Deliverable D5

ASSESSMENT OF SPATIAL AND SOCIO-ECONOMIC IMPACTS

CODE-TEN
Strategic Assessment of Corridor Developments,
TEN Improvements and Extensions to the CEEC/CIS
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Assessment of Spatial and Socio-economic Impacts

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1. Executive Summary

Shortly before the Single Market was established, the Commission of the European Communities perceived the need to develop Trans-European Networks (TEN). These networks were considered not from a sectoral angle, but as being closely linked to the constitution of the Common Market and to the problem of regional development.

These initial approaches were not left at the stage of a mere declaration of intentions, but were formalised as a proposal for Trans-European transport networks and in the creation of the so-called Cohesion Funds (Maastricht Treaty), destined to improve the infrastructure and environment of the lesser developed countries of the European Union.

The precise role of transport infrastructure in the process of regional development is still open to much debate. In its simplest form it is implied that a better infrastructure will lead to lower transport costs or to a wider range of choice and more competition. There seems to be a clear positive correlation between transport infrastructure endowment or interregional accessibility and the levels of economic indicators such as GDP *per capita* (Biehl, 1986; Keeble *et al.*, 1988). However, this correlation may merely reflect historical agglomeration processes rather than causal relationships, effective today (Brocker and Peschel, 1988).

In accordance with the Technical Annex “the CODE-TEN (Strategic Assessment of Corridor developments, TEN Improvements and Extensions to the CEE/CIS) focuses on the complexity of decision making in transport policy at the European level”(ICCR, 1997, p.2).

Integration and Expansion of transport corridors are the two words through which the current trend of transport geography of Europe can be expressed. The extension not only includes current expansion of the EU but also possible future expansion and activated (transport) contacts with CEEC/CIS and the Mediterranean. The main goal of Project CODE-TEN is to help with decision-making in the context of this complexity.

The present report is the output of 4th Work Package (WP 4) of CODE-TEN Project and its main purpose is to define a comprehensive list of indicators for measuring the spatial and socio-economic impacts of major transport projects like TEN.

In this section – Executive Summary – an overview about the structure and the context of the Deliverable D5 is given. This report is structured in three main sections:

→ Introduction (chapter **2**);

→ Strategic Territorial Impacts: a bibliography survey (chapter **3**);

→ Proposed Methodology for Assessing Strategic Territorial Impacts from Transport Projects (chapter **4**)
  → Measuring Accessibility (chapter **5**)
  → Corridor Assessment on the Basis of these Impacts: Displaying Accessibility Improvements (chapter **6**)

The intention of this structure is to start by presenting the relevant research, and then, based on the concepts used in the various studies, on the data requirements demanded for each model and on the results obtained in each, to propose a methodology for evaluating the strategic impacts from transport infrastructure improvements in the framework of the CODE-TEN project.

- In the first part (chapter **2**), the objectives of the CODE-TEN Project and the interrelationships among its Work Packages, as well as the methodologies that concern its main steps are reported. This section is focused on WP4 and on its role in the CODE-TEN Project.

  In order to define the desired list of indicators, the inputs provided by other projects should be used. These studies concern different types of sources: EC-DG VII: EC-DG XVI, scientific journals, conferences, etc. The interactive relation that WP4 establishes with other WP's (WP1, WP2 and WP6) is also referred in this part of the report.

- Second (chapter **3**), the results of the research made about accessibility indicators, socio-economic indicators and models of regional economic impacts of transport infrastructures, are reported. The aim of this chapter is not to present a detailed description of all the studies researched, but to understand their conceptual content and the way in which they can be related with our study.

  In the first section (**3.1**) of this chapter the first aim is to specify the type of impacts that are treated in this deliverable and to present a synthetic discussion of the "nature" of the relationship between economic development and transportation investments. The second aim is to compare the macro-economic and micro-economic analysis and define which one is more closely connected with the goal of the proposed methodology for measuring accessibility improvements presented in the chapter 4 of this deliverable.

  The survey of accessibility indicators was based on four studies, which are described in the section **3.2** of the present report.

  From the accessibility measures that were found, the most related with the objectives of WP4 are those which are reported on the UTS Study (Chatelus and Ulied, 1995). The aim of the accessibility indicators defined for UTS Study is to represent the transformations that changes in transportation improvements will likely induce in the development opportunities of each place. Here, independent multimodal indicators are defined for passengers and for freight.

  The socio-economic indicators' research was based only in SASI Project (*Technische Universitat Wien, Universitat Dortmund, University of Sheffield, 1997*). This survey is described in section **3.3**, which is divided into two parts: one related with the socio-economic indicators that are referred in this study and other in which an interpretation of such indicators as measure of the impacts of accessibility endowments in regional economic development is made.

  In the final part of the research (section **3.4** and **3.5**) various methods and models related to the regional economic impact of transport infrastructures were found. The main "lessons" received from the research made at this level are reported on the section **3.6**. In this section the relationship between the literature survey and the proposed methodology is stated and argued by reporting the operational uses of the accessibility concept found and the indicators and models researched most related with the CODE-TEN purpose.

The evaluation of changes in regional development thanks to the construction or improvement of transport infrastructure is presented in this last research through several points of view:

→ Proximity to the TEN and accessibility to activity centres along the road network;

→ Time, distance and cost impedance functions;

→ Factor-productivity, factor-mobility and interregional trade approaches;

→ Macro and micro-economic approaches, etc.

From all the papers found the most useful for our study seems to be the micro-economic approach, which is related with the specification of regional Computable General Equilibrium models (CGE) for simulating the short and long run effects of Cohesion Fund infrastructure project, as reported in the Study of Socio-economic Impact of Projects Financed by the Cohesion Fund, Modelling Report *(London School of economics and political Science, 1997).* This type of approach allows capturing a high level of project detail, and thereby, to discriminate between different projects in a way that empirical macroeconomic model cannot.

However, its use in the CODE-TEN Project is conditioned by its heavy structure (which is too much for an application with 10 corridors, each one with various alternatives), besides the efforts needed (available data with a high level of sectoral and regional disaggregation) to run it.

In relation to the other approaches we considered that none of those could be distinguished from the others with respect to a more favourable application in the CODE-TEN project.

These were the main arguments in favour of the methodological orientation proposed in chapter **4**.

- In the third part, a methodology for Assessing Strategic Territorial Impacts from Transport Projects in the CODE-TEN project is proposed. A summary of the proposed methodology is presented in chapter **4**, in which the reasons for choosing a new methodology are put forward and the main topics of that methodology are presented. Based on the conditions presented, a relatively simple methodology for which the required data is believed to be available in most cases is proposed.

  This methodology is divided into two main directions, which are Measuring Accessibility and Displaying Accessibility Improvements.

  - The first is reported in the chapter **5**, which is divided into two main dimensions covered by strategic territorial impacts of transport investments: Demographic Accessibility and Economic Accessibility. Both these indicators express the dimension of “partnership” that can be reached in a pre-specified travel time threshold associated with the 24-hour cycle of human activity.

    For demographic accessibility the population living in each reached region represents the number of partners, whereas for economic accessibility the potential trade of volumes (monetary units) play that role.

    The indices developed have to reflect conditions in passenger and freight transport. We decided to use conditions of passenger transport for demographic accessibility because this type of transport is more related with the population dimension whereas for economic accessibility it is the conditions of freight transport that are used, as it is more connected with trade flows and volumes. However, as it is explained in the chapter **5** and section **5.2.3**, the consideration of passenger transport conditions for calculation of economic accessibility indicators (by using the travel time defined for this type of transport) can also be used in some situations, particularly when thinking about service sectors.

Each one of the above dimensions is explained with more detail in sections **5.1** and **5.2**, respectively.

In the first dimension (section **5.1**) the adopted set of indicators for measuring changes of demographic accessibility is outlined, as well as the required data for the calculation of such indicator. Adaptation of accessibility indicators to make use of flows between pairs of regions is also reported and discussed in this section.

The second main dimension - Economic Accessibility - is referred in the section **5.2** of the present report. The concept of economic accessibility should be interpreted in connection with the potential gain of economic efficiency by reduction of transport costs in referred imports and exports. So, the model proposed for evaluating the relation between accessibility improvements and economic development of regions is based on the assumption that accessibility improvements should be treated as a gain of potential for economic development. The gains of accessibility are measured with respect to each of other regions and the weight of each region is defined in proportion to its relevance to the economic structure of the basis region.

Still in this section the data requirements and a simpler approach to be used in the cases for which the data needed for the calculation of economic accessibility indicator is not available, are presented.

Another concept that is analysed in this report is “Elastic Borders” which is reported in section **5.3**. Since the limits for aggregation of additional partners are always defined somewhat arbitrarily, we propose to introduce a certain “tolerance” in the maximum travel time, as we do in real life, by extending those limits by up to 10% if the dimension of the thus reached targets is worth it.

- In chapter **6**, a methodology is presented for displaying the improvements of demographic and economic accessibility for the various alternatives of each corridor. The reading of the improvements of accessibility for the various regions along the corridor is made both from a “global” perspective and from an “distribution” perspective. In the second perspective two approaches are presented: Considering Individual Regions’ Points of View and Building a Synthetic Indicator of Equality. The latter is based on the Lorenz Curve and the associated Gini index.

Finally, the conclusions are reported as a summary of the most important judgements and lessons that could be retained from this study. The difficulties that were found, as well as the assumptions made during the development of this report, are also reported.

2. Introduction

2.1 Objectives of the CODE-TEN Project and of this Deliverable

The objective of the CODE-TEN is to “apply the scenario approach to the study of TEN developments and corridor extensions to the CEEC/CIS, paying particular attention to the marginal long term effects and, in particular, the spatial distribution of environmental impacts and socio-economic impacts”. The main output of the CODE-TEN should be the development of a methodology for assessing transport policies and larger projects and following decision-assistance tools.

The scope of WP4 in accordance with the Technical Annex is to produce and define a comprehensive list of indicators for measuring the spatial and socio-economic impacts of major transport projects like TEN. The objectives of regional development and transport efficiency proposed by DG VII and DG XVI should also be considered in the elaboration of these parameters.

Elaboration of such a list of indicators has, among other things, made use on inputs from research in other tasks in the Strategic Transport part of the 4th framework Programme. For the specific purpose of CODE-TEN it ought to be useful to adjust some of the methodologies and parameters from these research projects. Thus, a first version of the list of indicators to be used will be produced on the basis of inputs provided by previous works done.

This report presents the work content and outcome of CODE-TEN WP4, and it is structured into two main parts, which are the **literature survey** and the **proposed methodology** for assessing strategic territorial impacts from transport projects. The proposed methodology is divided into main parts: the synthesis of selected indicators for measuring accessibility and the corridor assessment on the basis of these impacts.

3. Strategic Territorial Impacts: a literature survey

3.1 Spatial and Socio-economic Impacts

The spatial and socio-economic impacts under study in this report are related with the regional economic development implications of transportation improvements.

In recent years, there has been a resurgence of interest in the role of transport infrastructure and changes in accessibility on regional economic development. Although it has been clear that there is at least an association between transport infrastructure quality and economic development, it has often been extremely difficult to identify the precise nature of that association. More particularly, it has proved difficult to quantify it in a way, which can be satisfactorily incorporated in economic evaluations, especially of road programmes. It is needed therefore to set out carefully a more detailed economic analysis of the impacts of infrastructure.

The first aim of this section is therefore to bring a wide ranging historical approaches of the **“nature” of the relationship between economic development and transportation investments** which has been produced over the last years. The second aim is to present a **comparison of macro-economic with micro-economic analysis** and define which one is more closely connected with the goal of the proposed methodology for measuring accessibility improvements presented in the chapter 4 of this deliverable.

1. Concerning the first aim it has been consistently argued that there is a clear relationship over time between Gross Domestic Product (GDP - a measure of economic wealth) and a range of measures of transport and transport-related investments. Such comparisons have generally been made over the last fifty years since the advent of the car, and more recently of air travel. Since there have been no “principal” wars to reduce or change the direction of output it has also been a period of economic growth and stability. Likewise, there has been a substantial increase in trade within and between countries. So the demand for travel has increased in parallel with economic growth and many other measures of wealth - real income levels, wage rates, consumer goods, schools, life expectancy, etc - have also increased in a similar .

    However, there is no a priori reason why transport demand should rise with GDP because if efficiency and productivity increased, the links with GDP maye reduced. The transportation related to production and distribution processes (and individual passenger travel) could become either more or less intensive. In other hand, the simple linear relationship may be broken if prices rise substantially or if there is a concerted international action

    The use of less resources, particularly non-renewable resources in the national and international economies is the “key” for maintaining growth at these levels and reaching sustainable growth and development This means that we would expect a continued growth in GDP but with fewer resources used in transport. In addition the strong current technological development in information and telecommunications can also lead to a less intense relationship between transport and economic growth.

2. The above considerations are related to a macro-economic level analysis and the relationship between transport investments and macroeconomic indicators such as GDP. Apart from the arguments at the national level, there have also been strong urban and regional arguments for investment in transport infrastructure. For such an analysis a study at a microeconomic level should be done. The differences between the macro and micro levels are discussed in the following paragraphs.

> "A micro-level analysis focuses on relatively small economic areas, such as cities or regions, and tries to associate transport infrastructure development with changes in local economic indicators such as regional employment and output. At the macro level, therefore, the key concern is the effect of capital stock level on the output and factor productivity of the entire economy, whilst the micro level analysis considers the reaction of economic units, like firms and households located in a given region, to specific transport infrastructure investments." (*David Banister and Joseph Berechman, 1995*).

	Macro Level	**Micro Level**
Unit of Analysis	• Country • State	• Region • Metropolitan Area
Type of Public Investment	• Total Capital Stock • Capital Stock by Type	• Transport Infrastructure by Type
Modelling Approach	• Economic Production Function Sectoral Production or Cost Function	• Land Use Model • Accessibility Model • Land Use - Transport Equilibrium Model
Measured Effect	• GDP Growth • Total Factor Productivity • Partial Factor Productivity • Social Rate of Return	• Change in Location of Firms and Households • Use of Inputs by Firms • Output Decisions by Firms • Land Rents • Labour Participation
Project Evaluation	• Not Applicable	• Transport and Non Transport Costs and Benefits and their Distribution

Source: Transport Investment and Economic Development (David Banister and Joseph Berechman, 1995)

Table 3.1 – Macro *versus* Micro-economic Analysis

From this comparison, it can be seen that there are fundamental differences in relation to the objectives, the formal modelling approach, the type of data required and the implications for policy analysis.

Within the context of this deliverable, this distinction is an important one, as the focus in the proposed methodology is primarily concerned with the micro level analysis.

The reason for the concentration on the micro level is that it is only at the local level that the impacts of transport investment will actually be identified and the distribution of the benefits will be measured. Macro-economic analysis does not allow the subtlety of change and impacts to be measured, nor does it allow the causality of relationships to be established, nor does it control adequately for the full range of impacts to be measured.

In addition, transport infrastructure projects are location specific and their implementation is undertaken on a project basis, including the impact on a city or a region. At the regional level, since the same investment can disproportionately affect neighbouring regions by substantially raising output in one region while not changing or even lowering it in another, the firms may relocate in response to accessibility changes. If economic growth in the latter region is the main objective for undertaking the particular investment, an alternative policy may be required. So, a micro-economic analysis is definitely more useful for measuring the regional economic impacts of transport infrastructures and analysing the distribution of such benefits across all the basis regions.

In the following sections the results of a survey made about accessibility indicators, socio-economic indicators, models of regional economic impacts of transport infrastructure, are reported and some judgements with regard to the above considerations can be found. These indicators and models can be assumed as micro-economic approaches from the conceptual point of view. In the section 3.5, the socio-economic impacts of projects financed by the cohesion fund are measured in both levels - macro and micro-economic - and different models are presented for each approach.

3.2 Accessibility Indicators

In the context of the present study it is useful to start by considering relevant accessibility indicators used in other studies. Therefore, in the following paragraphs, a review of the research made with that purpose is presented.

“Infrastructure Capacity and Network Access” *(Izquierdo and Monzon, 1992) and* ***“Accessibilité Interrégionale”*** *(Chatelus, 1997)*

The definitions given by Izquierdo and Monzon (1992) and by Gautier Chatelus (1997), have a similar classification, which define three main groups of accessibility measurement: Topological; Aggregated and Disaggregated. These measurement groups can then be divided into several types of indicators. Some of the indicators that are referred in Izquierdo and Monzon are also referred in Gautier Chatelus, but there are concepts, which are only reported in one of the two documents. To simplify, the reference of each indicator should be outlined.

