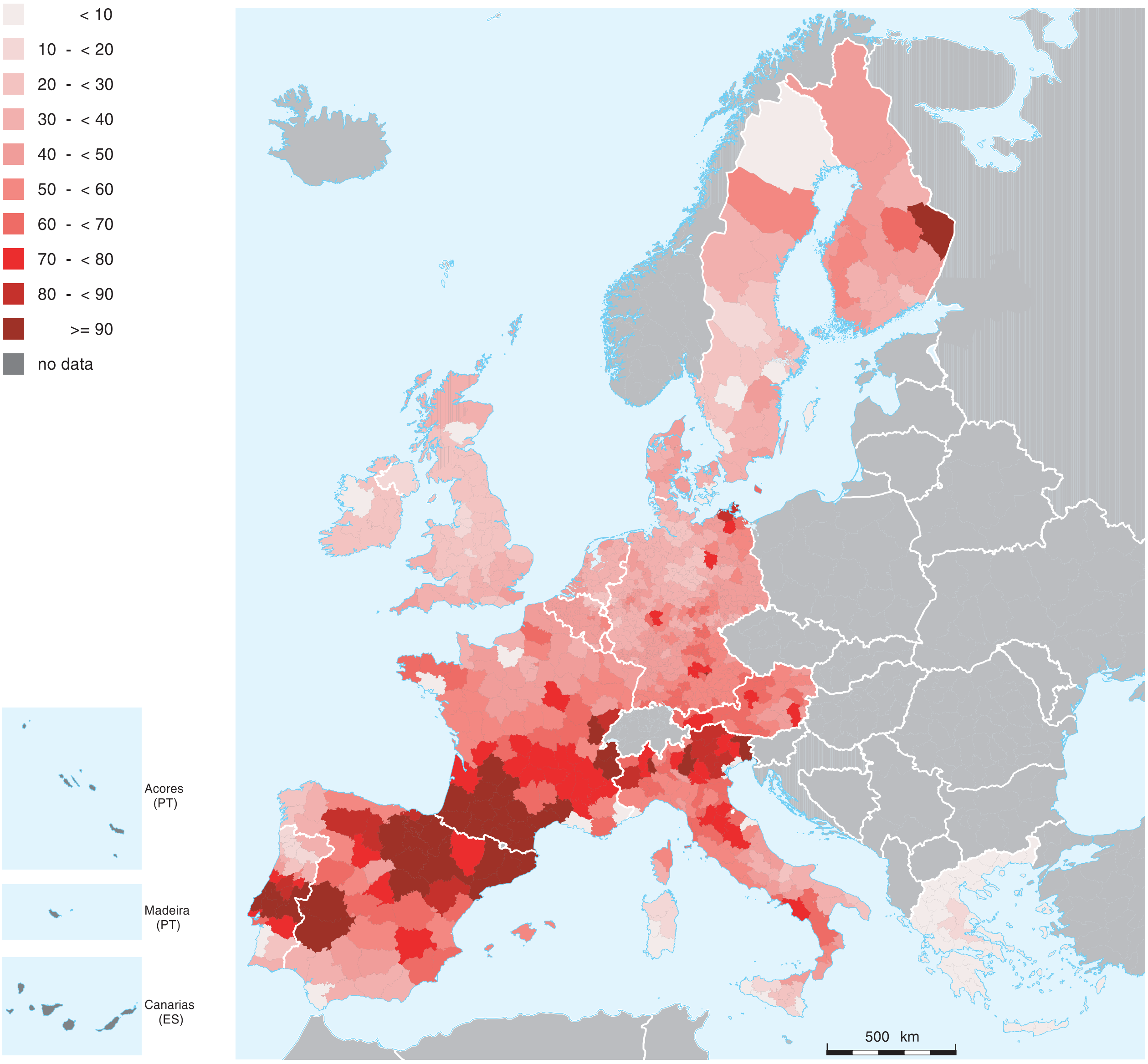


Figure 6.18
Rail accessibility 1996–2016: relative change in %



6.2.2 Cluster Analysis

In a final experiment, a cluster analysis of the 1,020 NUTS-3 regions with the reference indicators was performed. This exercise is complementary to the more comprehensive cluster analysis for NUTS-2 regions by Weber et al. (1999) using indicators of all seven working groups. It was thought to be of interest to find out whether a cluster analysis using only indicators of geographical position would generate meaningful clusters of regions comparable to those identified in Weber et al. (1999) with a more comprehensive set of data. In addition it was considered worthwhile to see whether the higher spatial resolution of NUTS-3 regions yields comparable results to those achieved with NUTS-2 region data. A third research question was whether meaningful clusters could be obtained *without* making use of the "genuine" geographical indicators, geographical latitude and longitude.

