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

Applied Research 2013/1/10

Draft Final Report | Version 21/12/2012

Volume 1
TRACC Executive Summary and Main Report
This report presents the draft final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

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Introduction

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

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

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This report is part of the TRACC Final Report. The TRACC Final Report is composed of four volumes.

- Volume 1 contains the Executive Summary and a short version of the Final Report
- Volume 2 contains the TRACC Scientific Report, i.e. a comprehensive overview on state of the art, methodology and concept, and in particular results on the global, Europe-wide and regional accessibility analyses and subsequent conclusions of the TRACC project.
- Volume 3 contains the TRACC Regional Case Study Book. Here, each of the seven case studies conducted within the project is reported in full length.
- Volume 4 contains the TRACC Accessibility Indicator Factsheets, i.e. detailed descriptions of all accessibility indicators used in the project.
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Volume 1a
TRACC Executive Summary
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Objectives

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

The important role of transport infrastructure (i.e. networks and transport services) for spatial development in its most simplified form implies that areas with better access to the locations of input materials and markets will, ceteris paribus, be more productive, more competitive and hence more successful than more remote and isolated areas. However, the impact of transport infrastructure on spatial development has been difficult to verify empirically. There seems to be a clear positive correlation between transport infrastructure endowment or the location in interregional networks and the levels of economic indicators such as GDP per capita. However, in most countries this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today. Attempts to explain changes in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful.

This uncertainty leads to a couple of policy and research questions regarding the accessibility situation, spatial patterns and dynamics at different levels (global, European and regional) for different transport modes (road, rail, water, air and combinations), regarding the impacts of accessibility and its possible policy driven dynamic in the context of changing framework conditions on regional development. From such policy and research questions the main objectives of the project are derived:

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

Conceptual framework

The TRACC conceptual framework is based on a systematic and comprehensive theoretical consideration of the major dimensions of accessibility, the most frequently used types of accessibility indicators and important extension of these. Accordingly, accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, type of transport, modes, spatial scale, equity and dynamics. In general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them: These functions can be defined and combined in different ways. The most common way of doing this is reflected in three generic accessibility indicators:

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

There is a large number of extensions of the above generic accessibility indicators. Four of them are addressed in this project, namely multimodal accessibility, intermodal accessibility, global accessibility and regional accessibility.

**TRACC set of accessibility indicators**

A comprehensive review of accessibility indicators used in research and practice has shown that there is no single standard accessibility indicator serving all purposes. The conclusion for TRACC has been therefore to develop a systematic and consistent set of accessibility indicators which is derived from the conceptual framework as summarised above and which matches a range of specific requirements.

Table 1 presents the resulting TRACC set of accessibility indicators. The indicator set is differentiated by the three main spatial contexts to be taken into account (global, European, regional), and at each level further differentiated by travel and freight. For the European level, accessibility indicators for travel are further divided into traditional and newer ones. For the regional level, the indicators are differentiated into those regional indicators for both travel and freight that can be calculated for the whole of Europe and those that are calculated in the regional case studies. For the latter, a distinction is made between traditional indicators and indicators looking at the accessibility to services of general interest to reflect current policy debates on the subject of services of general interest. At all levels, each generic indicator type is represented by one indicator.

**Illustrative results**

The TRACC project was successful in implementing the full matrix of accessibility indicator as defined in Table 1. By doing this the underlying conceptual framework was followed in which in particular the set of dimensions of accessibility is asking not for a single all-purpose accessibility indicator but for appropriate indicators for different circumstances and demands. The in total 27 accessibility indicators were calculated for different modes or combination of modes; six of them were implemented for road and public transport in seven case studies.

This results in an enormous amount of empirical material presented and analysed with the help of maps and diagrams in the different volumes of the TRACC Final Report. The interested reader might want to visit those other volumes for closer inspection of the results. Volume 4, the TRACC Accessibility Indicator Factsheets, contains detailed technical descriptions of all accessibility indicators used in the project including all maps developed for the ESPON Space. Volume 3, the TRACC Regional Case Study Book, contains the seven case studies conducted within the project in full length and contains all case study maps. Volume 2, the TRACC Scientific Report, contains a comprehensive overview on state of the art, TRACC methodology and concept, and in particular the presentation, analysis and interpretation of results achieved on global, Europe-wide and regional accessibility and subsequent conclusions.

Here, only very selective and illustrative examples for the type of results achieved can be presented in map form. Figure 1 shows an example for global accessibility using rail freight accessibility to sea ports weighted by container throughput. Figure 2 presents an aspect of Europe-wide accessibility by taking intermodal potential accessibility travel. Figure 3 is an illustration for regional accessibility displaying the urban functions available, expressed as number of cities reachable within one hour rail travel time. Figure 4 is a map which combines results of all seven regional case studies by showing access time to the next hospital for LAU-2 regions.
### Table 1. TRACC set of accessibility indicators

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Figure 1. Global freight connectivity – rail

Global potential accessibility freight (2011): by rail to intercontinental container throughput of European sea ports (percentage of average accessibility by rail of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

* Capital cities
* Intercontinental Container Seaport (>250000 TEU/year)
Figure 2. Potential accessibility to population, intermodal
Figure 3. Availability of urban functions, rail
Figure 4. Public transport travel time to next hospital.
Policy implications

- **Accessibility is a 2 dimensions driven variable**: Accessibility consists of two components, available activities of interest and transport infrastructure leading to them. Low accessibility values reflect in some cases sparsely populated areas and/or low service endowment, often in the European peripheries; but in others cases low accessibility values are driven by poor transport infrastructure, more often in Eastern Europe than in Western Europe. Accessibility related policy should not only concentrate on the transport infrastructure side as investments in the points of interest might be more efficient.

- **Global travel accessibility**. Seen from an accessibility perspective, the integration of European regions in the global economy is very heterogeneous. In particular for passenger travel, huge differences exist between European regions in terms of linkages to global destinations and global accessibility.

- **Global freight accessibility changing**. The progressive rise of Far East as trade partner opens to Mediterranean regions the perspective of exploiting a position advantage. In this respect, efficient multimodal infrastructures (ports, transhipment facilities, intermodal centres, roads, railways) might increase the global accessibility of Southern European regions thus reducing the current differences with respect to the North Sea area.

- **European travel accessibility patterns**. The dominating accessibility pattern in Europe for passenger transport is as follows: highest values in the Core of Europe, in capital city regions in other countries, and in other selected industrial or touristy regions such as Southwestern Scandinavia (Oslo-Gothenburg-Copenhagen), the Western Mediterranean coastal corridor (from southern Spain to northern Italy), the Rhone valley, Southern Italy, Saxony and Upper Silesia. Citizens in core regions are more likely to seamlessly travel in Europe or access global transport getaways (more transport services and point to point connections, shorter local trip legs) as they have denser motorway and rail networks and concentrate a higher number of European and global air hubs.

- **European freight accessibility patterns**. Geographical position, availability of infrastructures and strength of the economy are the three key elements which describe the pattern of European accessibility in relation to freight. Logistic activities tend to follow population and economic concentrations. Best connectivity to freight transport networks is recorded in the North Sea due to the presence of largest container ports in Europe, in addition to denser motorway and freight village networks. The Mediterranean rim has large container ports but less dense motorway and freight village networks in their hinterlands limit to a large extent high performance to coastal fringes. Main inland waterway axes (Rhine, Danube, Elbe) and canal systems in Germany back up good freight accessibility performance.

- **The cost of low EU Integration**. The comparison of potential accessibility patterns restricting origins and destinations within EU Member States or allowing for European wide mobility shows that an important number of European regions are likely to loose out when they are restricted to access only national activities, or in other words under lower EU integration conditions. This is especially obvious in border regions like western Poland, north-eastern and southern Germany, eastern and southern France. Low European integration can be due to political issues like border permeability to economic flows but more importantly due to cultural issues like barriers that languages represent to seek jobs or study abroad.

- **Local and regional peripheries do not match EU peripheries**. No significant differences can be observed for performance in regional and local accessibility between regions located at the European Periphery and regions located at the European Core. Regional case studies have revealed relatively homogeneous patterns within regions. Regional and local accessibility in case studies is much more dependant on the local conditions of population and economic activity than to their overall European localisation.
• **The East-West divide still persists at regional level.** From most locations in Europe, at least one regional centre can be reached in less than 60 minutes travel time, but only people in Western Europe have options to visit more than five different cities in that time. Infrastructure endowment is still much lower in Eastern Europe, so despite having relatively similar levels of service provision, accessibility to services remains lower than in Western Europe. Accessibility to transport infrastructure is also lower in Easter Europe.

• **The Urban-Rural divide still persists at regional level.** Accessibilities for capitals regions or for main agglomerations differ significantly from those for rural, peripheral and landlocked regions, as well as for intermediate areas. Minimum services are available with reasonable cost in most areas of Europe, even remote rural or sparsely populated, but the possibility to choose amongst different alternatives is concentrated in highly populated urban areas. Indicators focussing on availability of activities and services (travel cost) provide more balanced patterns on the territory than indicators focussing on the diversity of offer (cumulated opportunities, potential accessibility) which tend to provide more polarised patterns around largest metropolises and well deserved transport corridors.

• **Inner peripheries in all regions.** Inner peripheries with low accessibility values are not only located in the far North or in the Alpine space, as expected, but also in most European countries. The extent of these inner peripheries is substantially larger for rail than for car.

• **Balanced access to services of general interest.** The analysis of case studies show a balanced geographical distribution of public services in Europe, allowing for minimum service availability despite of population figures or economic activity of regions. Many case studies have identified the threat of diminishing accessibility to services of general interest caused by withdrawal of the public sector in the framework of the current financial crisis.

• **Public transport accessibility below car accessibility.** Accessibility patterns for cars and public transport differ to a large degree, both with respect to the level and also with the spatial patterns. Accessibility levels by car are in general higher at regional and local level than those for public transport, but public transport is still able to provide high levels of accessibility within metropolitan areas and in city centres, and along well deserved axes is. Accessibility indicators for cars tend to form different types of plateaus, while for public transport the same indicators form ‘stretches’ and ‘bands’ of high accessibilities along transport axis, interrupted by areas of low accessibilities where public transport is missing. Most of the case studies and most of the indicators applied demonstrate that accessibility by car is superior to accessibility by public transport. Only in a few metropolitan areas public transport is providing comparable accessibility to the population.

• **Impact of financial crisis.** Accessibility is a matter of transport infrastructures and of availability of functions. As for transport infrastructures, the impact of the financial crisis is likely to be detrimental in the light of the pro-cyclical approach in public investments dominating the EU architecture. Shortage of financial resources can easily lead to postpone or even cancel planned public investments, whilst private investments are also likely to slow down significantly. The picture could be different if the role of public expenditure as engine of aggregate demand to tackle economic crisis is re-discovered. As for availability of functions, two main linkages with the crisis can be mentioned. First, for some of the TRACC indicators public services (schools, hospitals) are involved. The concentration of services with the closure of minor local sites has been announced often in the last years. The financial crisis could provide the rationale for put this into practice. In that case, especially accessibility based on travel costs could significantly worsen for many (mostly peripheral) areas. Second, the crisis has been deepening (further than being fuelled by) disparities between European countries. So, current unbalances in accessibility to economic activity are likely to increase.
• **No clear significant overall patterns observed in relation to impacts of TEN-T projects in case studies.** Impacts observed varied largely from one case to another. The diversity of typologies of projects in each case, and the use of particular hypothesis for final performance of envisaged infrastructures (e.g. speeds in new rail links) may be in part responsible for these differences. In a number of case studies, largest metropolitan areas and urban regions tended to win less in relation to intermediate and rural regions (e.g. in the Czech Republic, in the Baltic States, and to some extent in the Western Mediterranean and in Finland). In Poland, road projects benefit to a higher extent the Warsaw – Katowice region, but also important gains can be observed in the far less populated eastern regions bordering with Belarus and Ukraine.