Measurement Groups	Type of Indicator
Topological	Existence / non existence[1] Density[1] Route factor[1]
Bilateral	Gravity[1] Utility[2]
Aggregated	Type of Sum: General Aggregation[2] Conditional Aggregation[1] Type of Cost[2]

Table 3.2 - The three main groups of accessibility measurement

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[1] *In Izquierdo and Monzon (1992) and Gauttier Chatelus(1997).*

[2] *In Gauttier Chatelus(1997).*

Topological Measurements

The topological measurements are the simplest and the point they have in common is that they have into account only the transport or communications network in the reference zone. In reality, these are not indicators of accessibility but of transport supply.

Existence / Non Existence

Existence / Non Existence is the simplest indicator of this group. In an analysis of this kind, the reference area is divided into different sub-zones corresponding to territorial units (municipalities, regions, etc) or the area is divided, for example, by placing a polygonal grid on the map of territory.

In the most recent version of the indicator, a value (1 or 0) will be allocated to each sub-zone depending on whether a certain means of communication exists or not. It is also possible to classify types of communications systems and use a code to denote the importance of each of them.

Density

Under “grid density” indicators we can include those which measure the supply of roads, tracks and means of communication of any kind and the surface area of the served zone.

The most usual formula for the density index is the following:

$$D = \text{km of network} / \text{Area of reference zone (km/km}^2\text{)}$$

As a measurement of transport infrastructure density in a zone, this accessibility index has others forms, the most common of which are described below.

The following index is used to classify the roads in the zone according to their characteristics:

$$D = \frac{1{,}5a + b + 0{,}4c}{S}$$

where:

a = km of road over 6 m wide and with surface in good condition;
b = km of road 4 to 6 m wide and in good condition;
c = km of compact earth or macadam forest track over 4 m wide;
S = area of the reference zone.

Another variant of this indicator is obtained comparing the size of the communications network with a territorial variable other than area, i.e. the number of localities in the zone, number of habitants, etc. We can also measure the size of the network with the number of the arcs in the graph. By using various combinations of these possibilities, a whole series of density indicators can be produced:

$$\beta = \frac{e}{v}, \; \tau = \frac{e}{3(v-2)}, \; \alpha = \frac{e-v}{(2v-5)}$$

where:

e = is the number of arcs;
v = is the number of centres (localities, industries, etc).

Route Factor

The route factor is an indicator which tries to measure the quality of the route, i.e. to establish how close it is to a straight line and determine whether the route permits satisfactory travel times and conditions.

It is written as follows:

$$r_{ij} = \frac{d_{ij}}{g_{ij}}$$

where:

r_{ij} = route factor between points j and i
d_{ij} = minimum distance via the communications network from i to j;
g_{ij}= geographical or straight line distance from i to j.

To calculate the value for each point or sub-zone in the reference zone, we calculate the route factor between this point or sub-zone and all the others:

$$R_i = \sum_j \frac{d_{ij}}{d_{gij}}$$

where:

R_i is the route factor for centre i, which is the sum of the values of each of the routes, connecting centre i with the others.

Other variants of the route factor exist and are used mainly in the study of road networks. The path-speed index is one such variant, which was used in the Spanish Government’s General Road Plan. In this index, the route factor distances are replaced by travel time; the numerator takes into account actual travel time between the points and the denominator includes the ideal time for travel in a straight line between the two points at average network speed.

A similar concept, that of E.S.S. (Equivalent Straight-line Speed), was used in the ***Evaluation of the Transport Program of the 1st Community Support Framework for Portugal*** (*TIS*[1] *et al., 1997*) to compare gains of accessibility among cities in different regions:

$$E.S.S.(i, j) = \frac{t_{i,j}}{g_{i,j}}$$

where:

$t_{i,j}$ = travel time between i and j;
g_{ij}= geographical or straight line distance from i to j.

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[1] Tranportes, Inovação e Sistemas (Transport, Innovation and Systems) -, a.c.e., José Viegas Consultores (Consultants), Lda and Cised Consultores (Consultants), Lda.

For a certain group of destinations of identical nature (neighbouring municipalities, regional capital, closest ports and land borders, national capital) the E.S.S. of each city for that level of relationship is defined as:

$$E.S.S.(i,\Omega)=\frac{\sum_{j\in\Omega}E.S.S.(i,j)}{\#(\Omega)}$$

where:

#(Ω) = dimension of the set of destinations.

This type of measure has recently been adopted in the MEANS project of DG XVI - ***Evaluating Socio-economic Programmes: selection and use of indicators for monitoring and evaluation*** (*CEC-DGXVI,1998, MEANS Collection, Volume no. 2*).

Bilateral Indicators

Gravity Indicators

They are perhaps the best known indicators of this type and their generic formula is as follows:

$$A_{ij}=\frac{O_i\times S_j}{T_{ij}^{\alpha}}$$

where:

A_{ij} = zone i's relative accessibility to an activity in zone j;
O_i = origin zone i's potential for taking part in activity of j;
S_j = volume of activity in zone j;
T_{ij} = travel time, cost or distance from i to j;
α = factor describing the effect of the type of activity on the distance between i and j.

The variable representing the origin (O_i) is usually the section of the population in the zone who wish to travel to j, or the persons who may be interested in taking part in the activities at j. The variable which express the importance of the destination (S_j) will depend on the type of study to be carried out; it may concern the number of shops, the number of jobs, population size, hectares of forest, the number of industrial facilities, hotel capacity, etc.

Utility Indicators

Utility models are based on the measurement of the actual utility to users of potential trip destinations.

These indicators can be written as an exponential type of gravity formula:

$$A_{ij}=\sum_j S_j\times f(c_{ij})$$

where:

S_j and $f(c_{ij})$ have the same meaning as in the gravity indicators;

The utility indicators are based on the economic theories of maximising net utility to the consumer.

Aggregated Indicators

This group of indicators makes it feasible to identify the possibilities of mobility at an individual origin point of the network and its possible destinations.

The distinctions between the different concepts of accessibility indicators are a consequence of consider the following two aspects:

- type of sum;
- types of costs.

Type of Sum

General Aggregation

From an origin i, we can sum, for all the set Ω of j destinations, one function that depends of the utility of reaching the destination and the generalised transportation cost for each pair Origin-Destination (O-D). The set of destinations could perhaps be the entire studied zone (for instance Europe), or an area defined with economic or geographic criteria, recomputed for each origin (for example, a 30 million people market).

The formula can be the following:

$$A_i = \frac{\sum_{j \in \Omega} (S_j \times f(c_{ij}))}{\sum_{j \in \Omega} S_j}$$

where:

A_i = accessibility indicator from i to the rest of space;
S_j = utility provided by access to zone j;
c_{ij} = transport cost to travel from i to j;
f() = attraction-decay function with relation to transport cost.

Conditional Aggregation

The most common of the disaggregated measurements is the conditional aggregation (accumulated opportunities) type. It is used to determine the cumulative utility of destinations of a specific kind that can be reached within a given time by using a transport network. The basic characteristic of the individual points is their position.

These indicators are useful since they clearly show the attraction of destinations and the travel impedance, enable comparisons to be made between zones or transport modes and are both simple and instructive in diagram form.

They are generally written as follows:

$$A_i = \sum_j B_j \times F(C_{ij})$$

where:

B_j = utility provided by access to zone j;
$F(C_{ij})$ equals 1 if $C_{ij} < C_k$;
equals 0 if $C_{ij} > C_k$;

C_{ij} = impedance measurement for isochrone (or equal costs) with a value k (10, 20, 30 ... minutes or monetary units).

Type of Cost

In fact, the complexity of the studied accessibility usually depends on the type of cost used in the formulation.

In addition to time and some other related variables (speed, real time compared with the theoretical announced time...), some investigators decided to include the monetary cost associated with the transport network. We then arrive to the utilisation of generalised costs, similar to those used in the equilibrium models for traffic forecasts. In this case, the cost can be represented in the following formula:

$$c_{ij} = (t_{ij} \times VT) + (d_{ij} \times CK) + (p_{ij}) + (k_{ij} \times VC \quad)$$

where:

t_{ij} = time units between i and j;
d_{ij} = distance between i and j (km);
p_{ij} = direct monetary cost between i and j;
k_{ij} = confort index between i and j;
VT = unit time value for users;
CK = mean cost by km;
VC = value for confort index.

Depending on the type of accessibility, we want to study, some variations to this formulation are possible.

Attraction-decay is modelled through a cost function f() that can be more or less complicated: f() is usually a negative exponential function ($f(c_{ij}) = 1 / \exp(\beta . c_{ij})$, as in gravity models) or another function decreasing with increasing cost.

“UTS Study - Union Territorial Strategies linked to the Transeuropean Transportation Networks” *(Chatelus and Ulied, 1995)*

The aim of the accessibility indicators defined for the UTS study is to represent the transformations that changes in transportation endowment will likely induce in the development opportunities of each place.

Each new transport technology (High-speed, railways, commercial supersonic planes…) is an attempt to carry more people, faster, to longer distances. There are however a few permanent constraints to human mobility: the daily time devoted to travel. So, the spatial extension of daily labour markets (based on daily commuting travel) has been possible due to continuous increases in the speed and capacity of transportation systems.

According to recent EC reports, *daily round trips opportunities for last minute business travellers* (travels below 3.0–3.5 hours one way) is the most relevant accessibility measure to indicate the transport system effectiveness serving the most demanding trips.

On the other hand, at European scale, below the threshold of 3.0 hours most road, high speed rail and air trips occur, and therefore a measure based on daily round trips can provide useful insights into the impacts of TEN on modal comparative advantages.

So, the UTS passenger accessibility indicators are based on the evaluation of the number of existing destinations below a given travel time, using the best multimodal path and taking into account waiting and modal transfer times.

Accessibility calculations for situations before and after the implementation of TEN, will give an specific measure for each place. This measure evaluates the expansion of the space made available by new transport projects, and indicates which transportation modes are more effective.

The complementary analysis of TEN impact on freight transport, for both road and combined transport systems, are based on the same conceptual approach (market accessible within a given time or cost by the best multimodal freight chain).

The formulation of these concepts into concrete accessibility indicators followed the so-called *Connectivity approach*, which emphasises the conditions for getting access to the different network, the constraints and discontinuities within them and the conditions for establishing intermodal transfers, and not only the direct travelling time between two nodes. The total time between places is then considered in relation not to its absolute value but in relation to the existing thresholds under which most demanding passengers and freight system operate.

Following the above considerations, independent multimodal indicators have been defined for passengers (CONT(T), developed by MCRIT – MultiCriteria Consulting) and freight (FreC(T), developed by INRETS – Institut National de Recherche sur les Transports et leur Securité).

- CONT(T) determines the space that can be reached from each place in daily round trips using the best available multimodal chain. CONT(T) can be referred to any data linked to the space reached. Typically the population reachable in less than 3 hours is used.

- FreC(T) is based on Combined Transport. It evaluates the size of the market that can be reached in a given amount of time (T) by the best road and rail combination. Additionally to FreC(T), FreR(M) has been defined to evaluate the direct costs to get access to a market with size equal to (M) by road. The road market (M) has been evaluated either in terms of population and GDP.

The Connectivity Approach that both CONT(T) and FreC(T) share is described in the following paragraphs.

- Accessibility Concept – space (or market) made available by the existing transportation services in each place at a given time.
- Goal – measure of changes in relative mobility opportunities across the territory.
- Connectivity Formulation – connection to the markets through the transport networks: travel time including waiting times, delays, and modal transfers.

CONT(T) Formulation

The CONT(T) indicator in the point (i) is defined as the total existing population (P_j) attached to all nodes (j=1,N) reached at ($t_{ij} < T_0$); (t_{ij}) being the minimum time to reach the node (j) from (i) using the shortest multimodal chain, including all modal transfers. Therefore CONT(T) has the following mathematical expression:

$$CONT_i(T_0) = \sum_{j=1,N} P_j \text{ ; if } t_{ij} \leq T_0$$

where:

T_0 has been fixed equal to 3 hours in order to evaluate feasible daily round trips;

t_{ij} = travel time for each arch (tv_{ij}) + waiting time to get connection to transportation services (tw_{ij}) + the modal transfer time (tk_{ij})

FreR(M) and FreC(T) Formulation

For road transportation, the cumulative cost to reach a market of size M from every node has been estimated. This market is the set of destinations that can be reached from the node with progressive accessibility costs until the cumulative weight of the reached destinations is M (i.e., M can be 30 million inhabitants, or the whole Europe). This market will be called market M onward.

The parameter used for the calculations is the direct costs to road haulier. The calculated costs are the total direct and indirect costs for a representative road haulier[1]. The driver is able to optimise his driving time, and spends exactly 9 hours a day on the road. In that case, the fixed costs are 221 FF per hour and the time T is the exact time of driving. The overnight costs were calculated on an average of 40000FF/year = 20FF/hour.

An "absolute" accessibility indicator: $FreR_{abs}(M)$, which represents the minimum real cumulative cost of access to a market M through road, is calculated based on mentioned hypothesis.

$$FreR_{abs}(M) = \min_z \left(\sum_{j \in Z} C_{ij} P_j \right)$$

where:

$C_{ij} = (FT \times t_{ij}) + (FK \times d_{ij}) + (Pé_{ij});$

FT = fixed costs per time unit;

t_{ij} = minimum time to reach the node (j) from (i);

FK = direct costs (of travelling) per km;

d_{ij} = real distance between i and j;

$Pé_{ij}$ = direct costs (road tolls)

Z such as $\sum_{j \in Z} P_j \geq M$;

P_j = population of the destination region j.

The relative accessibility indicator $FreR_{rel}(M)$ measures the quality of the network, independently from the distances. To perform it, an average cost has to be calculated by using a virtual network completely homogenous on the continent (all the links having the same speeds, with no tolls). Then, for each origin A, the absolute indicator $FreR_{abs}(M)(A)$ and the virtual indicator $FreR_{ref}(M)(A)$ are compared:

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[1] A representative haulier is a road haulier with an articulated truck of 40 tons. The case adopted, as a reference, is that of the French driver, making international transport of general good, driving a total of some 115 000 km per year during 225 days, following the legislation (spending at most 9 hours a day driving). The speed of the trucks was set at 77km/h on highways and speedways, 57 km/h on main national roads, and 40 km/h on secondary roads. The allocation of costs has been calculated according to the FNTR and the French Transport Ministry (DTT) official values.

$$FreR_{rel}(M)(A) = \frac{FreR_{abs}(M)(A)}{FreR_{ref}(M)(A)}$$

The FreC(T) calculates the maximum size of the market which can be reached in a certain amount of time T.

The structure of industrial production sets limits for freight transportation, which has great economic significance. Thus, what really interests of the medium/long-distance forwarders is to distribute their freight overnight. In most cases, it is useless to get goods in the evening or to send them in the morning. As such, the first relevant time limit for freight is the overnight jump. Other limits will naturally be set at 36, 60, 84 hours. It is also considered that the relations with big ports operate 24 hours a day.

The computation for the road transportation time was made taking into account the same speeds as for the FreR(M) indicator.

For Combined Transport, a table containing the current supply offered by the main European companies was considered. This table shows the minimum time between the last hour when one can leave its container and the time when the container can be taken from the terminal. Then that time and the terminal road transportation time at each end of the journey were combined.

Finally, the size of the market which could be reached under the given amount of time T is calculated.

The definition of FreC(T) indicator is as follows:

$$FreC(T) = \sum_{j \in Z} P_j$$

where:

$T = 36, 60, 84$ hours;
P_j = population of the destination region j;
Z such as $t_{ij} \leq T$;
$T_{ij} = t_{v1}+(t_{k1}+t_{v2}+t_{k2})+(t_w+t_{v2}+t_{k1})+t_v$;
t_{v1} = travelling time by road;
t_{v2} = travelling time by train;
t_{k1} = travelling time by road-rail;
t_{k2} = transfer rail-rail (between 2Ct services);
t_w = rail waiting time (between 2Ct services).

A different concept, but with a similar background, is the POINTER index, which was used in the ***GIS and impact assessment, Ph.D. dissertation, Department of Planning, Technical University of Denmark*** (*Kronbak, J. 1998).*

Here, the first step is defining two Time thresholds (T_a and T_t) corresponding to the minimum time needed for the type of interaction being considered, and the total time spent to go and come back from the place of interaction, including the time for the interaction itself. From any basis i, the POINTER index is calculated as:

$$\text{POINTER}\left(i, T_t, T_a\right) = \sum_{\mathrm{j}} \mathrm{P_j}.(T_t - (t_{i,j} + t_{j,i})) \qquad \forall j : (T_t - (t_{i,j} + t_{j,i)})) \geq T_a$$

This corresponds to the number of person.hours of possible interaction, instead of the number of persons as defined in the CONT index. The same argument as above with respect to a ladder of time thresholds should be applied. On the other hand, the values of T_a and T_t are obviously related, and T_t should typically be around 3 times T_a.