The maps in Figures 6.19 to 6.21 (pages 68 to 70) show the results. In all three cases cluster separation using Ward's method was applied. For the first map (Figure 6.19) only the three physical indicators "mean elevation above sea level", "length of seashore in percent of region perimeter" and "mean annual sunshine radiation" were used. The map clearly shows four clusters: northern and southern landlocked areas (Clusters 1 and 2) and northern and southern coastal regions (Clusters 3 and 4).

The second clustering experiment used only the three accessibility indicators. A more complex picture emerges in Figure 6.20. Clearly the high-accessibility areas in north-western Europe reproducing the "Blue Banana" between the south of England and northern Italy (Cluster 5) become visible. Within the "Banana" regions with important international airports form a cluster of their own (Cluster 4), regions with secondary airports are in another cluster (Cluster 2). The regions in Cluster 1 and Cluster 3 have medium accessibility, whereas Cluster 6 contains the most peripheral regions.

In the last cluster analysis all reference indicators except geographical latitude and longitude and language were used. Figure 6.21 shows a complex but easy to interpret pattern of clusters. Cluster 5 contains the most accessible regions in north-west Germany, the Benelux countries, northern France (including Paris) and south-west England. Cluster 2 contains southern Germany, the west of France and northern Italy. Cluster 3 is a clear expression of the Alpine regions. Cluster 6 contains northern coastal regions, whereas Cluster 7 consists of regions in the southern periphery with hot climate and low accessibility. Clusters 1 and 4 contain the remaining regions.

The experience made with the tool of cluster analysis is ambiguous. On the one hand, the method, in the best case, is able to generate meaningful and sometimes revealing groups of regions, which stimulate thinking about similarities and complementarities between regions. On the other hand, the method is very volatile and responds strongly and sometimes unexpectedly to only small changes in the selection of input variables, the aggregation and separation methods chosen and the number of clusters specified.