• **Specialised accessibility indicators.** Individual accessibility indicators are to depict different facets and different spatial structures. Accessibility cannot be assessed by just one indicator. Travel cost indicators to next “function” indicate the possibility of regions to have access to certain functions, while cumulated opportunities and potential accessibility indicators also include the variety of functions and therefore reflect the magnitude of alternative choices available. Potential indicators tend to show more laminar patterns (progressive), while availability of functions are more affected by singularities in the territory.

• **Raster approach to increase resolution of accessibility analysis.** A majority of the findings in TRACC are based on grid cell maps, free of administrative divisions. Several particular areas and spatial patterns can be noticed only on the grid cell basis. TRACC has proven that even at the level of zoom-in regions significant intra-regional disparities exist, which cannot be detected by the traditional, aggregated models. Such intra-regional disparities are often greater than those between regions, thus accessibility studies should acknowledge these disparities and should find ways how to capture them. Raster analysis allows for a more accurate identification of territorial patterns generated by high level and public transport corridors.

• **Public transport modelling approach.** The quantification of public transport accessibility could be improved by modelling different services (road public transport, regional trains, intercity trains…) as independent modes, allowing for multimodal trip chains. On the one hand this would allow to better identify the role of each mode (e.g. road public transport for short distances, often when train is not available, regional trains mostly for commuters, etc.), thus providing more precise estimations of times and costs for different demand segments/travel purposes (e.g. accessibility to schools would probably use different input than accessibility to hospitals or potential accessibility to population. On the other hand, modelling multimodal chains (even if in a simplified way) would allow to explore the role of interconnectivity and co-modality, which are increasingly relevant concepts in public transport planning to provide efficient accessibility.

• **Freight transport modelling approach.** Some freight services are based on lines with fixed paths and stops (likewise public transport). Modelling these lines more explicitly would improve the representativeness of the accessibility indicators as the information on the regions pairs actually connected would be more precise. A pre-condition for implementing this approach on an European scale would be however the availability of a reliable and frequently refreshed database of the lines, which are continuously evolving. For rail-road combined transport some information exists, but for maritime container data is much more scattered and difficult to access. Still about freight, road freight accessibility is significantly influenced by assumptions on driving times and costs (e.g. respect or not of the maximum driving limits per day, use of two drivers, accompanied and unaccompanied trucks on ferries). Improvements on modelling of these aspects could be useful.

• **to be further detailed and developed**
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1 Objectives

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

The important role of transport infrastructure (i.e. networks and transport services) for spatial development in its most simplified form implies that areas with better access to the locations of input materials and markets will, ceteris paribus, be more productive, more competitive and hence more successful than more remote and isolated areas.

However, the impact of transport infrastructure on spatial development has been difficult to verify empirically. There seems to be a clear positive correlation between transport infrastructure endowment or the location in interregional networks and the levels of economic indicators such as GDP per capita. However, in most countries this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today.

Attempts to explain changes in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful.

The reason for this failure may be that in countries with an already highly developed transport infrastructure further transport network improvements bring only marginal benefits. A different situation can be observed in some regions of the new EU member states where the lack of modern infrastructure (motorways, high-speed trains) is still a major barrier to economic development and where the rapid increase of freight flows by road on the main transport corridors between western and eastern Europe was not followed by new road, rail or multimodal transport investment.

While there is uncertainty about the magnitude of the impact of transport infrastructure on spatial development, there is even less agreement on its direction. It is debated whether transport infrastructure improvements contribute to spatial polarisation or decentralisation. From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region makes it easier for producers in the peripheral region to market their products in the large cities, however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies.

These developments have to be seen in the light of changes in the field of transport and communications which will fundamentally change the way transport infrastructure influences spatial development. Several trends combine to reinforce the tendency to diminish the impacts of transport infrastructure on regional development:

- An increased proportion of international freight comprises high-value goods for which transport cost is much less than for low-value bulk products. For modern industries the quality of transport services has replaced transport cost as the most important factor.
- Transport infrastructure improvements which reduce the variability of travel times, increase travel speeds or allow flexibility in scheduling are becoming more important for improving the competitiveness of service and manufacturing industries and are therefore valued more highly in locational decisions than changes resulting only in cost reductions.
- Telecommunications have reduced the need for some freight transports and person trips but they also increase the demand for transport by their ability to create new markets.
- With the shift from heavy-industry manufacturing to high-tech industries and services other less tangible location factors have come to the fore and have at least partly displaced traditional ones. These new location factors include factors related to leisure, culture, image and environ-
ment, i.e. quality of life, and factors related to access to information and specialised high-level services and the institutional and political environment.

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

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

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

Key policy questions

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

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

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

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

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

- What is the accessibility of European regions for travel by different modes (road, rail, air) at the European level?
- What is the accessibility of European regions for air travel at the global level?
- What is the potential of intermodal travel, in particular the combination of high-speed rail and air?
- What would be the impacts of different policies to make rail more competitive on the modal share of travel and travel accessibility?
- What would be the impacts of different policies to make rail and water more competitive on the modal share of freight transport and freight accessibility?
- What are the most favoured urban centres and most disadvantaged regions with respect to travel accessibility (island, mountain areas)?

Project objectives

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

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

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

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

The European transport system serves key roles in the transportation of people and goods in a local, regional, national, European and international context. At the same time, it is essential to Europe’s prosperity and closely linked to economic growth and quality of life. The grand challenge for transport is to make growth and sustainability compatible, by decoupling environmental impacts from economic growth, while assuring the competitiveness and innovative character of the European transport industry. Economic crisis, increasing scarcity of non-renewable energy sources, aging, migration and internal mobility, urbanisation, and globalisation of the economy are among the other challenges to be faced by Transport policy.

The Common Transport Policy

The Common Transport Policy (CTP) is an essential component of the EU policy since the Maastricht Treaty of 1992, when the concept of Trans-European transport Networks (TEN) was introduced for the first time, with a special emphasis on interconnection and interoperability of the diverse national networks. The main policy instruments of the CTP are the White Paper on Transport and the TEN-T programme. The TEN-T programme is intended to increase the co-ordination in the planning of infrastructure projects by the member states. Progress in the TEN-T implementation has been relatively slow due to the scale, complexity and cost of the proposed projects in the past. A new proposal of TEN-T guidelines was presented in October 2011, intended to focus the efforts of the program on key network elements of European relevance. The White Paper on Transport is the document of strategic reflection providing the conceptual framework for the CTP, having had substantial influence on EU, national and regional policies since 1992 (e.g. liberalisation of transport markets and modal change from road to rail). The 2009 EC Communication on the Future of Transport triggered the debate for the 2011 White Book revision, proposing that focus should now turn on improving efficiency of the transport system through co-modality, technology development, and prioritise infrastructure investment on links with highest returns. The new transport White Paper was presented in late March 2011.

According to the 2011 Transport White Paper, one of the major challenges in the field of transport is to break the system’s dependence on oil without sacrificing its efficiency and compromising mobility, in line with the flagship initiative “Resource efficient Europe” set up in the EU2020 Strategy and the new Energy Efficiency Plan 2011. Curbing mobility is not an option. The EU and Governments need to provide clarity on the future policy frameworks (relying to the greatest extent possible on market based mechanisms) for manufacturers and industry so that they are able to plan investments.

The concept of co-modality introduced by the White Paper back in 2006 implies that greater numbers of travellers are carried jointly to their destination by the most efficient (combination of) modes. Individual transport is preferably used for the final miles of the journey and performed with clean vehicles. In the intermediate distances, new technologies are less mature and modal choices are fewer than in the city. However, this is where EU action can have the most immediate impact. Better modal choices will result from greater integration of the modal networks: airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multi-modal connection platforms for passengers.

The EU-wide multi-modal TEN-T ‘core network’ presented by the TEN-T guidelines in October 2011 should be fully functional by 2030. The core network must ensure efficient multi-modal links between the EU capitals and other main cities, ports, airports and key land border crossing, as well as other main economic centres. It should focus on the completion of missing links – mainly cross-border sections and bottlenecks/bypasses – on the upgrading of existing infrastructure. Better rail/airport connections must be devised for long distance travel. By 2030, the length of the existing high-speed rail network should be trippled, and a dense railway network in all Member
States should be maintained. By 2050, a European high-speed rail network should be completed. By 2050 the majority of medium-distance passenger transport should go by rail, and by 2050, all core network airports should become connected to the rail network, preferably high-speed. The quality, accessibility and reliability of transport services is to be increasingly important, requiring attractive frequencies, comfort, easy access, reliability of services, and inter-modal integration.

The cost of EU infrastructure development to match the demand for transport has been estimated € 1.5 trillion for 2010-2030. The completion of the TEN-T network requires about € 550 billion until 2020 out of which some € 215 billion can be referred to the removal of the main bottlenecks. This does not include investment in vehicles as well as guidance and information systems.

Other key elements in relation to passenger transport are according to the transport White Paper improved energy efficiency performance of vehicles across all modes and more efficient use of transport and infrastructure through improved traffic management and information systems. The gradual phasing out of ‘conventionally-fuelled’ vehicles is a major contribution to significant reduction of oil dependence, greenhouse gas emissions and local air and noise pollution. The use of smaller, lighter and more specialised road passenger vehicles must be encouraged. By 2030, the use of ‘conventionally-fuelled’ cars in urban transport should be halved, and by almost eliminated in cities by 2050. Low-carbon sustainable fuels in aviation would have to reach 40% by 2050; at the same time it should be reduced EU CO2 emissions from maritime bunker fuels by 40% (if feasible 50%). Road pricing and the removal of distortions in taxation can also assist in encouraging the use of public transport and the gradual introduction of alternative propulsion.

According to the CTP Evaluation report (EC 2009), substantial progress has been made in the last 20 years towards meeting the objectives of the CTP of creation of a competitive internal market for transport services by liberalising the transport market. Market opening has been very successful in the air sector and there would be signs that market opening in the rail sector is starting to bring success. In all sectors, further reforms are required in order to fully implement liberalisation. Whilst there has been progress towards the objective of introducing a system of transport infrastructure pricing and taxation which better reflects marginal costs, and most of the specific measures proposed in the 2001 White Paper have been implemented, overall progress towards meeting this objective has been limited, largely because most decisions about pricing and taxation are still taken by Member States, and in some cases face strong public opposition.

In order to ensure that the limited TEN-T funds are used most efficiently to address infrastructure bottlenecks, decision-making about the allocation of funding should tend to be, according to the same source, increasingly based on cost benefit analysis of different schemes, using consistent criteria and parameters, not favouring specific modes of transport. The different environmental and other social costs of different modes should be taken into account in this cost benefit analysis. In fact, the EC provides unified criteria for project appraisals, as embodied in the regulations of the Structural Funds, the Cohesion Fund, and Instrument for Pre-Accession Assistance, through its Cost-Benefit guidelines. However many methodological issues remain unsolved (e.g. appraisal of the so called intangible effects, both positive and negative) and even worse, the very paradigms of e.g. time savings in cost-benefit analysis are still being debated intensely.