The weighting used for these total aggregations depends on the studied subjects. Freight accessibility is often based on the population, PIB and other economic aggregated figures. For the voyagers, opportunity measures are often used (population, activity levels).

3.3 Socio-economic Indicators

This section is divided into two parts:

1. The summary of the socio-economic indicators that are reported in the Deliverable D4 of the Project EUNET – ***"Socio-economic Indicators, Model and report"***, SubProject SASI – ***"Socio-Economic and Spatial Impacts of Transport Infrastructure Investments and Transport System Improvements"***, *(Technische Universitat Wien, Universitat Dortmund, University of Sheffield, 1997)*;
2. The interpretation of such indicators as a measure of the impacts of transportation infrastructure improvements.

The following table summarises the selection of socio-economic indicators used in other studies, as related in the SASI report.

Study	Indicators Used
"Disparity of Living Conditions and Welfare in the European Communities" (1993) [1]	(…among others) GDP per capita
	Average annual growth of GDP per capita
	Private expenditure per capita
	Unemployment rate
	Difference between growth rate of employment and growth rate of workforce
	Share of long-term unemployed
	Annual tariff working hours
	Number of flats per 1000 inhabitants
	Completed flats per 1000 inhabitants
	Share of people living in self-owned flats
	Life expectancy
	Number of doctors per 1000 inhabitants
	Hospital beds per 10000 inhabitants
	Prenatal mortality per 1000 birds
	Social expenditure in percent of GDP
"Cohesion and the Development Challenge Facing the Lagging Regions", Regional Development Studies 24, CEC (1995)	Level and change in GDP per capita
	Level and change in productivity
	Level and change in employment
"The Regional Impact of the Channel Tunnel Throughout the Community", ACT Consultants, Institut fur Raumplanung and Marcial Echenique & Partners (1996)[2]	Level and change of value added (sectorial disaggregation)
"First Periodic Report on the Social and Economic Situation and Development of the Regions of the Community", CEC (1996) [3]	Level and change in GDP per capita
	Level and change in productivity
	Level and change in employment/unemployment (by age; by Sex)
"Transport Research - APAS - Road Transport Evaluation", European Commission, DG VII (1996)[4]	(...among others) Net employment effects (implementation period, long-term induced employment), additional regional economic effects, prices and output of companies using transport services, flows of venture capitals, land use effects/conformity to plans
	indicator of accessibility
	quality level of services offered
	Compliance with EU technology development plans
	Achievement of broad or specific objectives of programmes

Table 3.3 - Indicators used in other studies

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[1] This study is mainly concerned revealing differences in life conditions among European countries. Therefore, spheres of life are selected and consequently reflected by indicators to describe them. Consequently, it is attempted to construct indices of average welfare and living conditions by unifying those indicators.

[2] This study concentrates on assessing the impact of the Channel Tunnel in socio-economic terms. This study purpose was: "to examine the way in which different types of regions in the Community and different sectors in those regions will be affected by development of a major new transport infrastructure; and to assess ways in which policy can be developed to ensure that maximum possible benefits can be derived from this that any negative effects are minimised."

[3] This report mentions a great number of measures serving to assess the various impacts of Union policies on the regions of Europe.

[4] The system of indicators developed in APAS serves as a base for many studies carried out by DGVII. Accordingly to the indicators terminology of APAS, the impacts modelled within the present study can be regarded as "non-core strategic".

Normally, what is associated with socio-economic conditions of a region are complex terms like “welfare” or “living conditions”, although it is obvious that they have to be simplified in order to derive computable variables.

In SASI report the two groups of indicators that are reported as being adequate to characterise the socio-economic impacts of transportation infrastructure on a regional level are:

- measures of regional economic performance;
- measures reflecting the social conditions in a region.

Obviously by choosing a limited set of variables one cannot expect to capture the full range of socio-economic impacts but a set of key figures that are supposed to reflect the policy relevant aspects of those impacts.

For that study of “Assessment of Spatial and Socio-economic Impacts” indicators can be interpreted as outputs of models: every model serves to represent reality to a certain extent. It is therefore important to note that the indicators proposed by SASI project *per se* are not used to directly measure socio-economic impacts of transportation infrastructure but are expected to reveal parts of the actual changes in a region’ s socio-economic conditions and its development.

The socio-economic and cohesion indicators that are presented in the SASI project are addressed in the following paragraphs.

In the course of the SASI project there is a clear relation between the micro and macro indicators: whereas socio-economic indicators are used to describe certain aspects of an individual’s situation (micro), cohesion indicators measure the differences of the latter in order to get an impression on how they are distributed over population or area (macro). It has also been outlined that micro-indicators should be used to derive indicators on macro level through aggregation methods.

Searching for cohesion indicators regarding economic performance measures is aimed at evaluating policy measures of decreasing economic disparities among European regions. The use of GDP in terms of parity of purchasing power (PPP) is suggested in SASI report. Regional disparities can be displayed by either calculating the ratio of the ten best / worst performing regions, the variance of GDP in PPP among the regions or the concentration index. For intertemporal comparison two annual data sets of those (resulting in rates of change) can be used together with the rank correlation coefficient, thus allowing to evaluate whether regional economic disparities increase or decrease according to policy measures.

The use of unemployment data as an indicator of social performance was outlined in SASI report, as well as the use of the distribution measures of regional unemployment as an indicator of social cohesion. The Univariate[1] and Bivariate[2] measures (methods of aggregation) are proposed to be used on unemployment data. The path of development in social cohesion can be examined by performing the above mentioned inter-temporal comparison.

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[1] Given a number of one-dimensional observations (each accounting for one particular region) some simple distribution measures can be calculated. Each region is given the same weight counting as one observation. Therefore a region’s size or population does not affect the value of the distributed variable (minimum-maximum ratio, variance and standard deviation, rank correlation coefficient by Spearman).

[2] Not giving the same weight to every observation by taking account of a second variable representing the number of employees or the population of the observations. The interpretation of such a measure would appear like: a certain share of people in Europe will live under best, second best…conditions; in addition, they can still be related to their origin region. A measure of even-or unevenness of the distribution can then easily be derived.

Finally, the SASI report addresses that the distribution of accessibility among the European regions is not supposed to be used as an output variable. As an input factor of the production function it represents a link between labour and capital endowment. Nevertheless, it is reported that as a first step in examination of regional disparities, as well as their development, a closer look at the distribution of accessibility seems to be useful. Thus, giving some information on the cause for regional disparities in economic and social concerns.

3.4 Models for Assessing the Economic Impacts of Accessibility Improvements

This section describes a set of models that were developed to measure and examine the economic impacts of transport infrastructure.

The following paragraphs are related to mathematical models that can establish and evaluate a relationship between accessibility and regional development. Some of these models were applied to specific case-studies (for example, the model developed to analyse the regional development effects of the M25 London orbital motorway).

“Accessibility in the European Union: the impact of the TE*N”* *(Journal of Transport Geography, Gutiérrez and Urbano, 1996)*

The aim of this paper is to evaluate changes in accessibility in the European Union from two perspectives: proximity to the Trans-European Network (TEN)[1] and accessibility to activity centres along the road network.

This study is an exercise in simulation and experimentation in order to examine what changes in accessibility should occur if the TEN is completed in its entirely by 2002. Accessibility analysis and presentation of results is taken using a vector geographic information system (GIS). This study shows some of the possibilities offered by GIS technology in the field of accessibility analysis.

Here we only report the concepts that were used in the above study.

Proximity to the TEN

On a European Union scale, the road proximity can be assessed simply by creating corridors along the network. In this study, the width of the corridors is given by a distance of 40 km in a straight line (less than one hour by road in the worst conditions) from the network for both situations considered (1992 and 2002).

In 1992, a marked contrast is to be observed between the central and peripheral countries. The formers already have a dense network, so that most of their territory falls within the corridors; the latter, on the other hand, display large gaps because of the lower density of their network.

In 2002, the predicted situation is quite different. As most of the new planned links are located in the peripheral countries, most of the gaps that existed will be covered.

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[1] The plan for Trans-European road network consists of some 54000 km of major communications routes, of which 37000 km were in use in 1992 and 12000 km are to be completed or upgraded by 2002.

The area within the corridors is a clear index for evaluating the changes that will come about as far as the degree of coverage of the network is concerned between 1992 and 2002. The observations that are presented in this study are the following:

- In 1992 69,9% of the was located within these corridors, but there were marked contrasts between the different countries;
- By the 2002 horizon, 84,9% of the European Union territory will be within the corridors of the TEN, an improvement of 15,0% over 1992.

Accessibility to the Main Centres of Economic Activity

In this study an index was used that simply offers a measure of the separation between places. This (inverse) accessibility indicator consists of calculating a weighted average of the impedances separating each node with regard to the chief economic activity centres trough the road network (by the minimal route), taking as weights the GDP of centres as follows:

$$A_i = \frac{\sum_{j=1}^{n} (I_{ij} \times GDP_j)}{\sum_{j=1}^{n} GDP_j}$$

where:

A_i = (inverse) accessibility of node i;
I_{ij} = impedance through the network between nodes i and j;
GDP_j = gross domestic product of the destination economic activity centre.

This model is more suitable than those of economic potential to measure the degree of separation between different places throughout the major Trans-European routes. While the results offer by this accessibility indicator are clear and easily interpreted, for it is simply a weighted average, the potential value is not easily interpreted in terms relating to geographical reality.

The following step of this study was the definition of economic activity centres and the calculation of impedances. In order to do that, 94 urban agglomerations of the European union with over 300000 inhabitants were taken as main centres of economic activity. Then, the total GDP of the agglomerations were estimated by taking account the assumption that the agglomerations had the same GDP *per capita* as the region in which they are located. The GDP figures for agglomerations thus obtained are used to weight the importance of the minimal-impedance routes according to the destination economic activity centre.

Physical conditions of the real-world infrastructure are represented by links and nodes. Thus, impedance by road between node of origin and the destination centre is the sum of impedances of the arcs travelled through and the nodes which cross the minimal route. The criteria following for the establishment of these impedances are outlined in this study, as well as the display (accessibility to the economic activity centres 1992, 2002) of the above model.

Road Transport Infrastructure and Regional Economic Development: the regional effects of the M25 London Orbital Motorway *(Journal of Transport Geography, Linneker and Spence, 1996)*

The M25 London Motorway has affected levels of accessibility in much of England. The objective of this model was to evaluate the nature of the relationship between accessibility and regional development. The methodology involves the construction of a series of measures of both regional development, as the impact or dependent variable, and accessibility, as the policy or control variable. The regressions also include a number of other potential explanatory factors. Accessibility is measured using time, distance and cost impedance functions for heavy goods vehicle (HGV) movements.

Measures of Regional Economic Development

The Accessibility / Non-Accessibility Measures

DS (Differential Employment Shift) is the differential shift in employment between 1981 and 1987 and is used to measure the performance of the local economy.

Changes in the distribution of employment are hypothesized to depend first on national economic forces which affect regional employment differentially. Second, spatial factors may be expected to influence the distribution of employment through variations in labour availability and transport cost. Variations in industrial structure were removed from the dependent variable by defining the change in a zone's employment as the difference between an area's actual employment change its expected change.

The expected change was calculated on the assumption that each industry in an area grows or declines at its national rate.

$$DS_i = \sum_k \left[\left(E_{k,i,t+1} - E_{k,i,t}\right) - \left(\left(E_{k,i,t} \times G_k\right) - E_{k,i,t}\right)\right]$$

where:

DS_i = differential employment shift in area i;
E = total employment;
G_k = national percentage growth rate in division k employment 1981-87;
k= industrial division (0-9);
i= zone;
t= 1981;
t+1=1987.

DL (Demand for Labour Index) is the demand for labour index between 1981 e 1987. This is a measure of the difference between the actual employment change and an expected change, which arises from the natural increase in the local population supplying a workforce to the area at current activity rates. If the difference (DL) is a positive demand for labour then labour supply arises from in-migration and/or in-commuting and/or increase in activity rates and/or reduction in unemployment. If the difference is a negative demand for labour then the opposite will be the case.

Employment change (ΔE) in an area over a given time period is split into the following components.

$$\Delta E = \sum_i a_i \Delta P_i + \sum_i a_i M_i + \Delta C + \sum_i \Delta a_i P_i + \Delta U$$

where:

ΔE = total employment change in the area;
a_i = base year activity rate for age/sex group i;
ΔP_i = natural increase in population in age/sex group i;
M_i = net migration into or out of the area of Sex group i;

ΔC = net change in commuting to or from the area;
Δa_i = change in activity rate for age/Sex group i;
ΔU = net change in numbers unemployed.

The term $\sum_i a_i \Delta P_i$ is the natural increase in the working population of an area and is the expected increase in employment in an area. The term $\Delta E - \sum_i a_i \Delta P_i$ is the employment change due to the relative intensity of demand for labour in an area. This index of the strength of demand for labour (DL) is expressed as a percentage of the area’s base-year employment.

For 1981 to 1987 the demand for labour (DL) index is operationalized as follows. First, the 1981 resident population figures for each area were projected forward six years. Second, these figures were then multiplied by average death rates for each age/sex group to find the survivors. These figures were then multiplied by average male and female activity rates based on standard regions to derive an estimate of the expected working population in each area in 1987.

ST (Industrial Structure Index) is an industrial structure index applicable to 1981. The industrial profile of an area in relative terms is weighted by the national rate of growth between 1981 and 1987 of each industry and summed.

$$ST_i = \sum_{ki} \left(W_{ki} \times G_k \right)$$

where:

ST_i = industrial structure index of area i;
W_{ki}= proportion of total employment in area i in industry k, 1981
G_k = percentage growth or decline nationally between 1981 and 1987 of employment in industry k;
k = industrial division (0-9).

CN (Congestion Index) is a congestion index that was derived based on population density using 1981 Census data. It is used to represent the influence of external diseconomies of scale.

ED (Employment Density) is an employment density index applicable to 1981 and is proxy for external diseconomies of scale. It represents the influence of highland and factory rents, highland and factory rents, high housing and journey’s work costs along with the general congestion of the major conurbations.

LA (Labour Availability) is a labour availability index applicable to 1981. It is calculated as the difference between the economically active population and the employment in an area divided by the employment.

MP (Market Potential) is the prefix for all accessibility variables and the remaining parts of their names are to be decoded as follows.

- The third letter refers to be impedance measure used: MPT is time-based; MPD is distance based and MPC is cost based.
- The remaining part of the code depends on whether the access measure refers to one point in time or change in accessibility over time.
- For the static accessibility calculations, the next part of the code refers to whether or not the measure includes the motorway (+M25) or excludes it (-M25), this being the main mechanism for determining the road effect.

- For the non-cost-based impedance measures the last part of the code is the specification of the date of the employment mass factor, either E81 or E87. This allows the employment effect to be incorporated with the road effect or excluded from it.
- For cost-based impedance there is an additional component, which refers to the date of the cost coefficients used, either C81 or C87. Again this facilitates the inclusion of the cost effect with the road and employment effect or exclusion from it.
- The dynamic accessibility calculations can be recognised by the inclusion of the Δ symbol.
- This is followed in the non-cost-based impedance measures by an indication as to whether the employment mass factor has been allowed to vary over time (E8187) or not (E81), thus allowing the inclusion of the employment effect or simply the road effect alone to be discerned.
- For cost-based impedance there is additional component, which indicates whether the cost coefficients have been allowed to vary over time (C8187) or not (C81), again permitting the cost effect to be either included or excluded from the accessibility calculation.

This Market Potential form of accessibility measure assumes that distant markets provide reduced opportunities. Summing between an area (I) and all other areas (j) gives an overall market potential value for the area (j). It is a measure of the relative accessibility of that area to the markets and input sources which the area's industries could either actually or potentially supply or be supplied from.

Market Potential can be expressed by the following formula:

$$MP_i = \frac{\sum_j P_j}{C_{ij}{}^{\alpha}}$$

where:

MP_j = Market Potential of zone i;
P_j = a measure of mass of market potential in zone j
C_{ij} = a measure of impedance or transport costs from i to j;
α = an alpha exponent often assumed to be equal to one.

The interrelationships between accessibility measures are divided into two groups: HGV static accessibility correlations and HGV dynamic accessibility correlations. The regression relationships between regional economic development and accessibility and non-accessibility measures are also distinguished between two analyses: HGV static accessibility regression results and HGV dynamic accessibility regression results.

HGV Static Accessibility Correlations

Generally the static market potential accessibility variables that are based on time, distance or cost, are all negatively correlated with both demand for labour index and the differential shift (with significance at the 95% level and at the 99% level). Areas with higher accessibility, then, are those with lower demand for labour and a lower differential shift.

This general conclusion runs counter to the research that confirmed a positive relationship between accessibility and employment growth. The case is that accessible locations seem to have become associated with a number of disbenefits, which together must have assumed an importance greater than the benefits generated by high accessibility.