Figure 6.19
Cluster analysis: physical indicators

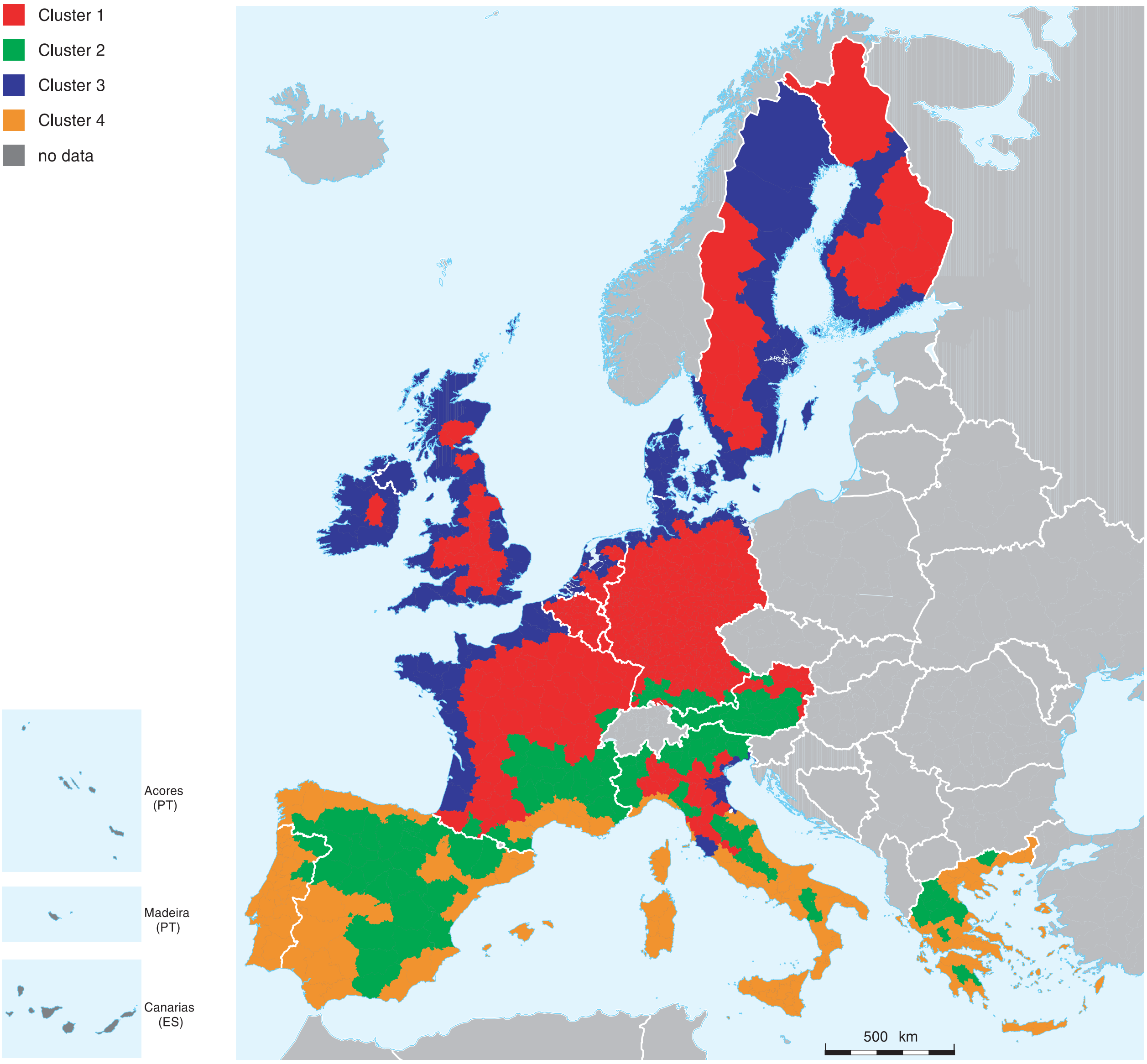


Figure 6.20