But emphases on different type of policy aims and instruments may change over time, also in the CTP. The Commission has identified seven transport policy areas in which specific policy measures could have a key role in stimulating the expected shift of the transport system to another paradigm. These policy areas are: pricing, taxation, research and innovation, efficiency standards and flanking measures, internal market, infrastructure and transport planning. Only a long-term and overarching strategy established for all identified policy areas has a reasonable chance of achieving the EU objectives. It should combine policy initiatives targeted at enhancing the efficiency of the system through better organisation, infrastructure and pricing with those that are more focused on technology development and deployment. It should also provide a framework for action at all levels of government.
Transport investment in Europe over time and over space

The total investment in infrastructure in Europe between 1995 and 2010 has been on average between 0.9% and 1.2% of total European GDP. The level of investment in Western European Countries has been substantially lower than in the Eastern European countries, but overall level are well above mean values in other regions of the World such as North America.

About 1/3 of all invested funds in transport were merely spent on infrastructure maintenance, and only about 60% were specifically dedicated to providing new infrastructure. The funding of new infrastructure proceeded mostly from National budgets of Member States (almost 90%), and only 5% of total expenditure was assumed by European funds (Cohesion Fund and ERDF) despite the fact that 50% of total investment was devoted to new infrastructure in TEN-T networks.

The analysis per mode reveals that around 60% of total investment has been devoted to Road mode, 20% to Rail and 10% equally split between Air and Water modes (including maintenance). However, almost half of the investment on TEN-T was devoted over the last 10 years to rail, and around 35% to road. This was especially important in Western European countries, where the development of High Speed Rail networks required large investments (around € 20 million per kilometre of HSR, against € 5 million per kilometre for motorways, on average). In Eastern European countries, investment on roads was still dominant.

Transport and Territorial Cohesion

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

The two dominant themes of spatial planning in Europe, as reflected already in the Europe 2000 study programme, are the urban and regional dichotomy, and the centre and periphery dichotomy. The “integration” between urban-rural, as well as between centre-periphery has always been the European narrative to overcome territorial unbalances. The necessary links to integrated urban and rural zones were included into the wider concept of “partnership”, later on by the ESDP. On the other hand, solving “missing links” in the networks of transport and communication was an important issue in the definition of the Trans-European Transport Networks, and the creation of “integration zones”, “polycentric and cross-border development areas”, between central and more peripheral regions.

The European Spatial Development Perspective (ESDP) of 1999 (European Commission,1999) lists the trans-European transport networks as major policy field of importance for European spatial development, only second to EU economic policy, because of their effect on both the functioning of the Single Market and economic and social cohesion. In line with its spatial vision of polycentric and balanced system of metropolitan regions, city clusters and city networks, the ESDP called for improvement of the links between international/national and regional/local networks and strengthening secondary transport networks and their links with TENs, including efficient regional
public transport systems, improvement of transport links of peripheral and ultra-peripheral regions, both within the EU and with their neighbouring third countries and promoting the interconnection of inter-modal junctions for freight transport, in particular on the European corridors.

Following the European Spatial Development Programme (ESDP), the Study Program on European Spatial Planning (SPESP), carried out a number of specific researches territorial structures and typologies, and the opposition between urban and rural areas. Urban-rural partnerships as defined by the ESDP required among others, a balanced settlement structure and improvement of accessibility (concerning land use and development of public transportation networks). Improved infrastructure and accessibility bring new kinds of rural-urban linkages.

The first Territorial Agenda of the European Union: Towards a More Competitive and Sustainable Europe of Diverse Regions of 2007 (European Commission, 2007) took up the vision of polycentric territorial development of the EU of the ESDP, highlighted the territorial dimension of cohesion and emphasised the importance of integrated and sustainable multi-model transport systems but failed to set priorities.

The new Territorial Agenda of the European Union 2020: Towards an Inclusive, Smart and Sustainable Europe of Diverse Regions of 2011 (European Commission, 2011d) puts spatial development into the framework of the Europe 2020 Strategy and the 5th Cohesion Report and takes up the proposals of the ESDP for inter-modal transport solutions, further development of the trans-European networks between main European centres and improvement of linkages between primary and secondary systems and accessibility of urban centres in peripheries.

The Europe 2020, the growth strategy of the EU for the coming decade, aims at five targets in the fields of employment, research and development, greenhouse gases, renewable energy, energy efficiency, education and social inclusion. (European Commission, 2010). The Commission emphasises that essential elements of the transport policy are better integration of transport networks, promoting clean technologies, and upgrading infrastructure. Among the obstacles to be overcome, insufficiently interconnected networks are listed. Transport is listed among the policy tools to be applied only in very general terms as “smart transport and energy infrastructure”.

A further example of the current debate on cohesion aspects is the changes in the understanding of the “urban-rural narrative” as put forward through the Spanish Presidency (2010). Its contribution highlights the need for a thorough investigation of urban-rural relationships and spatial trends in conceptualizing the new pattern of spatial relations, becoming visible through increased flows and implying analysis beyond core and periphery paradigms. New territorial paradigms emerge today thanks to ICTs and to faster and cheaper transport, increased accessibility and connectivity. These changes result on severe reductions of distance or cost to reach core areas of Europe from the peripheries (“cost of being peripheral”) and making remote places more accessible when well connected to the networks. Even when distance still matters, impacts on spatial development become today more complex, ubiquitous centres and peripheries can suddenly emerge almost anywhere, even in remote rural areas, and the challenge is to face increasing development opportunities but also to manage exposure to threats.
3 Conceptual framework

The TRACC conceptual framework is based on a systematic and comprehensive theoretical consideration of the major dimensions of accessibility, the most frequently types of accessibility indicators and important extension of these.

Accessibility dimensions

Accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, type of transport, modes, spatial scale, equity and dynamics. These dimensions are summarised in Table 3.1.

Table 3.1. Dimensions of accessibility

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origins</td>
<td>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.</td>
</tr>
<tr>
<td>Destinations</td>
<td>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).</td>
</tr>
<tr>
<td>Impedance</td>
<td>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).</td>
</tr>
<tr>
<td>Constraints</td>
<td>The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types of maximum driving hours) or by capacity constraints (road gradients or congestion).</td>
</tr>
<tr>
<td>Barriers</td>
<td>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.</td>
</tr>
<tr>
<td>Types of transport</td>
<td>Only travel or only freight transport, or both, may be considered in the analysis.</td>
</tr>
<tr>
<td>Modes</td>
<td>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.</td>
</tr>
<tr>
<td>Spatial scale</td>
<td>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.</td>
</tr>
<tr>
<td>Equity</td>
<td>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.</td>
</tr>
<tr>
<td>Dynamics</td>
<td>Accessibility indicators may be calculated for different points in time in order to show changes in accessibility induced by TEN projects or other transport policies, including their impacts on convergence or divergence in accessibility between areas.</td>
</tr>
</tbody>
</table>
Generic accessibility indicators

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

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

\[
A_i = \sum_j g(W_j) f(c_{ij})
\]

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

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

However, the generic equation of accessibility above is more general than the gravity model. Different types of accessibility indicators can be generated by specifying different forms of functions \(g(W_j)\) and \(f(c_{ij})\). Table 3.2 shows the most frequent specifications of \(g(W_j)\) and \(f(c_{ij})\) for the three most frequent types of accessibility indicator, where \(W_{\min}\) and \(c_{\max}\) are constants and \(\alpha\) and \(\beta\) parameters:

<table>
<thead>
<tr>
<th>Type of accessibility</th>
<th>Activity function (g(W_j))</th>
<th>Impedance function (f(c_{ij}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel cost</td>
<td>[ W_j \begin{cases} 1 &amp; \text{if } W_j \geq W_{\min} \ 0 &amp; \text{if } W_j &lt; W_{\min} \end{cases} ]</td>
<td>(c_{ij})</td>
</tr>
<tr>
<td>Cumulated opportunities</td>
<td>(W_j)</td>
<td>[ 1 &amp; \text{if } c_{ij} \leq c_{\max} \ 0 &amp; \text{if } c_{ij} &gt; c_{\max} ]</td>
</tr>
<tr>
<td>Potential</td>
<td>(W_j^\alpha)</td>
<td>(\exp(-\beta c_{ij}))</td>
</tr>
</tbody>
</table>

Table 3.2. Accessibility indicators
- **Travel cost.** If only destinations of a certain kind, e.g. cities beyond a certain size, are considered (the activity function is rectangular), and the impedance function is travel time or travel cost itself (i.e. the impedance function is linear), the accessibility indicator is total or average travel cost to a predefined set of destinations.

- **Cumulated opportunities.** If only destinations within a certain travel time are considered (the impedance function is rectangular), and the destinations are taken as is (the activity function is linear), the accessibility indicator measures the number of potential destinations (customers, business contacts, tourist attractions, etc.) that can be reached in a given time, e.g. a day.

- **Potential.** If the impedance function takes travel behaviour into account, i.e. the diminishing inclination to travel long distances (the impedance function is nonlinear, e.g. exponential), the accessibility indicator is a potential indicator. The activity function may take account of agglomeration effects or economies of scale (i.e. may be nonlinear, e.g. a power function).

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

- **Multimodal accessibility.** All three generic types of accessibility indicator can be calculated for any mode. At a European scale, accessibility indicators for road, rail and air are most frequently calculated. Modal accessibility indicators 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 and to ignore the remaining slower modes. Another way is to calculate an aggregate accessibility measure combining the information contained in the modal accessibility indicators by replacing the generalised cost $c_{ij}$ by the 'composite' generalised cost

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

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

- **Intermodal accessibility.** A further refinement is to calculate intermodal accessibility. Intermodal accessibility indicators take account of trips involving two or more modes. Intermodal accessibility indicators are most relevant for logistic chains in freight traffic such as rail freight with feeder transport by lorry at either end. Intermodal accessibility indicators in passenger travel involve mode combinations such as Rail-and-Fly or car rentals at railway stations and airports.

- **Regional accessibility.** Most accessibility studies concentrated on the accessibility of cities, i.e. network nodes which are assumed to represent the whole area or even a larger region. This presents two problems: (i) 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. (ii) The quality of the interconnections between the high-speed interregional and the low-speed local transport networks cannot be taken into account. Yet the ease of getting from home or office to the nearest station of the high-speed rail network or the nearest airport may be more important for the accessibility of a location than the speed of the long-distance connection from there.

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

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

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

To achieve this, the research in the project was divided into seven Tasks.

- **Task 1: Methodology/indicators.** The objective of the first Task is to review the existing methods and indicators for different types of transport, transport modes and spatial scales, to improve the methods to measure European accessibility by calculating other indicators than potential accessibility and to extend them by calculating not only European travel accessibility as done so far in ESPON but also freight accessibility and global and regional accessibility. Based on this review, this Task is to define the methodology of the project, in particular to define a set of accessibility indicators for the ESPON Programme for all spatial levels considered, which will be implemented in the subsequent Tasks.

- **Task 2: Network and socio-economic data.** The objective of this Task is to provide an assessment of network and socio-economic data including an assessment of data availability in the EU candidate countries and Western Balkan and to provide network and socio-economic datasets customised for all accessibility and impact modelling in the project at all scales addressed based on a comprehensive overview and assessment of available network and socio-economic databases.

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

- **Task 4: European accessibility: freight transport.** The objective of this Task is to calculate a set of freight accessibility indicators for European as well as global accessibility for the regions of the ESPON space and the Western Balkan. The accessibility patterns are to be transformed into European and global accessibility typologies. The results will be presented in maps of the ESPON territory showing the spatial distribution of the different freight accessibility indicators computed for various modes and with reference to the different types of accessibility.

- **Task 5: Regional accessibility.** The objective of this Task is to measure and analyse accessibility at the regional scale in Europe. This is to be done by two different approaches. On the one hand, a set of regional case studies encompassing different types of regions in Europe are to provide in-depth insight into regional accessibility indicators with as much as possible harmonised approaches across the different case studies. On the other hand, accessibility indicators
are to be calculated that show accessibility to regional destinations, but are covering the whole ESPON space and the Western Balkan on a raster base. Finally, regional accessibility results and European accessibility results are to be compared to gain insight into the relationship of regional and European accessibility.