HGV Dynamic Accessibility Correlations

The dynamic accessibility variables are produced by expressing the post-M25 accessibility as a percentage of the pre-M25 accessibility. All the variables ending in “E81” or “E81C87” show the pure M25 road effect on the accessibility of areas since the employment levels in each area are held constant in the calculations, being fixed at the 1981 level and using a fixed value of vehicle operating cost as of 1987. All the percentage changes in accessibility variables ending in “E8187” or “E8187C87” or “E8187C8187” include the M25 road effect and the employment effect, since these variables are based on 1981 employment pre-M25 and 1987 employment post-M25.

For those based on time impedance, the percentage changes in market potential time accessibility variables are all positively correlated with both the demand for labour and the differential shift (with significance at the 99% level). The dynamic variables are all more strongly correlated with the demand for labour than the differential employment shift. The dynamic distance variables generally show the same relationships (with significance at the 99% level and at the 95% level). For the dynamic accessibility changes based on generalised cost, the use of different value of time and vehicle operating cost coefficients in the calculation of these variables makes no difference to the correlation coefficients.

HGV Static Accessibility Regression Results

The variety of accessibility and non-accessibility independent variables outlined above were regressed against the dependent variables demand for labour (DL) and differential employment shift (DS).

The DL index was regressed against the index of industrial structure (ST), the congestion index (CN) and the accessibility variables. The ST index is positively related[1] to the DL index indicating that areas with a favourable industrial structure have faster employment growth. The CN index is negatively related[2] to the DL index indicating a low rate of employment growth in high-density areas.

The DS index was regressed against the three independent variables: employment density (ED), labour availability (LA) and the accessibility variables. The ED is negatively related[1] to the DS, and is statistically significant in all equations, and LA is positively related[2] to the DS but it was in no equation statistically significant and should be discounted.

For the static accessibility surface variables pre-M25 based on 1981 employment no market potential time, distance or cost accessibility variables are significant when regressed against the DS[3], but some are when regressed against the demand for LA. The only time-based variable in this category significantly related to the DL is MPT-M25E81 with an R^2 of 30,1%[4]. The only distance-based variable significantly related to the DL is MPD-M25E81 with an R^2 of 30,5%[2]. The only cost-based variable significantly related to the DL index is MPC-M25E81C81 and MPC-M25E81C87 with an R^2 of 30,5%[2].

For the static accessibility surface variables post-M25 based on 1981 employment again, no market potential time, distance or cost accessibility variables are significant when regressed against the

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[1] Denotes significance at the 99% level.

[2] Denotes significance at the 95% level

[3] With an R^2 of 16,2% and a significance at the 99% level and at the level 95%.

[4] see the footnote 1 in the previous page.

DS[1], but some are when regressed against the demand for LA. The only time-based variable in this category significantly related to the DL is MPT+M25E81 with an R^2 of 29,2%[2]. The only distance-based variable significantly related to the DL is MPD+M25E81 with an R^2 of 30,6%[2]. Lastly, only one cost-based variable, MPC+M25E81C87, seems to be significantly related to the producing an explained variance of 30,5%[2].

HGV Dynamic Accessibility Regression Results

The dynamic accessibility change variables with the M25 were also regressed against the DL index and DS variables.

In order to summarise the results and to show the formula of the regression/correlation model that has been referred, we decided to use the following tables, which are commented in this section of the paper.

Demand for labour	Differential shift
Time	*Time*
R^2=26.7%	R^2=16.6%
$DL=-143+1.49ST+0.533\ MPT\Delta E81-0,314CN$	$DS=-1077-135ED+347MPT\Delta E81+1747LA$
F=21.3 (6,48)[a] (2,37)[a] (-3,66)[a]	F=11.6 (-4,79)[a] (1,23)[b] (0,63)[b]
Distance	*Distance*
R^2 = 24,4%	R^2 = 16.5%
$DL=-146+1.55ST-0,122\ MPD\Delta E81-0,394CN$	$DS=-1107-137ED-598MPD\Delta E81+2184LA$
F=18.8 (6,63)[a] (-0,29)[b] (-4,87)[a]	F=11.5 (-4,89)[a] (-1,13)[b] (0,81)[b]
Cost	*Cost*
R^2=24.7%	R^2=16.2%
$DL=-150+1.59ST+0.592\ MPC\Delta E81C87-0.401CN$	$DS=-733-139ED-676MPC\Delta E81C87+2483LA$
F =19.1 (6,83)[a] (0,87)[b] (-5,08)[a]	F =11.3 (-4,98)[a] (-0,78)[b] (0,93)[b]

Notes: [a] Denotes significance at the 99% level. [b] denotes significance at the 95% level.

Table 3.4 - HGV Percentage Change in Market Potential Accessibility (M25 road effect and static 1981 employment) Regressions on DL and DS

This table shows that no dynamic market potential variable based on distance or cost is significantly related to the dependent variables. The dynamic market potential time variable MPTΔE81 is significantly related to the demand for labour index with an R^2 of 26.7%.

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[1] With an R^2 around 16,1% and a significance at the 99% level and at the level 95%.

Demand for labour	Differential shift
Time	*Time*
R^2=31.6%	R^2=20.5%
DL=-131+1.35ST +0.747MPTΔE818 -0,253CN	*DS=-1077-135ED+347MPTΔE8187+1747LA*
F=27.0 $(6,02)^a$ $(4,31)^a$ $(-3,07)^a$	F=15.1 $(-4,72)^a$ $(3,20)^a$ $(0,25)^b$
Distance	*Distance*
R^2 = 34,0%	R^2 = 23.5%
DL=-136+1.48ST -0,122MPDΔE8187 -0,394CN	*DS=-1107-137ED-598MPDΔE8187+2184LA*
F=30.0 $(6,85)^a$ $(5.,05)^a$ $(-5,48)^2$	F=18.0 $(-5,32)^a$ $(4,17)^a$ $(1,27)^b$
Cost	*Cost*
R^2=45.7%	R^2=31.2%
DL=-150+1.59ST+0.592MPCΔE8187C87-0.401CN	*DS=-733-139E676MPCΔE8187C87+2483LA*
F =49.2 $(6,43)^a$ $(8,31)^a$ $(-3,76)^a$	F =26.4 $(-5,01)^a$ $(6,23)^a$ $(0,71)^b$

Notes: ^{a} Denotes significance at the 99% level. ^{b} denotes significance at the 95% level.

Table 3.5 - HGV percentage change in market potential accessibility (M25 road and 1981-87 employment effect) regressions on DL and DS

All dynamic change accessibility variables perform better in terms of higher explained variances when regressed against the demand for labour index. The market potential time-based variable MPTΔE8187, the distance based variable MPDΔE8187, and the cost impedance variable *MPCΔE8187C87* all are significant in equations accounting for R^2 values of 31.6%, 34.0% and 45.7% respectively. However, all these accessibility change variables have employment change built into them as the M25 road effect change, so there is bound to be a degree of double counting involved.

It should be noted that still, even the best models in this study provide only limited values of R^2.

"Impacts models for urban infrastructure analysis" *(Infrastructure and Regional Development, Vickerman, 1991)*

Various methods and models have been developed to study infrastructure impacts on urban or regional economies. In this paper three classes were presented.

Factor-productivity Approach

In the factor-productivity approach it is taken for assumed that the positive external effects of infrastructure projects lead to an improvement of the productivity of other production factors, compared with the situation without such projects.

As long as infrastructure has a point character (airports, industrial effects, educational institutions, etc), their influence on urban productivity can be analysed by means of traditional production functions.

A general formulation of a production function for sector i in city r, with various types of infrastructure is:

$$Q_{ir} = f_{ir}\left(L_{ir}, K_{ir}, I_r^A, \ldots I_r^N\right),$$

where:

Q_{ir} = value added in sector i, city r;
L_{ir} = employment in sector i, city r;

K_{ir} = private capital in sector i, city r;
$I_r^A,..I_r^N$ = infrastructure of various types in city r.

This formulation may still be generalised by taking into account spatial spillover effects: the impact of infrastructure may transcend the boundary of an urban agglomeration.

Factor-mobility approach

Infrastructure improvements or expansions may also lead to a relocation of labour and capital between urban regions. Most empirical studies in this field focus on the influence of interurban network infrastructure.

Improvement of transportation infrastructure leads to a reduction of travel time or cost and hence to an improvement in accessibility of markets or inputs. This may in turn lead to a relocation of labour and capital. Accessibility, A, of a certain variable Z in urban regions can be defined as:

$$A_r(Z) = \sum_{r'} Z_{r'} f\left(c_{r'r}\right)$$

where:
$c_{r'r}$ = index of travel cost between regions r’ and r;
$f(c_{r'r})$ = attraction-decay function of distance;
Z = employment, production, inputs, etc.

The relationship between regional employment and accessibility can be expressed by the following formula:

$$\Delta E_r = a_1 D_r + a_2 w_r + a_3 L_r + A_r\left(Z\right)$$

where:
ΔE = differential shift in employment;
D = employment density;
w = wage rate;
L = index of labour availability.
$A_r(Z)$ = accessibility, A, of certain variables Z – employment, production, etc – in urban regions.

In most studies, a positive relation is found between accessibility and total employment. One must be aware that such result is not guaranteed by theory, however. Improved accessibility leads to an intensification of competition, so that it is not impossible that some cities will be negatively affected by an improvement in accessibility. Improving infrastructure has both distributive and generative effects. Distributive effects relate to a redistribution of economy activity among cities, the overall figure remaining constant. On the other hand, generative effects occur when the overall total changes.

Interregional trade approach

These models should at least contain the following linkages: between transport infrastructure and transport costs; between transport costs and trade flows; between trade flows and regional development.

The following formula expresses a formulation of an interregional model:

$$t_{irs} = \frac{K_{ir} \exp\left[-\beta_i \left(p_{ir} + \upsilon_{irs}\right)\right]}{\sum_q K_{iq} \exp\left[-\beta_i \left(p_{iq} + \upsilon_{iqs}\right)\right]}$$

where:

t_{irs} = share of region r in the deliveries to region s for goods produced in sector i;
K_{ir} = capacity level in sector i of region r;
p_{ir} = price level in sector i of region r;
υ_{irs} = transportation cost per unit of i between r and s;
q, r, s = region related subscripts;
i = sectors related subscript.

This model is concerned with the interregional input-output analysis, which automatically takes into account the linkages between sectors. Its results are related with the output and the value added for each sector production and each region, as well as, with the transactions and imports between sectors.

"A Model for Assessing the Impacts of Major Inter-Regional Transport Investments: Accessibility, Potential and Employment Change" *(Grandes Infrastructures de Transport et Territoires - Large Scale Transport Infrastructures and Regions, Simmonds, 1995)*

This paper describes a model created to provide some assessment of the generated long-term effects of the Channel Tunnel upon the regions of Europe, both in the UK and on the continental mainland.

The model was set up so as to include nearly the whole of the EEC and the EFTA as they were in 1991. The regions used as zones in the modelling are close to the Tunnel and in UK. This paper is divided into four main sections, dealing in turn with the transport model, the accessibility and economic calculations, the use of the model, and the comparison with other related models.

Here, we decided to report on the sections of this paper that are closer of the objective of this deliverable – Assessment of Spatial and Socio-economic Impacts. So the following paragraphs are related to the "Accessibility, Potential and Employment Change" approach that was carried out in that paper.

This approach took into account the importance of the different destinations, in absolute and relative terms, for the trade and business of the region whose accessibility was being measured. This importance was represented by the GDP of the destination region. The accessibility measure also included a representation of the effects of international borders, and a measure of travellers' sensitivity to travel time, i.e. the way in which increasing travel time between regions decreases their relevance to each other.

For the service model the accessibility function was based purely upon passenger travel

$$A_{ip} = \sum_j b_{ij} . W_j . \exp\left(- \mu_p . t_{ij}\right)$$

where:

A_{ip} = the measure of accessibility of region i for passenger travel;b_{ij} = the effect of international borders: $b_{ij} = 1$, if i and j are in the same country;

$b_{ij} < 1$, if i and j are in different countries, with different values for intra-EEC, intra-EFTA borders etc;

W_j = weight for the importance of destination j, i.e. its GDP;

μ_p = a parameter describing the sensitivity to travel time differences;

t_{ij}[1] = the composite average travel time;

The parameter μ_p was estimated so as the reproduce the sensitivity to travel time differences revealed by various sources of information on business travel flows within Europe.

The manufacturing and distribution sector was assumed to be sensitive both to this passenger accessibility, and to the equivalent accessibility for freight movement:

$$A_{if} = \sum_j b_{ij} W_j \left(C_{ij} - q\right)^{-\mu_f}$$

where:

A_{ij} = the measure of accessibility of region i for freight transport;

Cij = the composite transport cost;

q = a constant;

μ_f = a parameter describing the sensitivity to differences in travel cost;

The calibration of parameter μ_f was based upon observed data on freight transport flows within Europe.

The economic potential of each region was calculated using the accessibility value, as a measure of the market for region's output, multiplied by a measure of the region's capacity for production, namely the existing employment in the relevant sector.

$$P_{im} = \frac{A_{ip} + A_{if}}{2} \times E_{im}$$

where:

E_{im} = industrial employment,

and

$$P_{is} = A_{ip} \times E_{is}$$

where:

E_{is} = service employment.

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[1] $t_{ij} = -\frac{1}{\lambda_{ij}} \ln \sum_m \exp\left(- \lambda_{ij} . t_{ijm}\right)$, where: t_{ij} = composite average time from i to destination j; t_{ijm} = minimum time from i to j by mode m; λ_{ij} = a dispersion parameter reflecting travellers' sensitivity to differences in t_{ijm}.

The theory underlying the potential model is that the region's employment is influenced by its accessibility to markets and by its capacity to produce, relative to all other regions. We are therefore concerned with changes in the value of P_i as a share of the total population of the whole study area.

The region's share of total European potential due to any particular change from BASE case to alternative run ALT was calculated by

$$\Delta q_i = \frac{P_i^{ALT}}{\sum_i P_i^{ALT}} - \frac{P_i^{BASE}}{\sum_i P_i^{BASE}}$$

With this the expected change in each region's employment was calculated:

$$\Delta E_i = \sigma \times \Delta q_i \times E_o$$

where:

σ = sensitivity parameter, different for manufacturing and services;
E_0 = existing employment.

It should be noted that it is the share of potential that is critical, and hence relative accessibility. If a region i maintains the same level of accessibility but all other regions achieve better accessibility, then region i's share of total potential will fall, and a decrease in employment will be predicted there.

"Transport Infrastructure and Regional Development" *(Grandes Infrastructures de Transport et Territoires - Large Scale Transport Infrastructures and Regions, Blanc, 1995)*

Throughout History space has been structured by relations. We can say that one region's development depends on the relations it can maintain with the outside. But what makes relations possible? One of the prime factors is transport infrastructures. This is what this study is about: quantifying one region's potential, as far as transport networks are concerned, in order to analyse its influence in regional development.

In order to assess the regional economic impacts of transport infrastructures development, the indicator used in this study to measure these impacts is the GDP *per capita*.

We can find, in almost all regions, a significant positive impact of transport infrastructure improvement. However, the relationship between transport infrastructure and regional development is neither simple nor direct. This means that the effect of transport infrastructures is not automatic. It depends on transport infrastructure utilisation and on the regional development level.

There are two types of relationships between infrastructures and development.

- Increasing relationship: regions with weak infrastructure conditions in which that weakness can be a restrictive factor; regions with a good infrastructure condition that use perfectly the infrastructure to explore the exchanges. An increase in transport infrastructure leads to an increase in regional development.

- Decreasing relationship: regions that do not base their development on exchange but in other kinds of dynamic. Since current transport infrastructure enables circulation without congestion, the transport infrastructure should be considered sufficient. An increase in transport infrastructure has not any impact on development because the region does not have an exchange dynamic. The same resources could be used with advantage for other type of investment.

As referred above, the relationship depends on and so it is necessary to study the impact of infrastructure utilisation.

One model can be used to measure the regional GDP (*per capita)* in Europe (for the average region and except for Northern Ireland). It can be expressed by the following formula:

$$GDP\left(percapita\right) = -159.1 + 0.85TI - 4.10^{-3}\,TI^{2} + 6.10^{-6}\,TI^{3} + 1.44TUR - 2.10^{3}\,TUR^{2} + 3.38e^{\left(\frac{F}{P}\right)}$$

where:

TI = transport infrastructure;
TUR = transport utilisation rate;

$\frac{F}{P}$ = flows/population (regional insertion in exchanges)

The model parameters are: R^2 = 65.5%; F=17.3; LNHo[1] Model.

This study is then extended to other levels of regional GDP *(per capita)*. This extension involves the reformulation of relations between the preceding variables.