Cluster analysis: accessibility indicators

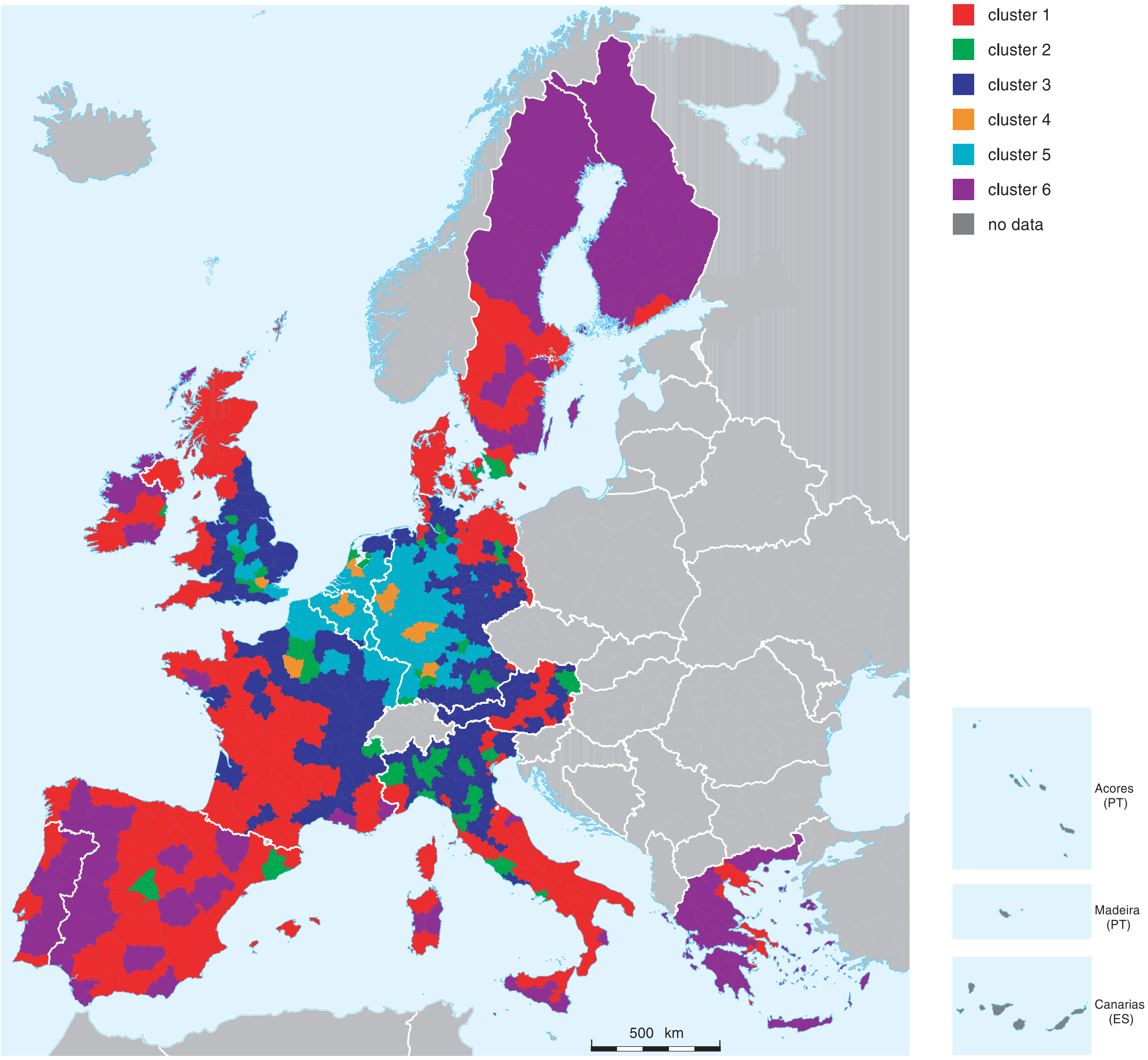
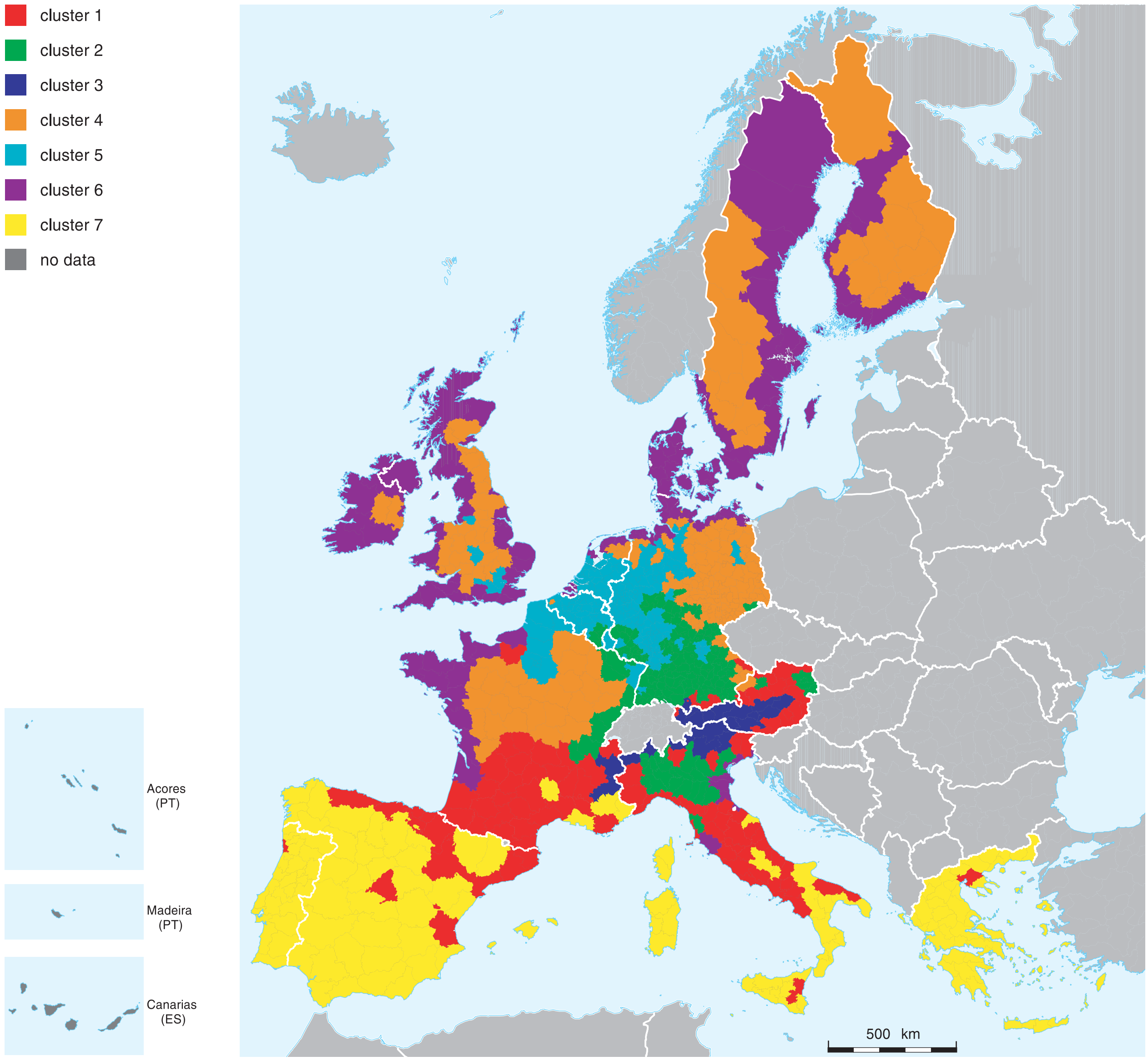