- **Task 6: Impacts of accessibility.** The objectives of this task are to analyse the relationship between different types of accessibility and regional economic development and the environment (energy consumption and greenhouse gas emissions) and to forecast the development of accessibility and GDP per capita, employment and population and energy consumption and greenhouse gas emissions of transport subject to a set of long-term scenarios of European transport policies and assumptions about future developments in vehicle technology and alternative fuels and fuel price increases. In addition the results are to be analysed by different cohesion indicators expressing the impacts of the policies modelled on the convergence (or divergence) of accessibility and socio-economic development in the regions of the ESPON space and the Western Balkan.

- **Task 7: Policy implications.** This Task is to summarise the findings of the project in relation to the goals of the European Union competitiveness, territorial cohesion and environmental sustainability for different types of regions and to evaluate the policy instruments available to the European Union and its member states to maintain and improve the different types of regional accessibility in order to draw as much benefit for regional development from accessibility with the smallest possible negative implications for territorial cohesion and the environment and to formulate policy conclusions which can stimulate and enlighten the ongoing political discourse on transport and accessibility policy for decision makers, experts and the wider public.

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

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

This chapter contains a summary of a comprehensive review of accessibility studies done in Europe (see TRACC Final Report Volume 2, Chapter 4, for the detailed review). A focus of the review was on studies published during the last decade. The review is organised in three main parts which address different spatial contexts of accessibility, i.e. global, European and regional followed by a fourth part on accessibility impacts.

Global accessibility studies

The understanding of global accessibility studies in this report is that studies are included that analyse the accessibility of Europe and its regions to the world. Only a few accessibility studies are addressing global accessibility. However, all generic types of accessibility indicators were represented. The indicators, however, were in most cases calculated for an airport or an airport city, consequently, air transport was the only transport mode. Only one study calculated global accessibility for a set of regions by incorporating the access time from the regions to the airports into an overall intermodal travel time. Most studies considered travel, but air freight was addressed in one study. In the freight study, not only travel time, but also other criteria such as quality of service and tariffs were included in the accessibility indicator.

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

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

European accessibility studies

Over the last decades a vast number of accessibility studies addressing Europe-wide accessibility have been published. The European accessibility models reviewed yield a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalities:

- More than half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunities indicators. A few models calculate several types of indicator.
- The origins for which accessibility indicators are calculated are usually NUTS-2 or NUTS-3 centroids, very few studies have a more detailed representation of space.
- The destination activities are usually population or GDP for potential type accessibility indicators and a pre-defined set of agglomerations for the travel cost indicators. For daily accessibility indicators both population and public facilities, such as airports, high-speed train stations, universities or hospitals are used as destinations.
- Nearly all models use travel time as impedance term, only few models apply travel costs or a combinations of both as generalised cost.
- Only few models consider constraints on the impedance term. Models that consider freight transport use statutory drivers’ rest breaks as constraints.

- Only few accessibility models consider barriers, such as waiting times at national borders. Only one model uses trade barriers, such as tolls.

- Nearly all accessibility models are based on passenger travel, only few models consider freight.

- Half of the models consider one mode only, in most cases road. The other models have networks for different modes, however, only two use intermodal travel times.

With respect to spatial disparity and its changing patterns over time, all European accessibility studies expose the existing core-periphery pattern of accessibility in Europe and all indicate that over time the gap in accessibility between core and peripheral regions has increased. A distinction can be made between potential and cumulated opportunities types of indicators. Whereas potential accessibility has improved in the former cohesion countries in southern Europe and increasingly also in the new member states in central and eastern Europe, cumulated opportunities, in particular where business trips are concerned, have increased mainly in central regions with good air connections. Another important distinction can be made between whether changes in accessibility are measured in relative or in absolute terms. Whereas in relative terms (e.g. in percent) accessibility has improved more in the peripheral regions, in absolute terms accessibility in the core regions in western Europe has continued to grow more.

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

- Most models focus on person travel and ignore freight transport although freight transport might be more relevant for peripheral regions. However, empirical work has shown that road accessibility by using car and trucks are highly correlated and that car accessibility can be used as a proxy for truck accessibility.

- Most models do only have an implicit relation to certain sectors of the economy, i.e. by concentrating on person travel the models are closely related to the service sector and neglect that transport has different relations with different sectors.

- Following that, the reality of the business environment in peripheral rural areas is hardly represented in the European accessibility models.

- Some models, those working with travel cost indicators, support the case for public investment in infrastructure by demonstrating increased cohesion. Other models, mainly of the potential type, are much more cautious or even forecast increased regional disparities as outcome of transport infrastructure investments.

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

Regional accessibility studies

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

**Trans-national accessibility studies**

For several trans-national areas in Europe, accessibility studies evaluated the situation from a viewpoint that is below the Europe-wide, but above the national scale. The trans-national accessibility models reviewed yield a wide range of approaches to the various dimensions of accessibility. They differ in many respects, but there are also some commonalities:

- About half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunity indicators. A few models are able to calculate more than one type of indicator.

- The origins for which accessibility indicators are calculated differ very much. The range is from NUTS-3 regions through municipalities down to a detailed representation of space in form of small raster cells.

- The destination activities are usually population for accessibility indicators of the potential type and a pre-defined set of agglomerations, cities or certain facilities, such as airports or hospitals, for the travel cost indicators. For cumulated opportunity indicators, population, cities or public facilities are used as destinations.

- Nearly all models use travel time as impedance term, only one model applies travel costs. Some models use airline or road distance.

- Only few models consider constraints on the impedance term in form of timetable restrictions for public transport.

- None of the trans-national accessibility models considers political, cultural or language barriers in the impedance term.

- Nearly all accessibility models are based on passenger travel, only few models consider freight.

- Half of the models consider one mode only, in most cases road. The other models have networks for different modes, however, only one model uses intermodal travel times.

With respect to the spatial pattern of accessibility observed, nearly all trans-national accessibility studies show large differences in accessibility for different parts of their study area. Regardless the type of indicator, spatial disparities are very much pronounced in those studies. However, it is also stated that the question of disparities in accessibility is a question of the destinations considered. That means that some trans-national areas show large disparities if Europe-wide accessibility is considered, but are much less polarised when destinations of regional interest are considered. In addition, when evaluating the access to public facilities, such as hospitals or regional centres, some of the studies conclude that the travel times are reasonable for most of the population and better than expected.

An overall assessment of trans-national accessibility models is difficult. The general tendency is similar to that of the European accessibility models in so far that none of the models is really able to serve all purposes. In addition, it is difficult to compare the results of the different trans-national accessibility models in more detail. The different ways of incorporating the dimensions of accessibility in the models, in particular the different destination activities considered, the different ways the impedance terms are calculated and the very large variety of spatial detail with respect to origins, destinations and network representation, do not allow to draw more detailed conclusions concerning spatial patterns in different types of regions than those stated above.
National and regional accessibility studies

The national and regional accessibility models reviewed yield also a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalities:

- Only one third of the national models and only every sixth of the regional model use potential type indicators, very few are calculating cumulative opportunities. The majority of the models use travel cost indicators mainly in the form of travel time to pre-selected destinations. A few models calculate more than one type of indicator.

- The origins for which accessibility indicators are calculated are in most accessibility models the centroids of municipalities. A few studies, mainly at the national scale, are less detailed in space. However, the main tendency of the last decade was a movement towards spatially more disaggregate accessibility models. This is done by using raster representations of space in which the cell size ranges from a few kilometres down to 100 m only in some regional applications.

- The destination activities are much more diverse than in the European or trans-national accessibility models. The potential type models work usually with population as destination activity, however, also accessibility to jobs is the subject of several studies. Many studies, in particular those working with travel cost type indicators, use urban and regional centres, network nodes and services of general interest as destination activities.

- With a few exceptions, all models use travel time as impedance term, the remaining models work with travel distance. None of the models at these scales use travel costs.

- Some of the models consider constraints on the impedance term. This is usually done when public transport is considered and represented with real timetable based travel times.

- None of the accessibility models considers barriers.

- Nearly all accessibility models are based on passenger travel, only two models at the national scale and none at the regional scale consider freight transport.

- Many of the models consider road transport only, in particular models at the national scale. Other models have networks for rail or for all means of public transport, a few include also walking and cycling. The use of intermodal travel times is a rare exception of the accessibility models at these scales.

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

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

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

**Accessibility impacts**

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

A further section of the reviews (see TRACC Final Report Volume 2, Chapter 4.4) addresses the state of the art of measuring, explaining and forecasting the impacts of accessibility. It first identifies the types of impacts of interest of accessibility of political interest. It then summarises the theoretical concepts explaining the relationships between accessibility and the impacts of interest. Guided by this theoretical background it reviews available empirical evidence about these relationships and existing mathematical models to forecast them. The section closes by proposing hypotheses about the likely effects of transport policies on the most relevant accessibility impacts.

**Types of impacts**

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

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

**Regional economic models**

There are three types of regional economic development models available: regional production function models, multiregional input-output models and spatial computable general equilibrium models.

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

However, there are also major differences.

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

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

- Another relevant difference between the models is their treatment of dynamics. Multiregional input-output models and SCGE models assume that markets are in equilibrium, at the start and target year, at the end of each period or after a number of periods. The production function models, however, are all recursively dynamic with different types of adjustment delays. This seems also to affect the sensitivity of the models to transport cost changes.

**Hypotheses**

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

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

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

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

Accessibility indicators

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

The review has shown that there is no single standard accessibility indicator serving all purposes. The conclusion for TRACC is therefore to develop a systematic and consistent set of accessibility indicators which is derived from the conceptual framework as laid down in Chapter 3 and which matches the following requirements:

- As different types of accessibility indicators provide answers to different questions, the three generic types of accessibility indicators, i.e. travel cost, cumulated opportunities (daily accessibility) and potential accessibility should be used at all levels considered.

- The TRACC project is expected to analyse accessibility at very different spatial levels ranging from the global through the European to the regional level.

- The spatial coverage should be at least the ESPON space. Candidate countries and other countries of the Western Balkan should be included if possible. Regional case studies should cover different types of the regional typologies developed by ESPON.

- The spatial resolution should be appropriate. This is NUTS-3 for the Europe-wide indicators and LAU-2 for the regional case studies. In addition, raster representations of space should be explored to analyse to what extent a finer spatial resolution influences results.

- All relevant transport modes should be addressed, i.e. road, rail and public transport, air and water as well as combinations of modes as multimodal aggregation and intermodal trip chains.

- Traditional accessibility indicators should be amended by newer forms of accessibility. The traditional indicators should guarantee continuity with previous ESPON studies; in particular the potential accessibility indicator should be updated to a recent year.

- There should be accessibility indicators dealing with passenger travel and indicators dealing with freight transport.

Table 5.1 presents the resulting TRACC set of accessibility indicators. The indicator set is differentiated by the three main spatial contexts to be taken into account (global, European, regional),
and at each level further differentiated by travel and freight. For the European level, accessibility indicators for travel are further divided into traditional and newer ones. For the regional level, the indicators are differentiated into those regional indicators for both travel and freight that can be calculated for the whole of Europe and those that will be calculated in the regional case studies. For the latter, a distinction is made between traditional indicators and indicators looking at the accessibility to selected services of general interest to reflect current policy debates on the subject of services of general interest. For all levels, each generic indicator type is represented by one indicator.

**Global accessibility**

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

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

- **Access to global cities.** What are the travel times from the European regions to selected global cities? New York and Tokyo serve as examples for non-European global cities. For each NUTS-3 region the shortest total travel time will be calculated including intermodal trips by road, rail and/or air to airports with intercontinental flights plus the flight time to the two cities.