3.5 Socio-economic Impact of Projects Financed by the Cohesion Fund

This report outlines the results of modelling work undertaken by the Economic and Social Cohesion Laboratory at the London School of Economics on behalf of the European Commission DGXVI (Cohesion Fund). In addition to outlining the models, it gives results from the analysis of specific Cohesion Fund investment expenditure undertaken using these models. The various modelling approaches aim to provide a coherent framework for analysing the impact of Cohesion Fund spending in the four Cohesion Countries - Greece, Ireland, Portugal and Spain.

The first two sections of the report outline vector autoregression specifications (VARs) and suggest how they could be used to consider the dynamic impact of Cohesion Fund spending. The paper in the third section describes the specification of regional Computable General Equilibrium models (CGE models), and shows how they can be used to simulate the short and long run effects of Cohesion fund infrastructure projects. The fourth section reports results from models of explicit distribution dynamics (MEDDs).

These sections are ordered according to the regional "specificity" of each model's outputs. The VAR models analyse the impact of an investment in a region on the economic performance of that region. They provide information on output, business investment, employment and other labour market indicators. In addition they provide useful information on spillovers between regions which give an indication of the aggregate and distributive impact of expenditure. The regional CGE models are less region specific. They are most useful for analysing the impact of investments that change the transport costs between regions. The model output provides information on the impact

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[1] This means that the model is linear, the residuals are normally distributed and there is homocesdacity (the parameters variance is constant throughout the sample).

across all affected regions. Finally, the MEDDs provide the broadest possible framework. They can be used to analyse the impact of investments on the distribution of economic variables across all regions of a country, or even across all regions of all Cohesion and Non-Cohesion countries in the European Union.

The methodology employed in the two firsts sections is to undertake a rich empirical analysis using time series data, but a very simple “reduced form” economic model (macro-economic approach). In the third section a diametrically opposite approach is taken. A model with a fully articulated micro-economic structure is built.

Our report of this study is divided in two sections - Macroeconomic and Microeconomic. According to the objective of this deliverable – Assessment of Spatial and Socio-economic Impacts - the most useful approach seems to be the micro-economic analysis. Therefore, the microeconomic approach is reported with more detail than the macro-economic analysis.

3.5.1 A Macroeconomic Approach

3.5.1.1 The impact of European Cohesion Fund Spending: VARs regional labour market issues

This chapter estimates the relationship between public investment, business investment and labour market variables through econometric analysis of a Vector Auto-Regressive (VAR) model. The VAR methodology captures the dynamic relationship between these variables.

In the model, public investment spending influences aggregate economic activity as follows:

1. Public spending has a direct positive impact on private investment decisions;
2. This increase in business investment further enhances the positive effect that public spending has on the employment variables in the region.
3. In turn, the movement in labour demand influences other labour market variables, such as employment, regional activity rates and migration between regions.

Public investment spending influences aggregate economic activity through direct job creation and also, indirectly, by increasing the productivity of private capital. The latter channel stimulates private investment, which leads to more job creation. At the aggregate level, such job creation is likely to lead to a fall in unemployment, since the labour is not likely to respond one for one to the new job creation. But at the regional level, the supply of labour is more responsive to economic incentives, because of inter-regional migration.

This model can evaluate the impact of exogenous changes in public investment spending on the regional economies of the four Cohesion countries. The analysis is carried out at the regional level, but some spillovers at the national level are also emphasised. The impact of public spending can be investigated by using a bivariate VAR. The estimated parameters are elasticities, reflecting the percentage increase in the dependent variable (private investment, in this case) due to a 1% increase in the exogenous variable (public spending). The same methodology is applied to the bivariate system involving private business investment and employment, population and activity rate, to examine the effect of employment, shocks on other labour markets variables.

The VAR model amounts to estimating the effect of the lagged values of all variables on the present value of each. By making use of the estimates, the dynamic response of each variable to a unit change in a given exogenous variable can then be simulated.

The parameters of the relationships are estimated utilising panel data for each of the Cohesion countries. Coefficients can, therefore, be calculated by exploiting the information contained both in the cross-sectional and time series dimensions. In this way, the impact of public spending on the economy of a "representative" region for each country is modelled. The level of disaggregation of the analysis is sometimes NUTS2 and sometimes NUTS3, depending on data availability.

3.5.1.2 The Impact of Cohesion Fund Spending: VARs - Regional Output and Employment in the Presence of Interregional Spillovers

The model outlined above uses VAR techniques to study the impact of local public investment spending on regional economic decisions by the private sector. This section of the report develops that work by extending it in a number of directions:

- The impact on public investment and labour market outcomes are integrated into the same system, allowing a richer range of interactions.
- Regional output is also added into the picture, permitting also the evaluation of the consequences of increased public investment for local output and productivity .
- The importance of local spillovers in economic activity from one region into neighbouring regions is explored. It is important in moving from the impact on local economic variables to the aggregate impact on the national economy.

This analysis has been concentrated on Spain because it was the country for which homogenous data were available for a somewhat longer period. It should not be forgotten that to develop a greater complexity model a greater data requirements is required.

The assumptions of the existing theoretical and empirical literature on local production are argued:

- technical progress may differ across regions because of differences in industrial structure;
- measured factor inputs may differ from those effectively employed in the production process because of for example the labour hoarding and capacity utilisation;
- adjustment cost may be important and that should be allowed for a more sophisticated dynamic structure.

Introducing more complex dynamic behaviour and allowing for the simultaneous determination of employment and output extends the existing work. To do this, a Structural Vector Autoregression (VAR) for private capital, is specified and estimated for private capital, public capital, employment, unemployment and output. The standard VAR formulation specifies each variable as a function of lagged values of both itself and all the other economic variables in the system. Because the VAR formulation involves only lagged values of variables it is easily estimated using standard techniques. Identification is the process of recovering the form of the macroeconomic model (that is all the economic variables interact) from the estimated VAR. The Structural VAR uses economic theory to identify the macroeconomic model.

The economic model is then essentially of the standard neo-classical synthesis variety. Its mains features are:

- The equilibrium, or natural level of output occurs when capital is fully employed and the unemployment rate is at its equilibrium.
- The equilibrium unemployment rate is determined within a "battle-of-the-mark-ups" framework. One relationship describes the way wages are set (by firms to motivate workers or as a bargaining outcome) which makes the real "supply" wage a decreasing function of the unemployment rate. Another relationship describes firms pricing and employment decisions. This framework is like standard competitive equilibrium but without the usual efficiency results - there can be equilibrium unemployment.
- The period's natural unemployment rate may depend on previous period's natural unemployment rates but is independent of the size of the labour force. Deviations around these natural levels of output and unemployment occur when there are unexpected disturbances to aggregate demand or when there are shocks to private or public investment.
- During recessions firms may be off their production functions because of hoarding of labour and other factors of production.

The above model can specify the interrelations between the fundamental shocks of the macroeconomic model and the observed disturbances of the structural VAR. Using these interrelations it can be showed how the underlying macroeconomic model can be identified and outline a simple, but consistent, estimation procedure. Results from these models are presented both statistically (reporting coefficients and significance tests) and graphically (using impulse response functions).

There are two refinements to do this "base" model that should be considered:

- The base model excludes motorways from the definition of public capital. It is showed that motorway expenditure has no explanatory power for the five other variables in the system. Plots of motorway expenditure show that large jumps in investment do not affect regional output and employment, which suggests that benefits may be occurred outside the region.
- The base model is extended by disaggregating public capital into transport (road, ports and airports) and other infrastructure capital (water and urban structures). Statistical tests suggest that the disaggregated model is preferred, but only because it improves the forecast of public investment. Thus, the single aggregate public capital variable has continued to be used in these analysis.

Interregional Spillovers

The importance of economy wide spillovers is then considered. The question is what is happening in one region as a response to what is happening in another. These interregional spillovers could be a result of positive agglomeration effects (the concentration of particular sorts of production in a given locale will encourage new producers to site their activities in the same locale since they reap extra benefits from being close to existing producers) and negative congestion effects (so-called congestion externalities which arise when the entry of another producer into a locale puts pressure on existing infrastructure facilities and reduces the attractiveness of the area to other firms).

The average GDP of physically contiguous neighbours is used to capture local spillovers. In order to examine the influence of local spillovers it would therefore be highly desirable to work at finer, NUTS3, disaggregation. However, capital stock data is only available at the NUTS2 level and it means that an assumption should be made: all NUTS3 stocks move equiproportionately with their NUTS2 counterparts.

Then the total current and lagged national GDP and the current and lagged values of the average level of output (in those other regions that directly border any given province) are added into VAR, as an exogenous variable to capture economy wide spillovers.

Unsurprisingly, economy wide spillovers are large and positive. Local spillovers are positive, but temporary, suggesting that such spillovers are demand-side driven. Re-estimation of the “base” model suggest that differences in impulse responses are from spillovers and not from disaggregation.

With regard to impulse responses, there are some notable differences between the model with interregional spillovers and the model without. In particular, and most relevant for this exercise, the effect on private investment is almost eliminated, while the effect on output and employment is almost halved in magnitude.

Finally, it should be referred that the model has been used to analyse the impact of specific Cohesion Fund expenditures (Madrid Ring Road and the Rias Bajas Motorway and a sample of environmental projects).

3.5.2 A Microeconomic Approach

3.5.2.1 Evaluating Regional Infrastructure: Computable General Equilibrium Models

This chapter presents the methodology to construct a computable general equilibrium model of the regions under study, and its use to simulate the effects of Cohesion Fund projects. The methodology employed in these models is very different from that used in the rest of the study. Rather than undertaking a rich empirical analysis using time series data, and then using simple reduced forms, this approach builds a model with a fully articulated micro-economic structure.

This micro-economic structure allows to capture a high level of project detail, and thereby, to discriminate between different projects in a way that empirical macroeconomic models cannot. For example, the effects of a transport project will depend on precisely how it changes the transport network and changes transport costs on different links in the network. It will also depend on the characteristics of the regions that experience a change in transport costs either internally, or to and from other regions. A transport project may be effective in quite discriminating ways as the cost of supply to these regions is reduced, and so too are the market access costs of firms located in the regions. A fully articulated micro-economic structure can capture these effects, and measure their impact on a wide range of economic variables - output and employment in various industries, and wage rates and real income levels. So, the CGE models can distinguish between two similarly sized projects in the same region which affect two separate transport corridors and can trace their overall effects.

3.5.2.1.1 The Issues

In this section, the main economic issues involved in the modelling approach are set out: It is helpful to think of the effects of a project as consisting of three types of elements: direct, induced and spillover. The direct benefits are those that accrue at unchanged activity levels in the economy. Taking as an example a road project, the direct benefits are simply the reduction in cost per journey on the road times the initial number of journeys. The induced effects arise from the fact that the project may change the levels of activities directly related to the project. For sample, the project will increase the number of journeys undertaken. Spillover effects arise as the effects of the project ripple through the wider economy.

This analysis will incorporate increasing returns to scale at the level of the firm and imperfect competition (in some, but not all sectors), and input-output linkages between industries so that there are potential forward and backward linkages. The combination of these forces gives rise to pecuniary externalities and spillovers, although possibly rather weak ones.

3.5.2.1.2 Overview of the Model

In this section the main elements of the model are outlined.

Locations and endowments

The first component of the model is a specification of the geographical space within which economic activity takes place. This takes the form of a set of regions, described as points in space linked by a transport network through which goods and services can be traded. Ideally a high level of regional disaggregaton is required.

Each region has an endowment of primary factors - in the models that are presented here, this takes the form of two types of labour (skilled and unskilled) and capital. These endowments are owned by a representative household in each location which spends its income on final goods. It is assumed that capital is perfectly mobile between regions, and that the price of capital is constant. Two different assumptions are made for labour: for each experiment, the results are reported both when labour is immobile between regions, and when labour is perfectly mobile. In the former case wage rates are determined by supply and demand in each location, this implying that regional wage rates are possible and are not offset by migration between regions. In the latter case wage rates are the same in all regions, and are determined by supply and demand for labour in the country area as a whole.

In addition to the regions within the country area under study, there are external trading partners. It is assumed two of these: the rest of Europe and the rest of the world. They are modelled much less fully than the internal regions, merely offering import supplies and export demands to the regions under study.

Production

There are a number of industrial sectors in the economy and these are divided into two types: perfectly and imperfectly competitive industries. In perfectly competitive industries production takes place according to constant returns to scale, and firms price at marginal cost. A single homogenous product type is produced by each of these industries in each region, although the possibility of that region's product type being differentiated from that other regions is allowed. Imperfectly competitive industries contain firms which operate under increasing returns to scale. In general, each industry will operate in each region, so each region contains some number of firms from each industry. This study use the standard Dixit-Stiglitz representation of increasing returns and imperfect competition.

This involves a number of assumptions on the demand system:

- each firms is constrained to operate in a single region only;
- each firm is assumed to produce a distinct variety of product;
- each firm is assumed to set price at a constant mark up over marginal cost;
- if each firm produces its own variety of product, the varieties are assumed to be symmetric.

That is, they are produced using the same technology, and face the same demand functions. Consequently, if they are sold at the same price, then they will achieve the same level of sales.

All sectors of the economy use as inputs to production the primary factors and intermediate goods. Corresponding to this, all sectors' output is used both as a final product and as an intermediate goods usage and the destination (final or intermediate use) of output comes from the input-output matrix. A consequence of product differentiation combined with the symmetry assumption is that all firms at particular location in a particular industry supply final demand and intermediate demand in same proportions.

The results reported are related with a "short-run" case, where industrial location is assumed to be constant, when the numbers of firms is held constant and with a "long-run", where entry and exit of firms has occurred in response to profit opportunities, when the number of firms is allowed to change.

Inter-locational Trade

One of the objectives of this study is to capture the possibility of intra-industry trade in each industry and between all locations.

Two assumptions related with this are assumed:

- The preferences related with the different locations of operations' firms and distinct varieties produced by them can generate demand at each location for output produced in all other locations, and hence can produce the full set of inter-locational trade flows;

- The firms that benefit from having a wide range of intermediate goods available and their intermediate demands will draw on output from all locations.

The volumes of these inter-locational trade flows are regulated by transport costs between locations. A high level of transport costs between two regions will raise the price of products traded between regions, and reduce the level of trade on that segment of the network. An important issue arises in measurement of these transport costs. Whereas a model of international trade would use data on international trade flows to infer the trade costs consistent with these flows, disaggregated data on inter-regional trade flows is unavailable. Therefore the estimates of trade and transport costs between locations are obtained, on the basis of which the model generates all the inter-regional trade flows.

International Trade

The regions in the model also serve as "ports" - points through which exports and imports to the rest of the EU and the rest of the world pass.

Imports are available at fixed world prices, and constitute an additional source of supply at each port location. They can be shipped from port of entry to other regions in a manner exactly analogous to the inter-regional trade in domestically produced goods. Changes in the cost of shipping from the port to a final demand region will cause substitution between ports, as final users may change the effect of port improvements on port usage.

Exports constitute an additional source of demand for domestically produced goods at each port location. As with imports, changes in the relative costs of using a particular port may cause changes in the volumes of exports going through the port, as exporters can substitute between the ports they use.

This study also assumes that overall demand for the total exports of each industry is a decreasing function of their price.

3.5.2.1.3 Data and Calibration

The model sketched out above was fitted to data for three country/country groups. A combined Iberian model was constructed for Spain and Portugal, and separate single country models for Greece and Ireland.

This section discusses the primary data requirements of the model, the procedures that were employed to ensure the internal consistency of the data, and the consistency of the data to the underlying computable general equilibrium.

Primary Data Requirements

Production

The model requires industrial data at whatever level of regional disaggregation is adopted, and as sectorally disaggregated as possible.

In the first instance, it was necessary to collect data on either the value of production or on the value added in each sector.

In practice, there are serious restrictions on the amount of data that are available at the regional level. So, the level of regional disaggregation finally employed in this study was not the same for all the countries: Spain - NUTS2; Portugal - NUTS2; Greece - own regional classification scheme which can be reconciled with the NUTS2 level of disaggregation; Ireland - NUTS3.

The level of industrial disaggregation was necessarily determined by the completeness of the corresponding regional data set. For each country the level of industrial disaggregation was: Spain/Portugal - NACE R17; Greece - again based on own classification scheme which comprises eight sectors of NACE CLIO; Ireland - three sectors of NACE CLIO.

National Accounts Data

As reported previously the model is a full general equilibrium model of regional production and trade. This means that both intermediate production and final goods production are explicitly modelled. With regard to intermediate goods production the primary data requirement was an input-output table which included both the table of intermediate consumption as well as details on primary inputs. From this, one can then derive the appropriate technical coefficients which are required for describing the intermediate demands and supplies of each sector.

The input-output tables thus provided the vertical coefficients for each of the industries at NACE CLIO classification level of disaggregation, and for the share of labour and capital in production. The input-output tables also were used to calculate the share of value added in each industry.