Figure 6.21
Cluster analysis: physical and accessibility indicators



7 Results and Policy Relevance

Article 2 of the Maastricht Treaty states as the goals of the European Union the promotion of harmonious and balanced economic development, stable, non-inflationary and sustainable growth, convergence of economic performance, high levels of employment and social security, improvement of the quality of life and economic and social coherence and solidarity between the Member States. A prominent role for the achievement of these goals play the trans-European networks in the fields of transport, communications and energy (TEN). Article 129b of the Treaty links the TEN to the objectives of Article 7a (free traffic of goods, persons, services and capital) and Article 130a (promotion of economic and social cohesion). In particular the trans-European transport networks are to link landlocked and peripheral areas with the central areas of the Union. These objectives were confirmed in the ESDP (1999, 14).

It can be asked whether the expectation is right that the trans-European networks, by linking the peripheral regions to the European core, will stimulate their economic development or whether, by primarily linking core regions, they are likely to contribute to spatial polarisation in Europe. If the trans-European networks, as the Maastricht Treaty suggests, indeed improve the accessibility of peripheral regions relative to the regions in the European core, it is possible that the peripheral regions benefit economically, though also the opposite may occur. If, however, the trans-European networks increase the difference in accessibility between the central and peripheral regions, then they will contribute to spatial polarisation.

The analysis of accessibility indicators confirms the view that the trans-European networks, in contrast to the claims of the Maastricht Treaty, may widen rather than narrow the differences in accessibility between central and peripheral regions in Europe (Vickerman et al., 1999). This does not imply that the relative gains in rail accessibility of peripheral regions may not be beneficial to their economic development, however these gains will always be overshadowed by the much larger gains in rail accessibility of the regions in the European core. A European transport policy truly committed to cohesion would have to significantly shift the focus to transport links within and between the peripheral regions, not in addition to but at the expense of transport investments in the European core. As the relative position of peripheral regions varies according to the mode of transport used, it is important to pay special attention to solutions which improve intermodal accessibility.