- **Global travel connectivity.** How many intercontinental flights can be reached from the European regions within a maximum travel time of three hours? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services will be calculated. If an airport is within the maximum travel time, the intercontinental destinations served from that airport will be added to the regional global connectivity value.

- **Global potential accessibility travel.** What is the relative position of the European regions towards global destinations? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services will be calculated. The intercontinental flights weighted by flight frequency and/or population/GDP of the final destination will be used as attraction, i.e. the mass term in the calculation of the potential accessibility.

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

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

- **Global freight connectivity.** What amount of intercontinental container throughput of ports can be reached from the European regions within a maximum freight transport time of 24 hours? For each NUTS-3 region the shortest total intermodal travel times by road, rail, water and/or air to seaports with intercontinental container services will be calculated. If a seaport is within the maximum travel time, the intercontinental container throughput of that port will be added to the regional global connectivity value for freight.
## Table 5.1. TRACC set of accessibility indicators

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<th>Spatial context</th>
<th>Basic characteristics</th>
<th>Generic type of accessibility indicator</th>
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<td><strong>Global</strong></td>
<td>Travel</td>
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<td>Access to global cities</td>
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<td>Travel time (intermodal) to global city (New York, Tokyo)</td>
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<td><strong>Freight</strong></td>
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<tr>
<td><strong>Europe</strong></td>
<td>Access to top ten MEGAs</td>
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<td>(traditional)</td>
<td>Average fastest travel time to top ten MEGAs</td>
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<td>European daily accessibility travel</td>
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<td><strong>Freight</strong></td>
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<td><strong>Regional</strong></td>
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<td>ICON based access time to motorway exits, rail stations, airports</td>
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<td><strong>Freight</strong></td>
<td>Access to freight terminals</td>
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<td>(Europe-wide)</td>
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<td>Availability of freight terminals</td>
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<td><strong>Travel</strong></td>
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<td>Availability of secondary schools</td>
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- **Global potential accessibility freight.** What is the relative position of the European regions towards global destinations with respect to freight transport? For each NUTS-3 region the shortest total intermodal travel cost by road, rail, water and/or air to ports with intercontinental container services will be calculated. The intercontinental container throughput of the ports will be used as attraction, i.e. the mass term in the calculation of the global freight potential accessibility.

**European accessibility**

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

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

- **Access to top ten MEGAs.** What is the average travel time from the regions to the upper level subset of the European MEGAs? For each NUTS-3 region the fastest travel time of road, rail and air transport to reach the top ten MEGAs will be calculated, and an average value will be determined.

- **European daily accessibility travel.** How many people can I reach within a day's round trip? How many people can visit my region within a day's round trip? For each NUTS-3 region the number of persons that can be reached within a one way travel time of five hours by road, rail, air and fastest mode will be summed up. Five hours per way will be used to allow for at least five hours of activities at the destination.

- **European potential accessibility travel.** What is the relative competitive position of European regions towards European destinations? For each NUTS-3 region the population in destination regions will be weighted by the travel time to go there. The weighted population will be summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator will be calculated for road, rail, air and as an multimodal aggregate. The indicator will be calculated with the same specification and network detail for the year 2011 as the potential accessibility indicators of ESPON 2006 and the Accessibility Updates. That means that the development of potential accessibility by road, rail, air and multimodal can be analysed over a time period of ten years in total. In an exploratory part of the project, the NUTS-3 regions used as origins and destinations will be replaced by small raster cells to investigate whether a more detailed representation of space would lead to better results.

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

- **Travel speed.** What is the average travel speed to serve regional transport demand? The rationale of this indicator is based on the assumption that transport policy cannot provide the same degree of accessibility everywhere in Europe, but might provide the same quality of the infrastructure by delivering comparable speeds to the regional transport demand. First, regional
transport demand will be calculated by a negative exponential model in which the number of trips from the region to all other regions is estimated. Then, the travel time to the destination regions will be converted to airline speeds. Finally, the average travel speed of a region will be calculated as the trip-weighted average speed to all other regions. This will be done for rail and road modes.

- **Urban connectivity.** What opportunities or restrictions for urban connectivity does transport infrastructure provide? For each city of more than 50,000 inhabitants the travel time to other cities of that minimum size will be calculated for road, rail and air travel. Urban connectivity is there if two cities are less than three or alternatively five hours of centre-to-centre travel time apart from each other. The indicator will be mainly presented in map form, but could also be numerically defined by using concepts of graph theory.

- **European potential accessibility intermodal travel.** What is the relative competitive position of European regions towards European destinations by using the best combination of all transport modes in intermodal trip chains? For each NUTS-3 region the population in destination regions will be weighted by the intermodal travel time to go there. The weighted population will be summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator will be calculated by using shortest intermodal travel times between regions.

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

- **Access to nearest maritime ports.** What are the costs to reach the nearest maritime ports? For each NUTS-3 region the average generalised travel cost for different commodities to reach the nearest three maritime ports will be estimated. Modes considered will be road, road and rail and road and inland waterway.

- **European daily accessibility freight.** What market area can be served by lorries from a region? For each NUTS-3 region the amount of GDP that can be reached within the maximum allowed driving time of a lorry driver will be calculated.

- **European potential accessibility freight.** What is the relative competitive position of European regions towards European destinations with respect to freight transport? For each NUTS-3 region the GDP in destination regions will be weighted by the generalised travel time to go there. The weighted GDP will be summed up to give the value of the potential accessibility freight for the origin region. Freight handling categories considered will be unitised goods, bulk and general cargo thus reflecting different conditions with respect to impedance, e.g. different times and costs for loading and unloading. Modes included will be road, rail, inland waterways, short sea shipping and air. For those modes that are generally used in combination with other modes, e.g. short-sea shipping needs feeder service by an inland mode to connect non-coastal regions, travel times and costs will be calculated based on intermodal trip chains.

**Regional accessibility**

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

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

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

- **Access to high-level transport infrastructure.** What is the access time to reach the nearest entrance nodes of higher-level transport infrastructure? Access time to the nearest transport nodes (motorway exits, main rail stations and airport) will be calculated for raster cells for road and rail. Following the ICON approach access times will be aggregated by including the relative importance and utility of the different networks for the regional population. Aggregation from raster cells to NUTS-3 will allow comparison with other accessibility indicators.

- **Availability of urban functions.** What amount of urban functions can be reached in reasonable travel time? By looking at road and rail transport, it will be assessed which functions of cities with more than 50,000 inhabitants can be reached within a travel time of 60 minutes maximum. Calculation will be made for raster cells and will be aggregated to NUTS-3 regions.

- **National potential accessibility travel.** What is the relative competitive position of regions towards national destinations? This indicator is similar to the potential accessibility at the European level. For each NUTS-3 region the population in destination regions will be weighted by the travel time to go there, and the weighted population will be summed up to give the value of the accessibility potential for the origin region. However, the destinations will be restricted to regions in the same country as the origin region. That means that in practice national accessibility calculations will be done separately for each country of the ESPON space and the Western Balkan. The potential accessibility indicator will be calculated for road and rail.

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

- **Access to freight terminals.** What is the access time to reach the nearest freight terminals? Access time to nearest transport nodes (cargo transport centres, seaports, inland ports, airports with cargo handling) will be calculated for raster cells for road and rail. Following the ICON approach access times will be aggregated by including the relative importance and utility of the different networks for the regional economic actors. Aggregation from raster cells to NUTS-3 will allow comparison with other accessibility indicators.

- **Availability of freight terminals.** What amount of options do regions have with respect to freight logistic centres? By looking at road transport, it will be assessed which number of freight terminals can be reached within a lorry travel time of two hours maximum. The indicators will be calculated for raster cells and will be aggregated to NUTS-3 regions.

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

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

- **Access to regional centres.** How distant or how far is the nearest regional centre? Proximity to an urban centre has often been used as a proxy for accessibility to jobs and different services such as higher education, health care, commerce etc. For each municipality or raster cell of the case study region, the minimum travel times by road and public transport to the nearest urban centre will be calculated.

- **Daily accessibility of jobs.** How many jobs can I reach from my place of residence? This indicator approaches the opportunities of the regional labour market from the point of view of the population. For each municipality or raster cell the amount of jobs reachable within a maximum commuting distance of 60 minutes by car and by public transport will be estimated.

- **Regional potential accessibility.** What is the regional population potential of a municipality? In order to evaluate the different locations within a region from the viewpoint of economic actors, e.g. firms assessing the regional labour market, or retail industries assessing the market area, the population potential of each municipality or raster cell within the case study region will be calculated. As for the other spatial levels the population potential will be calculated as the sum of people in destination areas weighted by the travel times to go there. Modes considered will be road and public transport.

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

- **Access to health care facilities.** What is my travel time to go to the nearest hospital? Travel times for each municipality or raster cells by road and by public transport will show the spatial diversity in access to important health care facilities.

- **Availability of secondary schools.** Do I have access to secondary schools in reasonable travel time and do I have a freedom of choice to select between different options? For each municipality or raster cells travel time contours of 30 minutes travel time by road and by public transport will be calculated, and it will be checked how many secondary schools will be reachable within this travel time.

- **Potential accessibility to basic health care.** What is my locational quality with respect to basic health care? Using general practice surgeries as destination activity in a potential accessibility indicator allows to assess the relative distribution of health care provision of different areas within the case study region. For each municipality or raster cell, the potential value is calculated as sum of general practice surgeries located in the case study region weighted by travel times by road and public transport. Depending on the data situation in the individual case studies, primary schools or secondary schools might be used instead of general practice surgeries.

**Implementation**

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

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

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

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

**Accessibility impact indicators**

As indicated in Chapter 4, the relevant impacts of accessibility at the European or national level are *economic* and *environmental* impacts. At the intraregional level, the most important impacts are *social* impacts.

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

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

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

What are the linkages of European regions to the world? How are the regions embedded in the global economy seen from an accessibility point of view? What are their linkages to global hotspots outside Europe or to European gateways to the world, what is the necessary transport effort to such destinations? To address such questions, TRACC has developed a set of global accessibility indicators that go beyond the few examples in the literature that usually provide restricted travel time indicators from airports only. The TRACC set of global accessibility indicators provides progress as it includes also freight accessibility indicators of the types cumulated opportunity and potential and as the indicators are not restricted to preselected rare points in Europe, but are calculated for all NUTS-3 regions of the ESPON space. This section can only provide a few illustrative examples; more is given in Volume 2 and Volume 4 of the TRACC Final Report.

A first illustrative approach to consider the global integration of European regions is to analyse the total travel effort people have to take into account when travelling to global destinations. As an illustrative example for that TRACC has calculated travel times from the European regions to selected global cities. Figure 6.1 presents the travel time from Europe to New York which serves as one proxy for such global hotspots. For each NUTS-3 region the shortest total travel time to New York City (Downtown Manhattan) was calculated. The travel time reflects intermodal trips from the centres of the regions. It is based on road, rail and/or air travel times to airports in Europe with intercontinental flights plus the flight time from there to New York, plus the travel time from one of the city's airports to Manhattan and includes necessary terminal times as well.

The travel times to New York differ very much across European regions (Figure 6.1). There are regions in Europe from which the total travel time is clearly below 15 hours. Not surprisingly, these regions are located in western parts of Europe with close access to airports with intercontinental flights. Countries in which most of the regions belong to this favourable group are the UK, Ireland, Iceland, Portugal and the Benelux. In addition, there are larger areas around Paris, Frankfurt, Madrid; Milano and Zürich and some smaller areas in Spain or France benefitting from relatively low travel times which can also be experienced when travelling from Copenhagen, Vien na or Rome. However, travel times clearly increase up to 18 hours in other regions of western Europe that have a longer access to intercontinental flight services; similar travel times have to be expected when travelling from capital city regions in eastern or northern Europe. Longest travel times exist from non-metropolitan regions in northern and eastern Europe; for few regions it might take almost a full day to travel to New York. This very unbalanced pattern of global accessibility is also reflected in the two other types of indicators describing global travel accessibility.