Inter-regional Trade Costs

Each of the models contains inter-regional trade within an open economy. The data described above includes only information on production by sector and by region, but not on the value trade between each region in each industry. Deriving this matrix is a central feature of the calibration procedure. Ideally this procedure requires information on transport costs between each region. However, such data is not available, so these costs have to be inferred or estimated which is done on the basis of distance.

The procedure is in three stages:

- The primary centre of economic activity within each region is located and the matrix of distances between each pair of regions is constructed. Given the distance matrix, the relationship between distance and transport costs is assumed. Using this in the model a pattern of gross trade flows between regions is generated. For some countries there is data available on the volume of trade between regions (although in units different from those of the model, and not always at the same level of disaggregation), and this was compared with the trade flows generated by the model.

- An interactive procedure was then adopted to adjust the relationship between distance and transport costs until the model produced a reasonable replica of the data on trade volumes.

- Finally, the relationship between distance and trade volumes is prepared to capture different transport costs in different industries. It is done by using external trade data and production data (exports plus imports relative to total production for each industry) to measure the trade ability of the output of different industries.

Ports

The external trade is limited to both intra and extra EU trade. However, as the country is broken down into a number of regions it is necessary to identify through which regions the external trade flows take place. Here too it is necessary to distinguish between different types of “ports” which should include land, air and sea. With regard to air and sea, data was obtained on the volume of trade going through each port. With regard to external trade over land, data was obtained on the total volume of externally directed road and rail traffic. The form of this data make it difficult to identify ports. The procedure employed here, therefore, was to identify the regions which are contiguous with other countries, to calculate for each of these regions their share of total contiguous regions’ production, and then to allocate the land traffic accordingly. The final stage of the ports process was to sum the total volume of trade by type of traffic going out of each region, and then to calculate each regions’ share of total external traffic.

Miscellaneous

In addition to the above for each country data was required on both intra and extra European trade for each sector, as well as a range of industry specific parameters.

These include:

- the value added share in each sector;
- the shares on manual and non-manual labour in each sector;
- elasticities of substitution between capital and labour and between the different labour types.

3.5.2.1.4 Simulation

This section of the study outlines the procedures that were followed to represent a cohesion fund project within the model, and then report results from simulating the economic effects of these projects. In the total there are six experiments which are reported on this study, one for each of the countries in the model. The six experiments are:

- North-South road link (Ireland);
- Madrid ring road (Spain);
- Rias-Bajas motorway (Spain);
- Tagus crossing (Portugal);
- Egnatia motorway (Greece);
- Pathe motorway (Greece).

Before presenting the methodology in some detail it is first important to outline some of the general considerations that are referred in the study. The experiments are all road projects, the direct effects of which are to reduce transport costs between and within regions. Calibration of these costs was based on the distance between regions, and the study models a project as causing a reduction of "effective distance" between regions. That is if a given road project is expected to reduce travelling time between two regions by one our, this can be approximated by reducing the effective distance between the regions by the average distance that could be travelled in that time, for example 100 km. Since trade costs were computed as a function of distance, this is turn translates back into a cost saving on the route.

The following paragraphs are related with the judgmental choices that are considered in the study for the implementation of the above procedure.

1. First, given some information on the project, how is this to be translated into an effective reduction in distance? Clearly time savings can be translated into effective distance reductions given estimates of average speeds. Rather more speculatively, kilometres of road improvement can be translated into an effective distance reduction, given estimates of average speeds with and without the project.

2. Second, what routes - links between regions - are affected by a particular road scheme? The decisions about which routes are and are not affected is a matter of judgement, based essentially on looking at road maps.

3. Third, what proportion of traffic on route is affected by a particular improvement? Clearly, not all journeys are made by road transport, and other modes of transport are unaffected. So, it is necessary to make judgements on each of these numbers, and use these to deflate the effective distance reduction - a 100 km distance reduction which is only used by half the journeys on the route is interpreted as a 50 km distance reduction. Therefore, two matrixes are obtained: Weight Attached to Different Projects on Inter and Intra Regional Travel and Weighted Effective

Distance Saved. In order to get some idea of the size of the experiments it can also be constructed a matrix with the WEDS relative to the original distance.

4. Finally, the effective distance reduction may be different for different industries. The model allows us to take this into account, with project impacting on different industries in different ways. But once again, the problem is getting hard information on which to base any such unequal treatment.

Clearly then, a number of subjective and somewhat arbitrary descriptions of the project have gone into the design of the experiments of this study, and this must be borne in mind in interpreting results.

The model is run for each simulation, incorporating the changed transport costs. Then it is compared the new equilibrium with the old. To assess the effects of the project, the simulations are carried out in four stages.

1. Compute direct effects. The value of transport costs savings is found with all endogenous variables held constant. To do this, the effective distance saved by the infrastructure project, between and within regions, is computed. Then, trade costs are computed as a function of distance, translating the effective distance saved into transport costs savings.
2. Compute the effects maintaining location of firms and workers fixed, but allowing output and sales to change. This approximates the induced effects of the project in so far as it permits changes in some endogenous variables, but ignores the possibility that the project may cause industrial relocation. This gives short run effects.
3. Compute the effects allowing the number of firms to change but holding the number of workers constant. The changes in the number of firms occur in response to short run changes in the level of profits and, as they occur, they further change profits through the linkage and factor market mechanisms. This gives medium run effects.
4. Compute the effects allowing workers to move in response to induced changes in wages between regions. This stage of the experiment allows “perfect” factor mobility in so far as both labour capital move to ensure equalisation of returns across all regions. This gives long run effects.

Using this four stages, it is possible to compute the welfare and labour income changes by region resulting from specific Cohesion infrastructure projects in the short run, medium run, and long run. This latter measure is useful because it gives a good indication of the impact of the project on demand for labour across different regions, although it is not of any direct welfare significance.

3.6 A review of the Indicators Researched

In this conclusion section a review of the main important indicators (their orientations and assumptions) is made. The relationship between this chapter and the next is stated and argued. The main arguments in favour of the methodological orientation developed in chapter 4 are also presented here.

The literature presented in this chapter was the result of a selection of a rather exhaustive survey of the English and French language bibliography. Some of the documents found were not included because they are not related with objective of the CODE-TEN and a high level of repetition of the same concepts was presented. However the full reference list of the consulted studies is included in chapter 7.

This deliverable covers all the inputs and resources mentioned in the technical annex of the CODE-TEN project. The DGVII and DGXVI were also been contacted and their (very scarce) leads and suggestions have been followed.

The operational uses of the accessibility concept that were found in the literature survey are resumed in the following paragraphs.

Accessibility has generally been defined as some measure of spatial separation of human activities. Essentially it denotes the ease with which activities may be reached from a given location using a particular transportation system. It is a concept often used, with a variety of meanings and for which no universally accepted definition has been accepted, even in the restricted domain of territory orientated sciences.

Accessibility must be seen as a measure of potential of opportunities for interaction (interplay), which might be specific to a certain motive (type of interplay) or generic (a wide range of motives). This potential always has to do with the difficulty of reaching the *other* (or any one of a set of *others*), as well as frequently, but not always, with the size of that *other*. If it is concerned with a specific motive, the size of the other is usually measured by its supply of the functions or services it is looking for, e.g. square meters of commercial floor space, number of concert seats, etc. If it is dealing with a generic set of motives, size is normally represented by the population.

There are two main dimensions that influence accessibility:

- my location with respect to the others (geodistance)
- the ease of connection between my place and those other places

This ease of connection is represented by several variables, key among them being the speed of displacement (which leads to travelling time when considered jointly with distance). Other important variables for this are frequency of service, price and flexibility of travelling times.

In most cases we will want to consider the joint influence of these two dimensions, but it may be useful to analyse the "ease of connection" side alone, when the goal is to evaluate the performance of a transport system, both in longitudinal and in transversal comparisons. In such cases, the influence of location must be put aside.

We will use the terms of "real accessibility" when the two effects are considered jointly, and "instrumental accessibility" when only the ease of connection is being considered. These indicators have already been referred in the section 3.2 although with a different "symbology" from that used in this section. The approach made in the following paragraphs gives a brief coverage resume the researched indicators most connected with the purpose of this deliverable.

Starting with "real accessibility", 4 types of indicators can be defined , all of them relating travelling time (as an indicator of the difficulty of reaching the partners) and quantity of partners reachable within that travelling time. Some of these indicators have already been referred in the section 3.2:

- TMIN (f), which is used for specific functions of urgency, rare use, or significant jump in the speed of travel, like an international airport or even a motorway node;

- $Q_{Aggreg} = \sum Q(j) \times F^{attrac}[T(ij)]$, which is used to obtain a scalar value aggregating the potential for interaction from one particular location. This has the difficulty of specification of an attraction decay function with increased travelling time which is valid for generic motives. The utility indicators mentioned in section 3.2 fall within this family;

- TMAX (Q_k), which is used for specific or generic motives, represents the time radius needed to reach a pre-specified quantity of opportunities Q_k. In most studies it is not easy to define the appropriate threshold values for Q_k and arbitrary values are used..

- $Q(T_k)$, which is used to measure the intensity of opportunities associated to a pre-specified time threshold, frequently associated with the 24-hour basic cycle of human activities. This framework facilitates the definition of threshold values. The “conditional aggregation” and CONT(T) indicators mentioned in section 3.2 fall within this family.

The two first of these indicators are scalars, and thus very easily applicable to establish order relationships. The two latter are step functions and can only be compared at the level of distributions.

When other aspects of ease of connection besides speed are considered, the following adaptations are suggested:

- Frequency of service: depending on the motive of access (and thus also on the travelling time), we define the period of the day over which accessibility is to be ensured (normally by specifying earliest departure time and latest arrival time), and the width of the time slot considered adequate as in interval between departures. For each of the intervals so defined, the desired indicator is computed, and then the average or the distribution of those indicators is used;

- Price: We start by defining the minimum available price and the successive levels for which the evaluation is to be made. At each price level, all services equal or lower than that level are considered, thus producing a growing function of accessibility indicators at prices not above each of the specified levels. Alternatively, price may be considered in conjunction with travel time for some function of “generalised cost”, on the basis of which the previously given definitions may be applied;

- Flexibility of departure times: Based on the slots defined for the computation of the influence of frequency of service, we consider for each slot with service the hypothesis of wanting to advance the departure time by 1 slot width. If there is service in that slot, use the travelling time of that service; if there is no service in that slot, add 1 slot width to the travelling time of the original service, and repeat the computations with the new values. An index of inflexibility may be computed by dividing A* by A where A is the original accessibility indicator and A* is the accessibility indicator obtained as described here;

For the case of “instrumental accessibility”, equivalent indicators can de derived for all of these except for the $Q(T_k)$ indicator. A key concept in the translation of these indicators is that of “Equivalent Straight line Speed” (ESS) or, for larger distances, “Equivalent Geospeed”, as referred in section 3.2.

According to the objective of CODE-TEN project the methodology proposed in this deliverable should be able to assess regional economic impacts of accessibility improvements for each corridor alternative. We also have to develop indices that reflect change for passenger and freight. The most related with this purpose are of the $Q(T_k)$ type defined above, because they are the most closely connected to development opportunities for most economic sectors and they are easily used for calculation of passenger and freight accessibility (see UTS Study).

Concerning indicators for assessment of the economic impacts of accessibility improvements that were reported in section 3.4, we consider that none of those can be recommended for application in the CODE-TEN project. The microeconomic approach based on general equilibrium models (presented in section 3.5) is the most related with our study. However, the heavy structure and data requirements of this model makes it impractical for use in CODE-TEN, where we have to measure the economic impact of 10 corridors, each one with various alternatives. After having seen the methodology for construction of a CGE model of the regions under study (in four countries) and its use to simulate the effects of Cohesion Fund projects (six experiments), it should be clear that the relevance of this model is strongly conditioned by the efforts needed (in respect with the available data and the costs and delays incurred to get it) to run it.

These are the reasons why we propose a new methodology for measuring the regional economic impacts of accessibility improvements, which builds on the main assumptions found in the literature survey and tries to use a simpler approach. That methodology is described in the next chapter.

4. Summary of the Proposed Methodology for Assessing Strategic Territorial Impacts from Transport Projects

After the survey presented in the previous chapter, it is clear that a large choice of indicators and models is available, depending on what aspects are thought more important and what data is available (or might be made available and at what cost and delay).

In the framework of the CODE-TEN project, the methodology presented in this deliverable is supposed to be applied to a large number of corridors, with varying levels of data availability and reliability.

Moreover, since most of these corridors are located in Central and Eastern Europe, models based on strong assumptions about competition between firms on the market world have to be applied with careful judgement (and delicate adjustments) in each case.

So, as it has already been refereed in the end of section 3.6 we decided to propose adoption of a relatively simple methodology for which the required data is believed to be available in most cases.

In the following scheme the proposed methodology and the interrelationships among its main steps are represented.

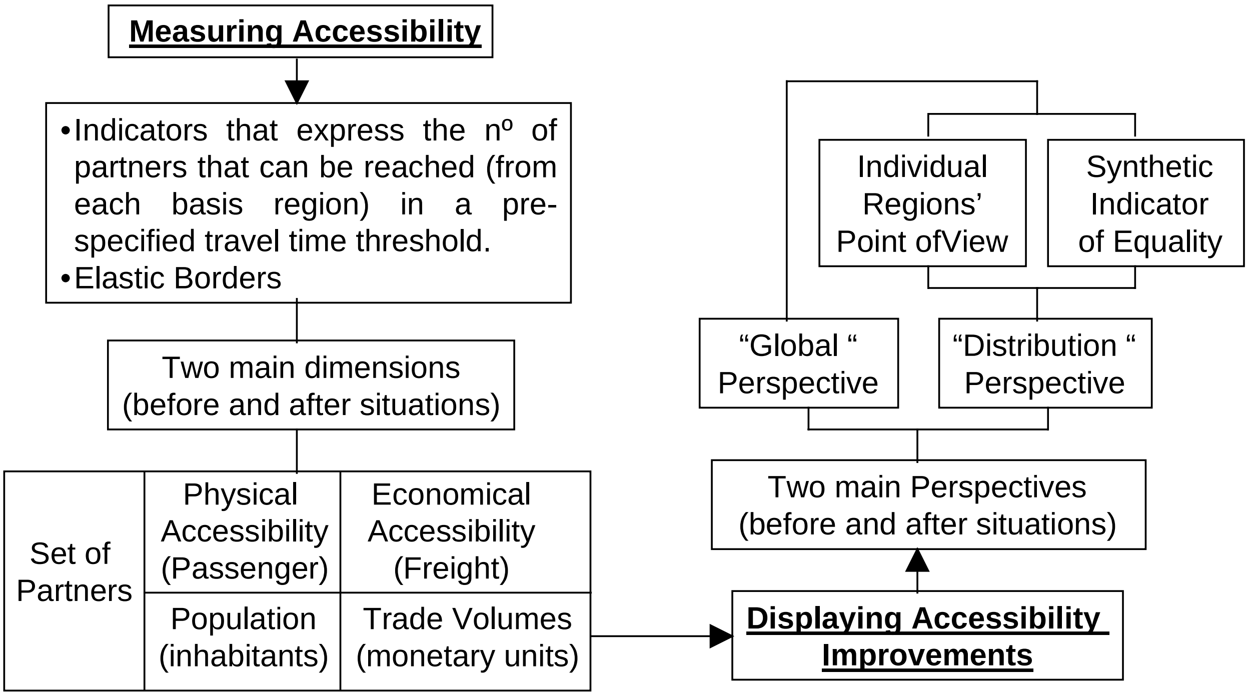

Figure 4.1 – Several Dimensions of Change of Accessibility

The methodology is divided into two main directions, which are **Measuring Accessibility** and **Displaying Accessibility Improvements**. The first corresponds to the chapter 5 of this deliverable and the second to the chapter 6. **Both directions should be applied for each corridor alternative**.

In relation with Measuring Accessibility the methodology reflects results of transport investments in the two main dimensions covered by strategic territorial impacts, considering the situations of before and after the improvement/construction of the infrastructure:

- Demographic Accessibility;
- Economic Accessibility, i.e., potential gain of economic efficiency by reduction of transport costs in referred imports and exports.

Both these indicators express the number of “partners” that can be reached (from each basis region) in a pre-specified travel time threshold associated with the 24-hour cycle of human activity. As it can be noted from the above definition, both these two main dimensions fall within the concept of real accessibility indicators, which is reported in section 3.6.

The **basis regions** that should be considered are all that are crossed by the new infrastructure and maybe the neighbouring regions of those. This decision requires careful analysis and probably involves different criteria for each case study.

For demographic accessibility the population (inhabitants) living in each region within reach is used as the weight of each partner region, whereas for economical accessibility the potential trade volumes (expressed in monetary units) play that role.