In recent years the role of transnational policies has grown in importance in the EU. Changes in competitive conditions set new requirements for infrastructure capacity and accessibility. Competitive advantage is more than earlier based on man-made, not natural resources, which emphasises the significance of fast passenger transport and information transmission. Even if these challenges are a result of globalisation, the possibility to find solutions is also strongly influenced by local conditions, e.g. the possibility to strengthen the resources of a certain region or centre by improving accessibility in the local daily region. In this situation, accessibility indicators are important for evaluations of different policy programmes, such as the trans-European networks. Other potential areas of evaluation studies include, for instance, the implications for accessibility of institutional changes in border regions. The results of the survey of accessibility indicators in this report can be used for dividing the regions of the EU into centres and peripheries (actually this division is a continuum), for comparing the divisions resulting from using different indicators and for evaluating the likely impacts of various policy measures on the differences in accessibility between central and peripheral regions.

Beyond all refinements of accessibility indicators, however, reappears the question of what they are to achieve. After all, accessibility is not a desirable good by itself but a means to an end. Therefore the final benchmark for the quality of accessibility indicators are not theoretical beauty or plausibility but discriminatory power with respect to differentiation between areas, explanatory power with respect to predicting area development and policy relevance with respect to EU objectives.

Finally, it is good to remember that geographical position is not everything. Of course there are highly accessible and highly successful regions and cities in the European core, and there are economically lagging areas at the European periphery. However, there are also prosperous peripheral regions and cities and declining old industrial regions in the very heart of the continent. Indicators of geographic position therefore have always to be seen together with other indicators of the endowment and situation of a region or city as identified in the other six working groups of the Indicator Task of the Study Programme.

8 Future Work

The work of the Working Group "Geographical Position" resulted in a number of recommendations to the European Commission for establishing and maintaining a set of reference indicators of geographical position suitable for being used for the differentiation of European regions, cities and corridors, for the targeting of regional policies and for analyses of interregional cohesion both at European and transnational level. The recommendations can be subdivided into three groups:

8.1 Adoption of a Set of Reference Indicators

Based on the review of existing and operational indicators, a set of reference indicators of geographical position sufficient for answering the most pertinent policy questions of the European Commission in the context of regional, transport, economic, agricultural and environmental policy both at European and transnational level should be adopted.

These indicators should comprise
- geographical indicators,
- physical indicators,
- cultural indicators and
- accessibility indicators.

The accessibility indicators should include indicators suitable for
- studying peripherality,
- identifying nodal areas,
- studying interstitial areas between nodes and
- studying cohesion between areas.

The selection of indicators to be included in the set of reference indicators should strike a balance between desirability based on the criteria stated in Section 5.2 (policy relevance, discriminatory and explanatory power) and feasibility in terms of data availability and computational effort.

A minimum set of reference indicators of geographical position should include the following indicators:

(1) Geographical latitude and longitude (of area centroid)
(2) Mean elevation above seal level (m)
(3) Length of seashore (in percent of area perimeter)
(4) Mean annual sunshine (kWh/m^2)
(5) Major and secondary language
(6) Accessibility by road to population (potential)
(7) Accessibility by rail to population (potential)
(8) Accessibility by air to GDP (potential)

The list of indicators included in the set of reference indicators should be regularly reviewed and if necessary amended.

In addition, cohesion indicators summarising the spatial distribution of indicators across areas should be defined. Cohesion indicators are meaningful only for the accessibility indicators because they are the only ones that can be influenced by policy. Commonly applied cohesion indicators are the coefficient of variation and the Gini coefficient. However, these two indicators measure only *relative* distributions and cannot be used to compare *absolute* differences between two distributions, for instance the absolute gains in accessibility accruing to regions through the trans-European networks.

8.2 Maintenance of an Integrated Database

The data required for the calculation of the indicators of geographical position in the set of reference indicators should be provided and updated in the REGIO and GISCO databases of Eurostat. This is straightforward in the case of the first five indicators, the geographical, physical and cultural indicators, as these are not likely to change over time. In the case of the accessibility indicators, both area data and network data are required:

- *Area data* include population and GDP. These data are routinely made available provided in the REGIO database of Eurostat.
- *Network data* include the European road, rail and airline networks. Road and rail networks have been made available in the GISCO geographic reference database of Eurostat. These networks presently do not contain information on link travel times or average travel speeds. For reasons of standardisation, this information needs to be provided. The European airline network currently missing in the GISCO database should be added to the database, including origin-destination flight time and frequency.