Global freight accessibility is described by three different indicators making reference to different dimensions. It is considered how far representative intercontinental global hubs are (travel cost type accessibility) as well as how much intercontinental traffic can be reached in a relatively short time (cumulated opportunities type accessibility) and, finally, the potential accessibility to intercontinental traffic. In order to get a comprehensive picture of the level of global accessibility of European regions the contribution of all three indicators should be taken into account.

The accessibility to intercontinental global hubs is significantly affected by the geographical position of regions. In general, western European zones are more accessible to the New York hub, while the South-eastern European zones are more accessible to the Shanghai hub. However, in most of the cases, for a European forwarder, the accessibility to European intercontinental ports is more critical than the connection from the European port to the overseas port. In other words, the navigation time for deep sea shipping is usually far less important than the time and cost of the European leg of the shipment. For instance, despite reaching Shanghai is faster from Genoa than from Le Havre, for the Paris region the latter is a much more convenient port than the former.
That’s why it is important to consider the access to European intercontinental ports, described by the other indicators. The picture these two indicators provide is somewhat different as the relevance of the geographical position changes and the role of infrastructures rises, with particular reference to rail and water accessibility (Figures 6.2 and 6.3). As far as rail (and road) is concerned, a clear separation is visible between central western Europe and peripheral Europe in terms of global freight connectivity: peripheral regions are connected to a much lower amount of intercontinental container throughput (Figure 6.3). The geographical position matters as the most important intercontinental ports are at the North Sea, but also to the poorer inland infrastructures in some regions (e.g. the Balkan area or the extreme north of Norway) or the distribution of rail intermodal centres has an effect. Infrastructures – i.e. ports and inland waterways – are of course of particular relevance for water accessibility (Figure 6.2). From this point of view it should be considered that the picture of accessibility shown in the maps can change if some ports are subject of large improvements which attract new traffic (as the case of Gdansk, for instance, where the opening of direct services with China has increased the port throughput at the extent that is might become one of the major intercontinental hub ports in Europe). Another significant change might occur if future melting of North Pole ice because of global warming makes the Northern Sea route an available alternative towards East.

The analysis of global accessibility of different parts of Europe crosses with the considerations on global accessibility by different transport modes. Modes should not be considered as pure competitors. In some terms they are at least partially complementary. Water (especially maritime) is a convenient transport alternative especially for larger volumes of freight on longer distances. Its role in the logistic chain is closer to the production than to the consumption end. Conversely, road transport is more efficient for small or even individual shipment and to reach the final distribution. Rail is in an intermediate position. Therefore different levels of accessibility depending on the transport mode considered can also suggest that different functions can be located in one region. For instance, southern Europe, which is better ranked in terms of global accessibility by water, performs better as European transhipment platform to handle large volumes to and from overseas. At the same time, despite maritime transport is dominant for the freight transport between Europe and Asia, land routes (mainly by rail but also by truck) exist and might develop in the future. Considering inland connections, the global accessibility of eastern European regions would be higher.

In summary, there are differences in terms of global freight accessibility between European regions which partly depend on their geographical position and part on availability of infrastructures. However these two aspects are not independent. While it is difficult to conceive that Scandinavian countries or Finland can fully remove the gap of accessibility due to their position, the advantage of the North Sea area is the result of the location of European major ports which however are not there only by chance but also because they can benefit of the geographical centrality. Nevertheless, the progressive rise of Far East as trade partner opens to Mediterranean regions the perspective of exploiting a position advantage. In this respect, efficient multimodal infrastructures (ports, transhipment facilities, intermodal centres, roads, railways) might increase the global accessibility of Southern Europe regions thus reducing the current differences with respect to the North Sea area.
Figure 6.1: Accessibility to global hubs: travel time to New York City.
Global freight connectivity (2011): Intercontinental container throughput (Ths. TEU) of European sea ports reachable within 72h Sea Shipping/Inland Waterway travel time (3 days)

- Capital cities
- Intercontinental Container Seaport (>250000 TEU/year)

Figure 6.2. Global freight connectivity – water
Global potential accessibility freight (2011): by rail to intercontinental container throughput of European sea ports (percentage of average accessibility by rail of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...

• Capital cities
○ Intercontinental Container Seaport (>250000 TEU/year)

Figure 6.3. Global freight connectivity – rail
7 Accessibility to European destinations

European accessibility indicators are expected to provide assessments of the attractivity and competitiveness of European regions in the European context based on their location and their integration in the transport networks. Compared to existing indicators, the TRACC set of European accessibility brings value-added as traditional accessibility indicators such as the accessibility potential have been updated to a current point in time, as additional new types of accessibility indicators and in particular of indicators addressing freight transport will enable new insights into European accessibility conditions.

Most of the accessibility indicators for passenger travel display huge disparities across the European regions. This is in particular visible in the potential type of accessibility indicators. The example presented in Figure 7.1 is European potential accessibility, intermodal. It shows the relative competitive position of European regions towards European destinations by using the best combination of all transport modes in intermodal trip chains.

The second example for European travel accessibility is devoted to a somewhat different approach on analysing the opportunities or restrictions that transport infrastructure provide to city citizens. The urban connectivity indicator displays from cities to other cities reachable within certain travel time bands. The higher the number of possible travel connections to other cities the greater are the opportunities for business activities, city networking or for social interaction. Figure 7.1 shows for road travel the international connectivity of cities, i.e. national destinations are excluded to display the opportunities for international interaction of urban actors.

International urban connectivity for road is mainly restricted to neighbouring countries: Relations within the Benelux countries and towards Northern France and Western Germany are those with highest accessibilities, so as relations between Portugal and Spain, Spain and France, France and Switzerland and Italy. There are also many fast city-to-city relations along the former Iron Curtain between East Germany and Poland and the Czech Republic, between Austria and Slovakia and Hungary, as well as between Italy and Slovenia and Croatia. In general, taken all modes and intermodal urban connectivity together, the picture looks quite promising but there are still some interesting observations:

- Even though many East European cities can be reached quite well from Western Europe, connectivity between cities in the East is significantly lower. The number of city-to-city relations below 300 minute threshold within Eastern Europe is much lower compared to Western Europe, and if they exist travel times are on average much longer.

- Similarly, international urban connectivity between the Nordic countries is poor. Cities in the northernmost territories are mainly well connected by flights to the capitals, but not between themselves.

- For all modes results clearly visualize the 'blue banana', i.e. the area in Europe with highest accessibilities ranging from London via Benelux and Paris, along the river Rhine valley towards Northern Italy. Clearly for road and rail, but even for passenger flights o/d relations within this part of Europe show by far shortest travel times. This of course is first of all due to the rather dense network of cities (and consequently the short geographical distances between them), but also the high-standard transport infrastructures in these areas contribute to these high connectivity.

- Despite recent efforts to overcome the Pyrenees barrier, the Iberian Peninsula is still suspended from rest of Europe. For road and rail only very few o/d-relations are below five hours threshold, but even for passenger flights average travel times from Portugal or Spain to other countries are quite long.
Three indicators illustrate freight accessibility of NUTS-3 regions at the European level. A travel cost type accessibility indicator provides a measure of the closeness to the nearest maritime ports. Cumulated opportunities type accessibility is measured by the size of GDP which can be reached within the legal daily driving time. Both these two indicators are related to one specific mode (water and respectively road). Potential accessibility is examined for all the alternative modes.

A large volume of freight concerning intra-Europe trade is moved by ships, however most of this volume consists of large shipments of bulk goods. As far as daily shipments of intermediate as well as final products are concerned, inland modes are however dominant. Therefore a representative picture of European freight accessibility needs to consider all modes. The accessibility to closest ports provides an integrated measure of the level of accessibility of regions with respect to maritime freight terminals, as an important element in the economy to allow exports of local commodities and imports. In this respect, the indicator is computed with reference to ports with a throughput of at least 4 million tonnes yearly, i.e. those ports which actually play a role as gates towards other regions. Not surprisingly, coastal zones are generally more accessible. Nevertheless, geographical position is not enough and even coastal zones may have a poor accessibility if infrastructures (ports) are not adequate (i.e. only minor ports are located nearby or connections are expensive).

The message coming from the spatial pattern of the cumulated opportunities indicator (which is computed for trucks only, but road is the dominant inland freight transport mode) and of the potential accessibility indicators is that a group of regions in the central-western part of Europe have a clear advantage in terms of freight accessibility. This group of regions covers the Benelux, the western side of Germany, the northern edge of France and the southern side of UK. Around this core area, other neighbouring regions may be very well positioned according to one or more indicators even if there is always at least one measure for which they are significantly weaker than the core area. For instance, Denmark has good accessibility levels by water and also by unitised rail, but it is well below the average for road. The multimodal indicators reflect the prevailing role of the core area both for unitised and for non-unitised goods (Figure 7.3).

The separation between unitised and non-unitised goods is especially relevant for rail transport. Non-unitised goods represent pure rail transport, which does not need intermodal centres, but just of the rail network, which is quite homogenously available over the whole European territory. Instead, for combined transport (road + rail) of unitised goods the proximity to intermodal centres becomes a very significant accessibility factor. Thus, despite an overall decrement moving from the centre to periphery can still be observed, there are some regions e.g. in Italy or south France or Czech Republic with levels of European potential accessibility higher than e.g. some German regions thanks to the availability of intermodal facilities. The position of intermodal centres is also detectable in the differences of accessibility of regions in western France or in Italy.

Combined transport is the most dynamically growing segment of rail freight so promoting the accessibility for unitised rail could be considered a key strategy for the development of regions. However, it is relevant to observe that, unless a large growth of rail freight volumes is expected in the future, there are organisational reasons for intermodal centres not covering all the European territory in a homogenous fashion. Below a certain threshold of throughput, intermodal centres – which are usually private facilities – are not economically sustainable. It is therefore reasonable that they collect freight from a catchment area which can extend beyond a specific region. This means that the current pattern of unitised rail accessibility is correlated to a picture of those zones that have built a competitive advantage in infrastructural and logistical terms. This advantage could not be easily reduced by other regions in the future.

In brief, geographical position, availability of infrastructures and strength of the economy are the three key elements which describe the pattern of European accessibility. There is no need to say that these elements are correlated to each other.
Figure 7.1. Potential accessibility to population, intermodal
Urban connectivity: Road, international (2011)

- 0 - 90
- 91 - 120
- 121 - 150
- 151 - 180
- 181 - 210
- 211 - 240
- 241 - 270
- 271 - 300

City > 50,000 inhabitants

TRACC zones

Figure 7.2. Urban connectivity, road, international
Multimodal European potential accessibility freight (2011): Accessibility potential to GDP (unitised) (percentage of average accessibility of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

Figure 7.8. European potential accessibility freight – multimodal unitised
8 Accessibility to regional destinations

Regional accessibility indicators are to provide the base for an analysis of the restrictions and opportunities for daily life provided by the transport infrastructure in the regions to population and economic actors.

In relation to passenger transport, core areas in Europe have better access to high-level transport infrastructure than peripheral regions, as they tend to have denser motorway networks, good rail networks and concentrate most air hubs. This implies that citizens in core regions are more likely to seamlessly travel in Europe or easily access global transport getaways (higher availability of transport services, of direct point to point connections to other European cities, and shorter trip legs on local and regional road and rail networks). Outside the Core, national capitals (e.g. Warsaw, Madrid, Helsinki) and reference touristic regions (e.g. the Spanish Mediterranean coast and islands, Naples) provide areas of increased regional connectivity.