So, the gains in economic accessibility are interpreted in connection with the reduction of transport costs in imports and exports (trade volumes). This indicator corresponds only to the so-called “direct effects” as described in section 3.5, where a micro-economic approach based on general equilibrium models was presented. The description presented in that section of the efforts needed to run the model with a few projects in only four (relatively developed and economically open) countries should make it clear why it was thought prudent in the present framework to stop at the evaluation of these first order potential gains.

The indices developed have to measure change for passenger and freight transport, taking into consideration permanently available transport options (road) as well as options that are made available only at pre-specified times (like in rail and shipping). In all cases, air travel is not considered since airports are not part of the corridor investments being considered and the price levels in this mode (except for tourist purposes) are much higher than in the others.

In order to avoid too many calculations we decided to measure change for passenger transport through demographic accessibility because this type of transport is more related with population dimension whereas for economic accessibility freight transport is the basis of analysis, as it is more connected with trade flows.

However, the calculation of economic accessibility indicators based on passenger transport can also be pertinent in the case, for example of an economy of services.
Considering this last hypothesis we decided to report the values of travel time and travel time threshold considered in each case - passenger transport and freight transport - and the respective justification in the section 5.1.1, in which the indicators for measuring change of demographic accessibility are presented.

Still concerning this first direction – Measuring Accessibility - some additional considerations about the definition of travel time thresholds are made through the development of a new concept called “Elastic Borders” (section 5.3). This is related with the introduction of a certain “tolerance” for aggregation of partners.

Concerning the second step of this methodology, as the accessibility improvements will be displayed for both dimensions, a connection between that and the first direction is established, as it can be observed in the figure.

Similarly, two main perspectives are also proposed for the before and after situations which are a Global perspective and a Distribution perspective. The latter is still divided into two approaches corresponding to the individual Regions' Point of View and to a Synthetic Indicator of Equality.

The "topics" introduced here will be explained with more detail in the next chapters.

The implementation of such methodology requires the:

- Elaboration of a Transport Information System, which is developed as an integrated database with interfaces and which includes information for the countries under study (*in Deliverable 2 of CODE-TEN*)
- Handling of a Geographic Information System for convenient representation of the key aspects under study and computation of the indices.

5. Measuring Accessibility

5.1 Proposed Indicators of Demographic Accessibility

5.1.1 Measuring the Change of Demographic Accessibility

In the evaluation exercises for the various corridors, a relatively small number of indicators has to be computed so that the main features of the changes arising from construction of the infrastructure may be captured by the readers of the report in general and by decision makers in particular.

We have opted not to use aggregated indicators (like Q_{aggreg}) referred in the previous section because their (scalar) facility of comparison and representation are accompanied by a much greater difficulty of physical interpretation for laymen. Instead, we will use a (small) family of cumulative indicators of the $Q(T_k)$ type defined above.

The formula of the adopted indicator is:

$$Q(T_k) = \sum_{j=1,N} P_j \ , \quad \text{if } t_{i,j} \leq T_k$$

where:

Q_{Tk} is the indicator of demographic accessibility;
T_k is the pre-specified travel time threshold;
i is the basis region;
j are the destinations reached;
$t_{i,j}$ is the travel time;
P_j is the total existing population of destination j.

Given the scale of projects being considered, for passengers, this will consist of two indicators, related in both cases to time thresholds of one day and two days. However, for passengers these time thresholds refer to the round trip, whereas for freight they refer to one-way travel only.

	Passengers		**Freight**	
Indicator	AP1	AP2	AF1	AF2
Time Threshold	1 day	2 days	1 day	2 days
	(round trip)		(single trip)	
Travel Time				
Road	4 h	7 h	9 h	18 h
Rail / Road+Rail / Shipping	3.5 h	9 h	12 h	28 h

Table 5.1 – Variables considered in Passengers and Freight Indicators Development

Some explanations are necessary to justify these values:

- Time threshold of one day and two days: if we considered a travel time threshold below one day the number of trips that would be covered would be irrelevant from the operational point of view. In other hand with a time threshold too much higher than two days the number of "partners" reachable would be irrelevant from the measurement point of view (the number of partners reachable would not reflect the improvements made).
- Round trip for passengers, single trip for freight: this merely reflects the judgement made by those who decide to make the transport. Persons are supposed to come back to the point of origin and count the total round trip time as their cost, but freight does not come back and if there is a professional organisation involved in transport production, they (not the client) must find the demand for the following days of that rolling stock;
- Relation between total time and travel time: for passengers it was assumed a minimum of 3 useful hours at the destination for one day journeys and of 4 to 5 hours for 2 day journeys. For freight, the maximum number of driving hours was used for the road, whereas the full 24 hours were used for the rail, discounting only time losses for loading and unloading, as well as for intermediate stoppages at high traffic junctions;
- Differences between travel times for road and rail in passenger transport: we are supposing that the interested person is the driver, and that there are some time losses because of discontinuity of service on the rail. So, for a one day journey, more hours can be used by car than by rail. But for a 2 day journey, fatigue is an element for the driver, and not so por the railway passenger, so longer travelling times are acceptable.

As it has already been referred in the chapter 4 the calculation of demographic accessibility by using the values defined for freight transport (which would reflect the changes for that type of transport) should be use only in specific situations. So, according to the above formula and table, for passenger road transport, the demographic accessibility indicator express the number of inhabitants reached in 4 hours and 7 hours for a cycle of one and two days, respectively.

The units of these indicators are inhabitants in all cases. For each of the 4 indicators of accessibility of a given region *i*, any region *j* reached within those time limits (after consideration of the elastic borders effect) will be accounted for, even if that access is possible only by one of the modal solutions. To avoid presentation of too much information, we are not planning to present mode-specific accessibility indicators.

Graphical presentation of these results for a before-after comparison is then very simple, using for instance a stacked bar style graphic like the one shown here:

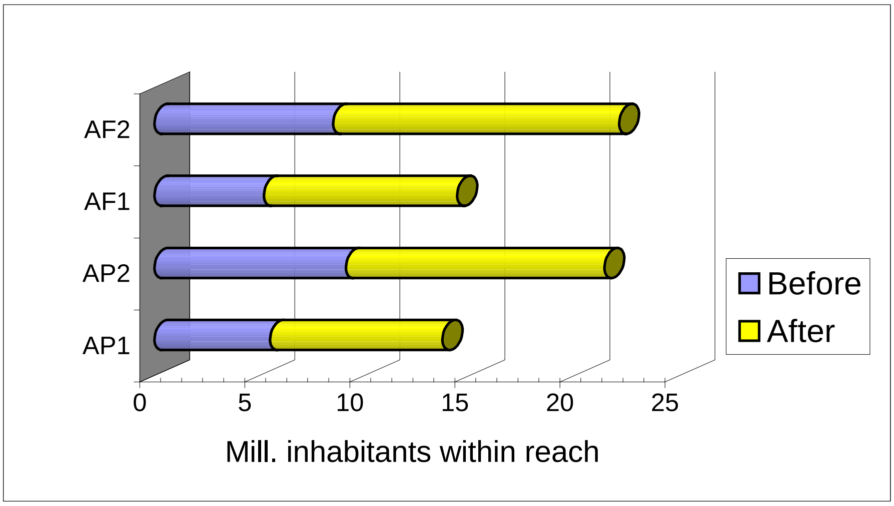

Figure 5.1 - Demographic Accessibility for Passengers (AP) and for Freight (AF) Time Thresholds of 1 and 2 Days

Identically, if several regions are to be compared in their before and after situations of accessibility, this can easily be done, although desirably not with all 4 curves (for all regions) in the same graph.

5.1.2 Data requirements

As it can be concluded by the formula of demographic accessibility indicator, the required data are the number of inhabitants in each of the regions reached. The regions are connected to the networks by specific nodes and links. The regions are at least NUT II regions and in some cases the regionalisation is more detailed. In these cases it is possible to aggregate/disaggregate the information in any way such that we are still using political or administrative units.

5.1.3 Using Transport Flows in Accessibility Indicators

Accessibility indicators making use of flows between pairs of regions, can also be defined. This can be done in more than one way, and proper care must be taken in the interpretation of the meaning of the results in each of those cases:

- The simplest way is to use the relative flow between one (home) region and each of the other regions as the weight to be adopted in the calculation of an indicator of Q_{Aggreg} type, as defined above;

- But when using that we are omitting the question of general intensity of long-range mobility, which is certainly bigger for richer and centrally located regions than for poorer and peripheral regions. So, if flows in relation to each region are used as proxies for weights of those regions, possibly there must be a correction to compensate for lack of mobility (total flow / total population of the base region);

- Another way would be to use the flows as weights not applied to quantities of population (which are already reflected in the flows) but to the distances travelled to reach them, thus obtaining a weighted distance travelled. Here it would be expectable that more central regions would have greater average distances travelled, but the weighting process and the strong prevalence of shorter connections in all cases would possibly make such an indicator more dependent on the size of regions adopted in the modelling than on the accessibility we want to measure;

Possibly the best application of flows in these indicators will be in the distributional indicators, TMAX (Q_k) and Q (T_k), using as Q not the value of opportunities (i.e. populations) but that of actual flows. This type of definitions covers the concerns about mobility (some higher levels of Q_k may simply not be reached) and still preserves the comparability between regions in the main aspects we want to consider.

However it should be referred that using flows instead of population of target regions allows consideration of real intensity of contact instead of time / distance as its proxy (thus incorporating border effects for instance - section 5.3), but may lead to underestimation of importance of removal of some barriers. This means that the risk of underestimation of demographic accessibility is higher with flows than with population because the project itself can change the flows between two regions and so that substitution requires careful use.

5.2 Proposed Indicators of Economic Accessibility

5.2.1 Measuring the Economic Impacts of Accessibility Improvements

On regional economic development, transport infrastructure and services are a necessary element for improvement and modernisation, many other elements intervening in the decisions that lead to growth of GDP and increase or sectoral shift of employment. **Even when there may be correlation between accessibility and employment or GDP, causality is certainly questionable. So, any conclusions taken in relation to this will always be in terms of “potential for” and not of “expectation”.**

It is recognised that the main direct economic effect from improved accessibility in one region is the gain in productivity of the exporting businesses located there, as they will lower their costs of placing the product in external markets, as well as of the importing businesses, as they will be able to obtain their inputs at lower costs. This argument goes in line with the previously reported work from the SASI project (where transport was referred to as an input factor) as well as from the paper by Vickerman (where formulations based on factor mobility and inter-regional trade were developed).

These productivity gains, when coupled with the necessary initiative and inventiveness, can then lead to increased sales, in traditional or new markets, and possibly again to economies of scale and another round of productivity gains. This may attract new business to the area, by imitation or as suppliers to the visibly successful “old” businesses. In the case of very low degree of entrepreneurship in the benefited region it may also happen that its local economic basis decreases because its degree of protection from external suppliers is reduced with the improved accessibility.

However, the occurrence of any of these secondary effects is difficult to anticipate, as the accessibility gains are only a necessary condition, but the supplement needed for each of those effects may be or not be present. The great number of retrospective studies made with actual data has served to show that no solid statistical relation between improved accessibility and economic development (and increases in employment) of regions can be established, thus recognising that additional explanatory variables (not necessary the same variables for all cases) would be needed.

Based on this, the improvements of accessibility should be treated as a gain of potential for economic development. A simplified model is proposed here, trying to reconcile relevance of the values obtained from its computation with likely availability of the input variables for most regions.

This is made by measuring the gains of accessibility with respect to each of the other regions, each region being weighted in proportion to its relevance to the economic structure of the basis region (through the input-output matrix of the latter), instead of by its population.

This concept is mathematically translated in the section below. Let us adopt the following notation:

X_i^s : Total annual production value of region *i* in sector *s*

$a_i^{s,r}$: Technical coefficient of incorporation of sector *s* into sector *r* in the production of region *i*

D_i^s : Total annual final demand of sector *s* in region *i*

The Exporting Affinity from region *i* to region *j* can then be defined as:

$$E(i,j)=\frac{\sum_s X_i^s\left(D_j^s+\sum_r a_j^{s,r}.X_j^r\right)}{\sum_s X_i^s}$$

Likewise, the Importing Affinity of region *i* from region *j* can be defined as the exact symmetrical of the expression above, namely:

$$I(i,j)=\frac{\sum_s X_j^s\left(D_i^s+\sum_r a_i^{s,r}.X_i^r\right)}{\sum_s X_j^s}$$

These expressions are independent. The dimensions of these expressions are in money units per annum. Total Commercial Affinity between these two regions can be defined as:

$$TCA(i,j)=E(i,j)+I(i,j)$$

and represents the “number of partners” of region *j* as seen from *i*, as it would be its population for the computation of “normal” accessibility indices.

This substitution of P(j) by TCA(i,j) for the calculation of this Economic Accessibility can be made for the most usual type of (scalar) accessibility index of a region

$$A(i)=\sum_j P(j).F^{attrac}\left[t(i,j)\right]$$

where:

F is the decay of the attraction force between the two regions, decreasing as the time (or distance or cost) between them increases.

But this substitution can also be made in the same way for other (vectorial) indices such as the one adopted for demographic accessibility:

$$Q_{i,L} = \sum_{j:\{t(i,j)<L\}} TCA(i,j)$$

where:

> L is a threshold of travel time (or distance or cost), and we want to calculate the total number of partners (Population or Total Commercial Affinity) that lies within that travel-time from basis region *i*.

The presentation of results of this type of analysis can thus be made in an identical manner to that described above for the demographic accessibility indices, comparing the ex-ante and ex-post situations, for time-ranges of 1 day and 2 days. The main difference is that on the dependent variable axis of the graph we will not represent “inhabitants” but “trade volumes” reachable within a certain time range.

5.2.2 Data requirements

As it can be observed from the above formulation, for the application of the methodology proposed - economic accessibility indicator - some additional data is required in relation to the information that has been already included in the TIS (*in deliverable 2 of CODE-TEN project*). In the following paragraphs the additional data needed is described in a decreasing order of priority, i.e., first, the ideal information required for the implementation of such indicator and then the alternative data that can be used for the same objective.

1. Regional input-output matrix from which the regional annual production and consumption values (monetary units) disaggregated by economic sector can be provided. Similarly the technical coefficients needed for the calculation of exporting and importing affinity of each basis region can also be obtained from these matrices.

2. In the cases where regional input-output matrixes are not available, the national input-output matrices can be used for the calculation of technical coefficients, but the regional production and consumption have to be provided from other sources.

3. **The most important requirement for the calculation of technical coefficients is that the input-output matrices (regional or national) have the inputs to each sector disaggregated by contributing economic sector independently of being local or imported inputs.**

4. If the regional or national input-output matrices have not the imported inputs disaggregated by economic sector some simplifications/extrapolations can be made by admitting that the importation at the European scale is not relevant, and performing a transformation of scale for the case of those regions.

These data requirements should be provided for all the European regions and the economic disaggregation that should be used is the economic classification adopted for employment in Transportation Information System –TIS – (*in Deliverable 2 of CODE-TEN project*) (NACE CLIO 17).

The TIS developed in the framework of the CODE-TEN project is designed as a system for the greater European area and includes CEEC/CIS. The TIS provides information at regional or national level for networks and corridors. In this context corridors are defined as geographic areas alongside the nine transport axes as defined by the Helsinki conference of European transport Ministers but both East and West.

The TIS distinguish two categories of information:

1. Contains network data and regional data which are directly related to the network and which can be used for models estimating traffic demand, distribution of traffic demand to origin-destination relations and to transport mode. Network related data are organised in a form of GIS using MAPINFO. All data are determined as parameters describing links, nodes and regions. Regions are connected to the networks by specific nodes and kinks and they are at least NUTS II regions.

2. Contains sets of vehicle operating cost, all information determining transport policy in the related country as well as relevant environment aspects.

5.2.3 A Simpler Approach for the Regions where the required Data is not Available

In the regions for which the required data are not available and the calculation of economic accessibility indicator is not feasible we propose a simpler approach for measuring the potential gains in productivity of regions provided by the accessibility improvements related to the construction of a transport infrastructure.

This simpler approach is based on the substitution of total commercial affinity, in the second dimension (economic accessibility) of this methodology by a socio-economic indicator that reflects the economic strength of target regions in the pre-specified travel time threshold (thus incorporating border effects for instance): Gross Domestic Product (GDP) or Employment

The following formula expresses this new approach:

$$Q^2(T_k) = \sum_{j=1,N} GDP_j \text{ , if } t_{i,j} \leq T_k$$

where:

$Q^2(T_k)$ represents the total number of partners (GDP or Employment) that lies within the travel time $t_{i,j}$ from basis region *i*;

T_k is a threshold of travel time (or distance or cost).