The spatial resolution of the database should, as a minimum, be at the NUTS-3 level. For more detailed analyses, also data at the NUTS-4 and NUTS-5 levels should be available. The spatial resolution of the area data determines the degree of detail of the network databases and the connector links connecting the centroids with the networks. To study the development of accessibility indicators and cohesion indicators over time, historical area data and network data need to be provided. It is important that the data needs of all seven indicator groups be co-ordinated and that the database be open for future developments and the yet unknown requirements of methods still to be developed.

8.3 Development of a Manual of Indicators

To enable researchers to calculate the reference indicators in a comparable way, a manual for their calculation should be developed. The manual should contain for each reference indicator the exact definition and, in the case of accessibility indicators, a precise and operational specification of how the indicator is to be calculated, including the necessary model parameters, a test data set and the correct results to be obtained as well as a sample software code needed to produce those results.

Like the integrated database, all software should be in the public domain for easy exchange and dissemination.

8.4 Further Areas of Research

In addition to the above efforts to establish a set of reference indicators of geographical position, further research is needed:

One area of research should examine possible refinements of the accessibility indicators as suggested by the specific indicators presented and indicated in Table 5.2. One refinement are accessibility indicators taking account of time table information and transfers in rail and air line networks. Another underdeveloped field are multi- and intermodality in both passenger and freight networks. Little research has been done on political, economic and cultural barriers. More research is needed on different forms of accessibility indicators or accessibility indicators for different types of actors and users. In all cases the added value of the increased complexity in terms of discriminatory power (with respect to differentiation between areas), explanatory power (with respect to predicting area development) and policy relevance (with respect to EU objectives) should be assessed.

A second area of research should explore new concepts of accessibility indicators that have not yet been made operational, such as indicators taking account of telecommunication (as a substitute or complement to physical travel) or indicators that are not scalar values but multi-valued distributions. As above, the gain in discriminatory and explanatory power and policy relevance should be weighed against the cost of the extra complexity.

A third area of research, finally, should further develop advanced ways of visualisation of geographical position such as *chronocartes* and time-space maps.

9 Conclusions

The Working Group "Geographical Position" explored issues of developing indicators of geographical position as part of a series of indicators for the spatial differentiation of regions, cities and corridors at European and transnational level.

The discussion started from definitions of geographical, physical, cultural and accessibility indicators of geographical position and developed a framework of accessibility with its various dimensions yielding a typology of accessibility indicators. Based on a review of existing accessibility indicators used in the countries of the European Union, criteria and requirements for European accessibility indicators taking account of the policy objectives of the European Union both at European and transnational level were developed. A set of reference indicators taking account of practical requirements was proposed. In addition further indicators were identified for future consideration.

All reference indicators were demonstrated by maps. In addition, cohesion indicators for comparing spatial distributions of accessibility were presented. Finally, the NUTS-3 regions were grouped based on the eight reference indicators using cluster analysis.

Based on that experience, recommendations for the adoption of a set of reference indicators of geographical position, the maintenance of an integrated database and the development of a manual of indicators were made. In addition, relevant areas for future research were identified: the refinement of existing accessibility indicators by taking account of time table information in rail and air networks, of multi- and intermodality in passenger and freight networks, of political, economic and cultural barriers and of different types of indicators and different types of actors and users, the exploration of new concepts of accessibility indicators, such as indicators dealing with telecommunications or multiscalar indicators, and the exploration of advanced techniques of visualisation.

Other important issues remain outside the aim and scope of the first phase of ESPON but may need to be addressed in the longer-range future. The interdependency between accessibility and regional development, though it has been a topic of several large 4th RTD Framework projects, will remain on the research agenda. The potential impact of information technology on accessibility – and hence regional development – is a large and hardly approached research area. Also the constraints set by spatially dispersed demand on the use of new transport technologies need to be studied. The capacity of network infrastructure and demand for transport are very unevenly distributed. Because the supply of infrastructure cannot be increased gradually (the problem of indivisibility), spatially dispersed demand sets serious constraints to the utilisation of such systems. In this situation, the process of technology diffusion is an essential issue in regional development.

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