In relation to freight transport, best connectivity is recorded in the Atlantic rim between the Benelux and Germany due to the presence of largest container ports in Europe, in addition to denser motorway and freight village networks (Figure 8.1). The Mediterranean rim has large container ports as well, even if well behind Northern European ones, but less dense motorway and freight village networks in their hinterlands limit high connectivity scores only to coastal fringes, to a large extent. As Mediterranean ports are better positioned in the international shipping routes to Asia, should expansions of capacity be undertaken in these ports as planned and better connections provided with the European hinterland, overall connectivity of the Mediterranean rim could increase sensibly in the future.

Access to and availability of public and private services and functions provided in urban centres is crucial for daily life of citizens. The overall pattern of availability of urban functions is similar to that of passenger connectivity (Figure 8.2). Capacity of reaching large numbers of regional centres within limited travel time (cities larger than 50.000 inhabitants accessed in up to 60 minutes) is once again highest in the core of Europe, in selected capital city regions in other countries, and in other prominent regions such as south-western Scandinavia (Oslo-Gothenburg-Copenhagen), the Spanish Mediterranean corridor (Murcia to Barcelona), the Rhone valley, Saxony, Southern Italy, and Upper Silesia city district. From most locations in Europe, at least one regional centre can be reached in less than 60 minutes travel time by road, but only people in western Europe have options to visit more than five different cities in that time. The situation for rail is less developed. Here, inner peripheries with low accessibility values are not only located in the far North or in the Alpine space, as expected, but also in most European countries. The extent of these inner peripheries is substantially larger for rail than for car.

National Potential Accessibility for a specific NUTS-3 region is a construct of attractiveness of all other NUTS-3 regions in the country and generalised costs needed to reach these regions from the origin region. As the analysis is performed on a strict national basis, country borders are forced impermeable so foreign NUTS-3 regions become inaccessible from another country. In doing so, this indicator allows identifying a ranking of the regions within each country according to their proximity to the higher levels of national economic activity. Regions with a high potential accessibility have more opportunities to arrange a spatially distributed value chain in the domestic economy, have more alternatives in terms of national supply and demand market and so on.

Figure 8.3 shows the spatial pattern of national potential accessibility using rail as illustrative example. Each country has its highly accessible areas and its own peripheral areas. However, the pattern differs across Europe. Most of the countries in eastern and northern Europe have a clear core periphery pattern in which mostly the capital region performs best and the border regions have lowest accessibility. In other countries, there are larger corridors of higher accessibility; a consequence of a more polycentric distribution of population and network design or a consequence of the effects of high-speed rail services. In some countries such as Italy or
Germany, highest accessibility is not to be found in the capital regions but around other important agglomerations. In some countries such as Poland or the Czech Republic areas that are located closer to the European core and thus have a fairly good European rail accessibility are rather peripheral when considering the national context.

The most significant finding in relation to the set of travel and freight national potential accessibilities is the large amount of regions that are likely to loose out substantially when they are restricted to access only national activities. This is especially important in regions such as Western Poland (at the German Border), North-eastern Germany (Danish and Polish borders), Southern Germany (Swiss, Austrian and Czech borders), Eastern France (German and Italian borders) and Southern France (Spanish borders).

This exercise, despite being fictitious up to a certain extent, reflects the potential opportunities lost from decreased or even from insufficient European integration (often due to cultural, social and even language issues). For instance, lack of integration in health and educational systems around Europe may force citizens in border regions to travel more (e.g. to national capitals) for certain higher education options or for complex health treatments that would otherwise do if integration was greater. Language obstacles may force citizens to move further within their countries for better job opportunities than would otherwise do if labour markets were more integrated and language barriers were lower.

Being to some extent economic integration larger in Europe than social and cultural integration, potential loses are more accurately portrayed under the travel national potential accessibility maps than in freight ones.
Figure 8.1. Access to high-level freight transport infrastructure by 5x5 grid cells
Figure 8.2. Availability of urban functions, rail
Figure 8.3. National potential accessibility, travel by rail to population.
9 Accessibility to regional and local destinations

Global and European accessibility are important location factors for firms and working and leisure travel of people. However, for the daily life of citizens, regional/local accessibility to jobs, services and public facilities may be more important than global or European accessibility. One part of the TRACC project was therefore concerned with regional accessibility in a set of regional/local case studies in order to gain systematic knowledge on accessibility patterns in different types of regions throughout Europe. Case studies are presented in detail in Volume 3 of the TRACC Final Report.

One of the technical objectives for the regional case studies was to implement the methodologies as similar as possible in order to allow a comparison of the resulting accessibility patterns not disturbed by artefacts induced by methodological differences. In each case study, the set of regional accessibility indicators as defined in the TRACC set of accessibility indicators was implemented, calculated and analysed in a highly comparable way.

A pragmatic component had to be part of the case study selection process. Only those areas could be selected as case studies for which project partners had already a fairly good database for accessibility modelling. The seven TRACC case study regions selected are: West Mediterranean in Spain and France, Northern Italy, Bavaria in Germany, the Czech Republic, Poland, the Baltic States and Finland. Together, they form an arc stretching from the Mediterranean Sea in south-western Europe up to the far north of the Nordic countries.

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

The results for the different accessibility indicators across the seven case studies can be summarised as follows:

- **Access time to next regional centre.** Results are relatively similar in all case studies for car with minimum values (25th percentile) around 20 to 30 minutes, and maximum values (75th percentile) around 40 to 60 minutes. More populated case studies tend to have better values (Poland, Northern Italy, Western Mediterranean), while case studies comprising sparsely populated regions tend to have higher access times (Finland, Baltic States, Czech Republic). Access time to next regional centre by public transport provides much more diversity of results. While minimum values (25th percentile) are fairly similar for all regions around 30 to 40 minutes (except in the Baltic States, with 60 minutes), maximum values (75th percentile) show a wider dispersion going from around 60 minutes for Northern Italy case study to 120 minutes for the Baltic States (Figure 9.1).

- **Access time to hospitals.** Minimum access times (25th percentile) and maximum access times (75th percentile) are lower than those observed for accessing regional centres, in all case studies. This reflects that the threshold for providing hospital equipments in Europe is generally below the 50,000 inhabitants. Therefore, the health system is more easily accessed than the network of medium sized cities in Europe would seem to intuitively provide a priori. The relative differences of access times between urban, intermediate and rural regions are similar for this indicator than those observed for accessing regional centres (Figures 9.2 and 9.3).
• **Availability of jobs and secondary schools.** These indicators reveal in all case studies a more unbalanced performance between different territorial typologies than all other indicators. In all cases, except for Czech Republic, urban regions have a clearly differentiated behaviour in relation to intermediate and rural regions in terms of opportunities reachable. This is especially important by car, but also relevant by public transport. The overall magnitude of cumulated opportunities varies widely from one case study to another, mostly depending on the total amount of population (Figures 9.4 to 9.6).

• **Potential accessibility to population and to medical practitioners.** The potential type indicators show a much more unbalanced pattern between urban and rural regions than access time indicators. As expected, all urban regions perform substantially better than intermediate and rural regions, and much better than overall case study averages. Differences between different territorial typologies are more visible by car accessibility than by public transport (Figures 9.7 to 9.10).

The results from the case study analysis lead to the following conclusions:

• **Minimum availability of functions vs diversity of services and activity on offer.** Indicators considering merely the availability of activities and services, i.e. travel time to the closest target activity or service (Ind1 and Ind4), provide more decentralised patterns on the territory than indicators accounting for the magnitude of available offer, regardless if they consider cumulated opportunities or total potential accessibility. The latter tend to reflect polarisation in largest metropolises and well deserved transport corridors and quickly diminish towards more remote areas, while the former tend to provide more balanced patterns across territories. This reflects that minimum service and administrative endowments are granted to a reasonable extent in most areas of Europe (e.g. at least one hospital available, at least one regional centre available), but differences reveal to be more acute when analysing the amount of possible alternatives of choice for between most populated urban areas and more sparsely populated rural areas (e.g. number of jobs available, schools, doctors).

• **Public services endowment vs availability of economic / social activities and private services.** In general, out from all case studies it seems to appear that the distribution of public services in Europe is much more balanced than the distribution of economic and social activity (population, jobs). This can be attributed to the nature of European welfare systems, where administrations care for minimum endowments of services in less accessible areas, e.g. in rural areas or in peripheries. A few case studies, however, have pointed out the danger of diminishing accessibility to public services driven by the financial crisis in Europe, due mostly to the withdrawal of the public sector and the process of recentralisation of services towards larger regional centres.

• **Public transport accessibility vs car accessibility.** The results illustrate that a distinction between different modes is clearly needed. Accessibility patterns for cars and public transport differ to a large degree, both with respect to the level and also with the spatial patterns, so that modelling results for one mode cannot be used as proxy for the other mode. While accessibility indicators for cars tend to form different types of plateaus, the same indicators for public transport form ‘stretches’ and ‘bands’ of high accessibilities along certain transport axis, interrupted by areas of low accessibilities where public transport is missing. Apart from this, in general as demonstrated by the indicator calculations, the accessibility levels by car are higher than those for public transport, but still in city centres and for along some axes public transport is able to reach as high levels as cars do. Regarding public transport as such, one may furthermore think of even splitting ‘public transport’ mode into individual indicators for rail and bus/tram.

• **Lack of Services vs lack of infrastructure.** Accessibility is a matter of both transport infrastructure endowment and availability of services in destinations. In some case studies,
low accessibility values tend to reflect most remote areas within regions, often substantially less populated (e.g. in interior regions of the Western Mediterranean case study or in northern regions of the Finland case study). In other case studies, low accessibilities are mostly driven by poor transport infrastructure endowment, more often in Eastern Europe than in Western Europe (e.g. in Poland, the Baltic States and Czech Republic). In this direction, reports on Economic and Social Cohesion by DGRegio (2007, 2010) point out to the fact that improved accessibility tends to create new job opportunities for rural and urban areas but that potentialities from improving accessibility depend on the previous competitiveness of the regions concerned, being some regions liable to lose out as they become more open to competition from elsewhere. The reports claim the importance of combining investment in transport infrastructure with support for businesses and human capital development to achieve sustainable economic and social development.

- **Territorial Typologies.** In all countries, accessibility for capital regions or for main agglomerations differed significantly from that for rural, peripheral and landlocked regions, as well as for intermediate areas. Therefore, the aggregation of raster results to different types of regions provides additional insights into accessibility patterns of a study area. Even though in this study only six zoom-in areas and only five different types of regions were used, interesting findings were obtained. A combination of raster approach with a typology approach deems promising to obtain high-resolution results on the one hand and easy-to-communicate summary results on the other hand.

- **European peripheries vs European core.** In general, no significant differences can be observed in terms of regional and local accessibility between case studies located in the European Periphery (e.g. Finland, Baltic States or West Mediterranean) and case studies located in the European Core. Regional and local accessibility in all case studies depends to a higher extent on the total level of population living in the concerned region and the level and quality of transport infrastructure endowment.

- **On accessibility indicators.** Accessibility of a region cannot be assessed by just one indicator. In case studies a set of six different accessibility indicators were identified which should help analysing different aspects of access to markets and access to public services. In fact, the results for the different indicators have shown that this broad set is quite useful as the individual indicators are in fact able to depict different facets and different spatial structures. Only results of the last indicator, i.e. accessibility potential to basic health care, seem questionable since this indicator too much reflects the national health care systems rather than locational advantages or disadvantages. Moreover, the definition of this indicator as a potential indicator may be questionable, since one may discuss whether the number of doctors is really a good ‘weight’.

- **On spatial resolution of indicators.** Several findings of this study are based on grid cell maps, free of administrative divisions. Several particular areas and spatial patterns can be noticed only on the grid cell basis. TRACC has proven that even at the level of zoom-in regions significant intra-regional disparities exist, which cannot be detected by the traditional, aggregated models. Such intra-regional disparities are often greater than those between regions, thus accessibility studies should acknowledge these disparities and should find ways how to capture them. Raster approaches allow capturing the fine grained accessibility surfaces generated by public transport and also reflect the axial structures caused by high-level transport infrastructures. Raster approaches provide more accurate images which are not dependant on the size of territorial units (e.g. NUTS-3 or LAU-2), a recurrent problem in any mapping and modelling activity. Another advantage of the raster approach is that results can be afterwards easily aggregated to any spatial level, such as LAU-2 or NUTS-3 (as done in this study), or higher. Also, comparisons and cross-over correlations with other variables such as population distributions are easy to implement.
Figure 9.1. Travel time to next regional centre by urban-rural typology (minutes)

**Finland**

**Baltic States**

**Poland**

**Czech Republic**

**Bavaria**

**Northern Italy**

**West Mediterranean**
Figure 9.2. Car travel time to next hospital.
Figure 9.3. Public transport travel time to next hospital.
Figure 9.4. Jobs available within 60 minutes car travel time
Figure 9.5. Jobs available within 60 minutes public transport travel time
Figure 9.6. Secondary schools available within 30 minutes travel time by urban-rural typology
Figure 9.7. Potential accessibility to population by car (Index: each case study average = 100)
Figure 9.8. Potential accessibility to population by car (absolute values)
Figure 9.9. Potential accessibility to population by public transport (Index: each case study average = 100)
Figure 9.10. Potential accessibility to population by public transport (absolute values)
Chapters 10 to 13 to be developed
14 Policy implications

- **Accessibility is a 2 dimensions driven variable:** Accessibility consists of two components, available activities of interest and transport infrastructure leading to them. Low accessibility values reflect in some cases sparsely populated areas and/or low service endowment, often in the European peripheries; but in others cases low accessibility values are driven by poor transport infrastructure, more often in Eastern Europe than in Western Europe. Accessibility related policy should not only concentrate on the transport infrastructure side as investments in the points of interest might be more efficient.

- **Global travel accessibility.** Seen from an accessibility perspective, the integration of European regions in the global economy is very heterogeneous. In particular for passenger travel, huge differences exist between European regions in terms of linkages to global destinations and global accessibility.

- **Global freight accessibility changing.** The progressive rise of Far East as trade partner opens to Mediterranean regions the perspective of exploiting a position advantage. In this respect, efficient multimodal infrastructures (ports, transhipment facilities, intermodal centres, roads, railways) might increase the global accessibility of Southern European regions thus reducing the current differences with respect to the North Sea area.

- **European travel accessibility patterns.** The dominating accessibility pattern in Europe for passenger transport is as follows: highest values in the Core of Europe, in capital city regions in other countries, and in other selected industrial or touristy regions such as Southwestern Scandinavia (Oslo-Gothenburg-Copenhagen), the Western Mediterranean coastal corridor (from southern Spain to northern Italy), the Rhone valley, Southern Italy, Saxony and Upper Silesia. Citizens in core regions are more likely to seamlessly travel in Europe or access global transport getaways (more transport services and point to point connections, shorter local trip legs) as they have denser motorway and rail networks and concentrate a higher number of European and global air hubs.

- **European freight accessibility patterns.** Geographical position, availability of infrastructures and strength of the economy are the three key elements which describe the pattern of European accessibility in relation to freight. Logistic activities tend to follow population and economic concentrations. Best connectivity to freight transport networks is recorded in the North Sea due to the presence of largest container ports in Europe, in addition to denser motorway and freight village networks. The Mediterranean rim has large container ports but less dense motorway and freight village networks in their hinterlands limit to a large extent high performance to coastal fringes. Main inland waterway axes (Rhine, Danube, Elbe) and canal systems in Germany back up good freight accessibility performance.

- **The cost of low EU Integration.** The comparison of potential accessibility patterns restricting origins and destinations within EU Member States or allowing for European wide mobility shows that an important number of European regions are likely to loose out when they are restricted to access only national activities, or in other words under lower EU integration conditions. This is especially obvious in border regions like western Poland, north-eastern and southern Germany, eastern and southern France. Low European integration can be due to political issues like border permeability to economic flows but more importantly due to cultural issues like barriers that languages represent to seek jobs or study abroad.

- **Local and regional peripheries do not match EU peripheries.** No significant differences can be observed for performance in regional and local accessibility between regions located at the European Periphery and regions located at the European Core. Regional case studies
have revealed relatively homogeneous patterns within regions. Regional and local accessibility in case studies is much more dependant on the local conditions of population and economic activity than to their overall European localisation.

- **The East-West divide still persists at regional level.** From most locations in Europe, at least one regional centre can be reached in less than 60 minutes travel time, but only people in Western Europe have options to visit more than five different cities in that time. Infrastructure endowment is still much lower in Eastern Europe, so despite having relatively similar levels of service provision, accessibility to services remains lower than in Western Europe. Accessibility to transport infrastructure is also lower in Easter Europe.

- **The Urban-Rural divide still persists at regional level.** Accessibilities for capitals regions or for main agglomerations differ significantly from those for rural, peripheral and landlocked regions, as well as for intermediate areas. Minimum services are available with reasonable cost in most areas of Europe, even remote rural or sparsely populated, but the possibility to choose amongst different alternatives is concentrated in highly populated urban areas. Indicators focussing on availability of activities and services (travel cost) provide more balanced patterns on the territory than indicators focussing on the diversity of offer (cumulated opportunities, potential accessibility) which tend to provide more polarised patterns around largest metropolises and well deserved transport corridors.

- **Inner peripheries in all regions.** Inner peripheries with low accessibility values are not only located in the far North or in the Alpine space, as expected, but also in most European countries. The extent of these inner peripheries is substantially larger for rail than for car.

- **Balanced access to services of general interest.** The analysis of case studies show a balanced geographical distribution of public services in Europe, allowing for minimum service availability despite of population figures or economic activity of regions. Many case studies have identified the threat of diminishing accessibility to services of general interest caused by withdrawal of the public sector in the framework of the current financial crisis.

- **Public transport accessibility below car accessibility.** Accessibility patterns for cars and public transport differ to a large degree, both with respect to the level and also with the spatial patterns. Accessibility levels by car are in general higher at regional and local level than those for public transport, but public transport is still able to provide high levels of accessibility within metropolitan areas and in city centres, and along well deserved axes is. Accessibility indicators for cars tend to form different types of plateaux, while for public transport the same indicators form ‘stretches’ and ‘bands’ of high accessibilities along transport axis, interrupted by areas of low accessibilities where public transport is missing. Most of the case studies and most of the indicators applied demonstrate that accessibility by car is superior to accessibility by public transport. Only in a few metropolitan areas public transport is providing comparable accessibility to the population.

- **Impact of financial crisis.** Accessibility is a matter of transport infrastructures and of availability of functions. As for transport infrastructures, the impact of the financial crisis is likely to be detrimental in the light of the pro-cyclic approach in public investments dominating the EU architecture. Shortage of financial resources can easily lead to postpone or even cancel planned public investments, whilst private investments are also likely to slow down significantly. The picture could be different if the role of public expenditure as engine of aggregate demand to tackle economic crisis is re-discovered. As for availability of functions, two main linkages with the crisis can be mentioned. First, for some of the TRACC indicators public services (schools, hospitals) are involved. The concentration of services with the closure of minor local sites has been announced somewhere in the last years. The financial crisis could provide the rationale for put this into practice. In that case, especially accessibility based on travel costs could significantly worsen for many (mostly peripheral) areas. Second,
the crisis has been deepening (further than being fuelled by) disparities between European countries. So, current unbalances in potential accessibility to economic activity are likely to increase.

- **No clear significant overall patterns observed in relation to impacts of TEN-T projects in case studies.** Impacts observed varied largely from one case to another. The diversity of typologies of projects in each case, and the use of particular hypothesis for final performance of envisaged infrastructures (e.g. speeds in new rail links) may be in part responsible for these differences. In a number of case studies, largest metropolitan areas and urban regions tended to win less in relation to intermediate and rural regions (e.g. in the Czech Republic, in the Baltic States, and to some extent in the Western Mediterranean and in Finland). In Poland, road projects benefit to a higher extent the Warsaw – Katowice region, but also important gains can be observed in the far less populated eastern regions bordering with Belarus and Ukraine.

- **Specialised accessibility indicators.** Individual accessibility indicators are to depict different facets and different spatial structures. Accessibility cannot be assessed by just one indicator. Travel cost indicators to next “function” indicate the possibility of regions to have access to certain functions, while cumulated opportunities and potential accessibility indicators also include the variety of functions and therefore reflect the magnitude of alternative choices available. Potential indicators tend to show more laminar patterns (progressive), reflecting overall patterns, while availability of functions are more affected by singularities in the territory.

- **Raster approach to increase resolution of accessibility analysis.** A majority of the findings in TRACC are based on grid cell maps, free of administrative divisions. Several particular areas and spatial patterns can be noticed only on the grid cell basis. TRACC has proven that even at the level of zoom-in regions significant intra-regional disparities exist, which cannot be detected by the traditional, aggregated models. Such intra-regional disparities are often greater than those between regions, thus accessibility studies should acknowledge these disparities and should find ways how to capture them. Raster analysis allows for a more accurate identification of territorial patterns generated by high level and public transport corridors.

- **Raster Approach to Accessibility Modelling** The raster approach has turned out to be very useful in several indicators (e.g. connectivity analysis, Finland and Baltic State case studies), and should be developed further. Raster approaches provide more accurate images which are not dependant on the size of territorial units (e.g. NUTS3 or LAU2). Raster approaches allow capturing the fine grained accessibility surfaces generated by public transport and also reflect the axial structures caused by high-level transport infrastructures. Another advantage of the raster approach is that results can be afterwards easily aggregated to any spatial level, such as LAU2 or NUTS3 (as done in this study), or higher. Also, comparisons and cross-over correlations with other variables such as population distributions are easy to implement.

- **Public transport modelling approach.** The quantification of public transport accessibility could be improved by modelling different services (road public transport, regional trains, intercity trains…) as independent modes, allowing for multimodal trip chains. On the one hand this would allow to better identify the role of each mode (e.g. road public transport for short distances, often when train is not available, regional trains mostly for commuters, etc.), thus providing more precise estimations of times and costs for different demand segments/travel purposes (e.g. accessibility to schools would probably use different input than accessibility to hospitals or potential accessibility to population. On the other hand, modelling multimodal chains (even if in a simplified way) would allow to explore the role of interconnectivity and co-
modality, which are increasingly relevant concepts in public transport planning to provide efficient accessibility.

- **Freight transport modelling approach.** Some freight services are based on lines with fixed paths and stops (likewise public transport). Modelling these lines more explicitly would improve the representativeness of the accessibility indicators as the information on the regions pairs actually connected would be more precise. A pre-condition for implementing this approach on an European scale would be however the availability of a reliable and frequently refreshed database of the lines, which are continuously evolving. For rail-road combined transport some information exists, but for maritime container data is much more scattered and difficult to access. Still about freight, road freight accessibility is significantly influenced by assumptions on driving times and costs (e.g. respect or not of the maximum driving limits per day, use of two drivers, accompanied and unaccompanied trucks on ferries). Improvements on modelling of these aspects could be useful.

- to be further detailed and developed
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