Another alternative to the $Q_{i,L}$ is the calculation of demographic accessibility indicator ($Q(T_k)$) presented in the section 5.1.1 but using the defined travel time for freight transport.

It is also proposed, in a first step, the calculation of both indicators ($Q_{i,L}$ and $Q^2(T_k)$) in the cases for which the required data for implementing the economic accessibility methodology ($Q_{i,L}$) is available and, in a second step, the comparison of the results obtained for these two approaches.

5.3 Elastic Borders

An interesting new idea that arose out of the reflection on these topics is that of **“Elastic Borders”** with respect to the time thresholds defined. Since in real life these time thresholds do have a physical relation to our 24-hour cycle but are not sharply defined, with this concept it is intended to accept partners shortly beyond the defined time-range as long as their contribution to the overall index is significant.

One interesting formulation would be to allow a maximum tolerance of 10% over the defined T_k, accepting inclusion of new partners as long as the elasticity of the final index with respect to the time extension is greater or equal to one, i.e. a time tolerance of 5% should be rewarded with an increase of at least 5%of the overall accessibility index being calculated.

This largely corresponds to real life behaviour and strongly reduces the effects of arbitrariness in the definitions of those thresholds.

The 10% established as the maximum tolerance are not a rigid value. The tolerance introduced will depend from the case in study. Each corridor alternative is a case of study that should be treated taking into consideration its own particularities. The density of the network as well as other relevant features of the network and the regions under study have to be considered in the definition of that tolerance.

6. Corridor Assessment on the Basis of these Impacts

In this chapter a **methodological proposal is presented for displaying the improvements of accessibility for the various alternatives of each corridor**[1] and joint consideration of these improvements in a joint assessment of these strategic territorial impacts.

The purpose of this methodology is the consideration of accessibility improvements in the two main dimensions that were defined in the previous chapter: demographic accessibility ($Q(T_k)$) and economic accessibility ($Q_{i,L}$). The corresponding indicators express the number of partners that can be reached (from each basis region) in a pre-specified travel time threshold. For demographic accessibility the set of partners is represented by the population (inhabitants) attached to all such nodes (j=1…N) whereas for economic accessibility this is made by the trade volumes (monetary units).

The methodology presented is based on an example of 9 hypothetical regions, whose real accessibility values for "before" and "after" situations are reported in the figure 6.1.

The improvements of accessibility for the various basis regions along the corridor can be represented by an accessibility profile of each corridor alternative. This is represented in the following figure:

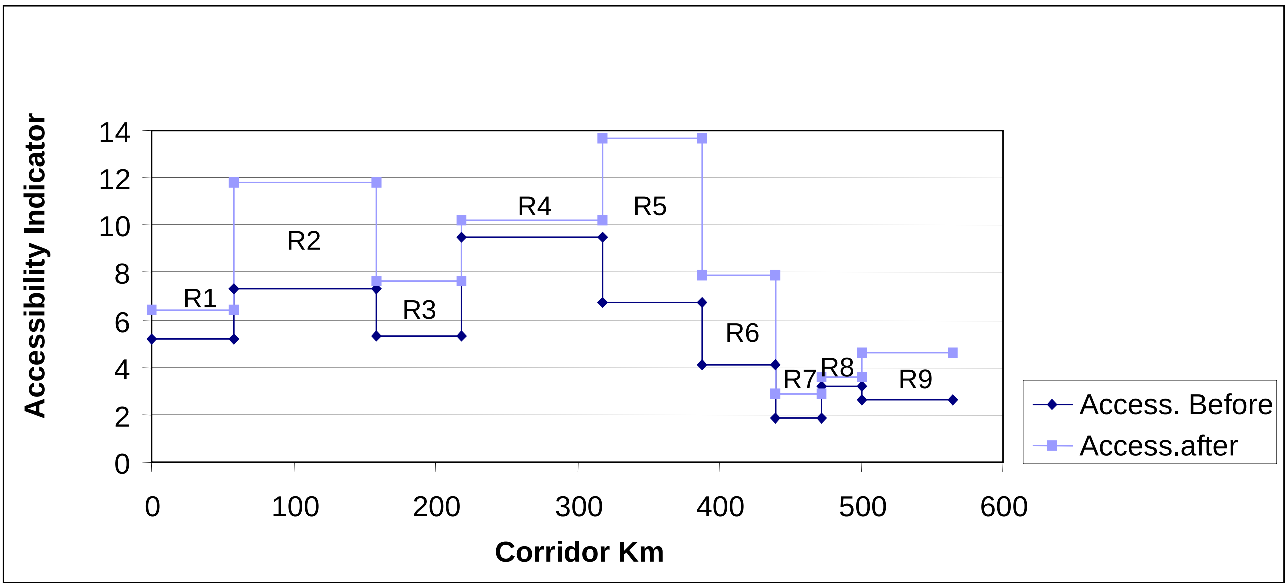

Figure 6.1 – Accessibility profiles: Before and After

This can be read both from a "global" perspective and from a "distribution" perspective (considering the comparison of values region by region).

1. The first perspective is the global evaluation of the benefits provided from the construction of infrastructure, i.e., is the evaluation of the accessibility supplied by the corridor as a whole. The

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[1] It is the second objective of the proposed methodology that has been referred in chapter 4 and in the figure 4.1.

accessibility of each basis region is computed for the "before" and "after" situations. Then, the sum of such values is computed and the global benefits are calculated. The formula is:

$$B = \sum_{i}^{N} (AA_i - AB_i)\,,$$

where:

i is the basis region (1..N);
AA_i is the accessibility of region i after the construction / improvement of the infrastructure;
AB_i is the accessibility of region i before the construction / improvement of the infrastructure;
B is the accessibility gain of the corridor.

This formulation may include some multiple counting, in that the same regions may be accessible from several basis regions. For a "pure" global evaluation, such multiple count should be avoided, although the result obtained by the direct application of the above formula is not without meaning: the fact is that it is not the same thing whether a certain region not in the corridor is (easily) accessible from one or from two of the basis regions in that corridor. So, we propose to measure it both ways.

2. Besides analysing the accessibility gains of the corridor as a whole, it is convenient to understand which are the most (or less) benefited basis regions with the improvement of the infrastructure. This suggests further developments related with the comparison of accessibility gains between basis regions. So, in this second perspective the accessibility for each basis region is evaluated and compared with the situation of the other regions along the same corridor.

Assessing ex-post accessibility values (AA_i) or accessibility gains (AA_i-AB_i), is an important question. Both indicators are important and are used because political comparisons make use of both aspects.

Considering Individual Regions' Points of View

This analysis can be based on a rectangular graphic, in which the horizontal x-axis represents the ex-post accessibility value of each basis region and the vertical y-axis represents the accessibility gain of each basis region. A grid is imposed, with the span of the horizontal and vertical axes being defined by the minimum and maximum values observed for the corresponding variables, these points being redefined as 0 and 100 respectively. According to the situation of each basis region in the grid a classification of weak (0-20), medium (20-80) and strong (80-100) accessibility indices can be attributed in both axes. The following example was constructed for the same 9 regions (with the same accessibility values) of figure 6.1.

The lower left corner of the graphic represents the regions that will feel less well treated (a poor gain and still resulting in a poor position), whereas the upper right corner will represent the best treated (and more envied) regions, with a strong improvement and a start resulting position. In this example, those regions are R7 and R8 (first case) and R5 (second case).

The result obtained for region R2 means that this region finishes in a high level of accessibility thanks to a strong gain. In opposition the starting and ending accessibility levels of region R4 are very close which justify its position in the graph.

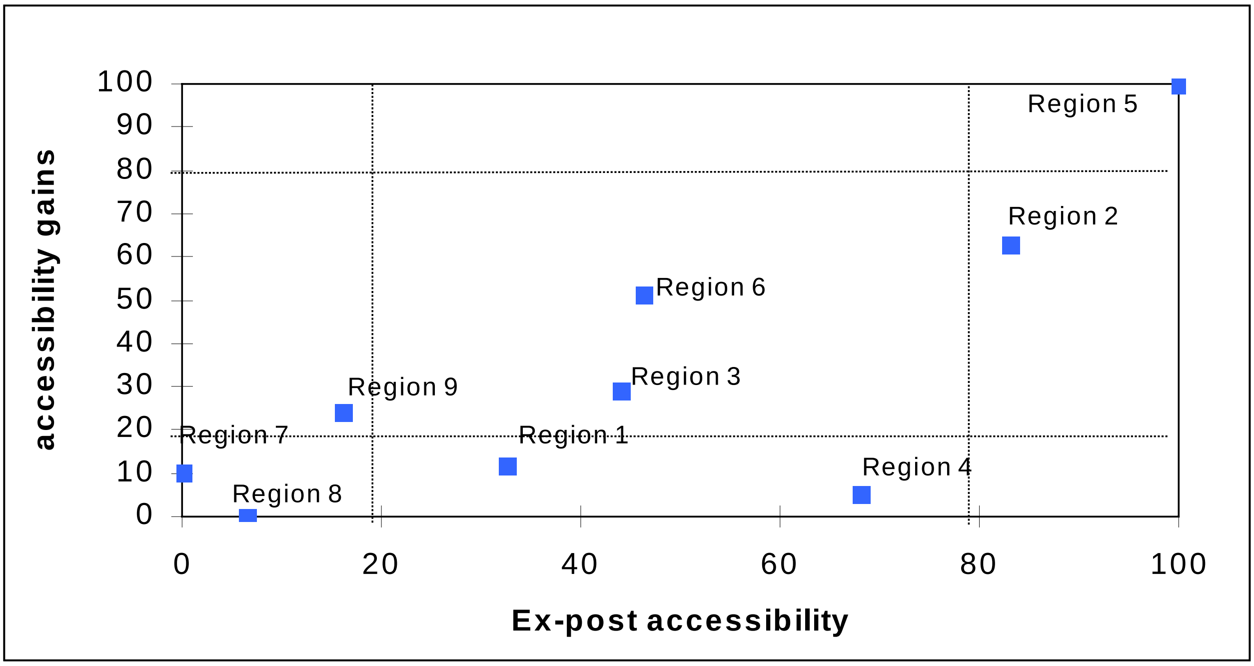

Figure 6.2 – Ex-post Accessibility and Accessibility gain

It is possible to represent various corridor alternatives in the same graph, in which case the scale of the axes should be redefined, i.e., the origin and ending points should be the minimum and maximum value observed among all the corridor alternatives (Min{min}, Max{max}) respectively.

Building a Synthetic Indicator of Equality

This approach also intends to analyse the distribution of accessibility from a central (the "distributor") point of view. The graphic method above shows the accessibility situation of one region in relation with that of all the other basis regions. Here, a global evaluation of the equality of accessibility distribution across all the basis regions is made.

For a synthetic evaluation in this respect (equality of distribution across subjects), a commonly used method is the Lorenz curve and the associated Gini index.

This section is divided into two parts: the introduction of the Gini index and Lorenz curves concepts and their application for measuring the distribution of accessibility values.

Lorenz Curves and Gini Index

The Lorenz Curve is usually the cumulative distribution function of income, with the x-axis as the proportion of income earners. In a society with perfectly equal income distribution, the cumulative share of income would be equal to the cumulative population share. The heavy 45º line represents the mythical egalitarian society.

The gap between the actual lines and the mythical line is a function of the degree of inequality. The Gini index measures the gap between the actual line and the 45º line and is computed as the area between the Lorenz curve (of the real distribution) and "ideal" curve divided by the area under the "ideal" curve (which is always exactly one half). The more unequal the distribution being analysed, the higher the Gini index. In a perfectly unequal society, in which one person (or household or family) had all the income, the Lorenz curve would look like a backwards "L", and its value would be 1.00. Real economies have some, but not completely inequality, so the Gini coefficient for real economies systems are between 0 and 1.

The Gini coefficient is a summary measure of the deviation in the Lorenz curve. The formula for computing the Gini with n elements sorted (in this case from lowest to the highest), is:

$$G = \sum_{i=1}^{N} 2\left(X_i - Y_i\right)\Delta X_i$$

where:

N = number of ranking groups;
X_i = i/N (value of the mythical curve);
Y_i = value of the cumulative distribution of the analysed variable – real curve (between 0 and 1) ;
$\Delta X_i = X_i - X_{i-1}$

Application of the Above Concepts for measuring the equality of Accessibility Changes

For measuring the accessibility changes arising from construction or improvement of the infrastructure, two temporal situations are analysed and compared in this approach, which are "before" and "after" that construction.

For each situation, the accessibility indicators of the various basis regions (population and trade volumes reached in the travel-time threshold) are classified in rank order, from low to high accessibility.

For the sake of demonstration, let us develop an example with 9 regions (the same of above examples). For each corridor alternative and for each accessibility indicator a table like the following one shown here will be produced:

	Value of Cumulative Distribution of Accessibility (%)								
Xi	0	12,5	25	37,5	50	62,5	75	87,5	100
Yi(Before)	0	11	18	30	44	45	64	72	100
Yi(After)	0	6	16	32	44	46	68	83	100

Table 6.1 –Cumulative distribution of accessibility values by region (example)

Here, we have two Lorenz curves for the cumulative distribution function of accessibility (before and after). The horizontal axis shows the rank orders and the vertical axis the value of the cumulative frequency distribution of accessibility values (of basis regions).

The degree of inequality of accessibility distribution is expressed by the Gini index. The expected changes in accessibility (of each basis region) derived from the construction of infrastructure would be evaluated by the difference of the Gini index of the "before" and "after" curves.

In the following paragraphs a formulation of the application of such concepts is presented. The example is based on the numbers of Table 6.1.

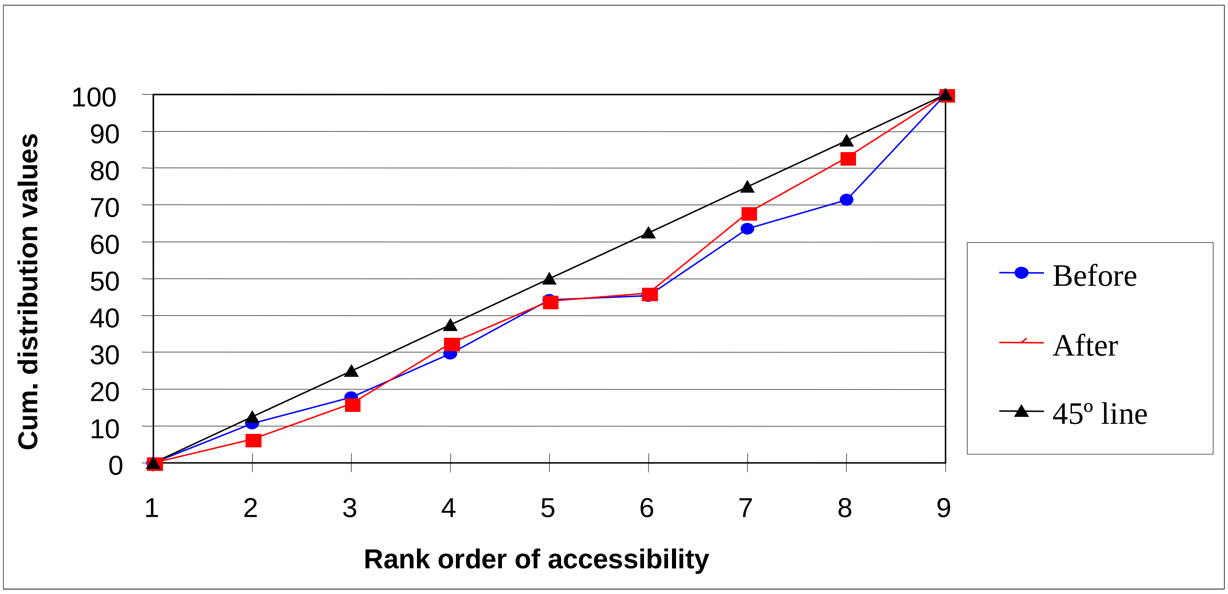

Figure 6.3 - Lorenz curves - accessibility distribution by range

The above graph shows that the gap between the "after" and the mythical lines is somewhat lower than the gap between the "before" line and that line, which means that a more equalitarian distribution of accessibility across the regions is observed.

It should be noted that there is no room for reading "improvements" by direct comparison of the values on the two curves, for two different reasons:

- After converting the real accessibility of each region in a scale from 0 to 1 (with different scaling factors for each case), the relationship between "before" and "after" accessibility values can change;
- The regions with the same rank in these curves could be different.

This can also be observed and quantified by the Gini Coefficient for the two situations. The following table shows the values of Gini index that are obtained from the application of the formula to the example of Table 6.1.

	Gini Coefficient
Before	0,168
After	0,135

Table 6.2 - Gini coefficients before and after the construction of infrastructure (example)

So, the Gini coefficient is lower after the construction of infrastructure, which confirms the indication from the graphic that a more equalitarian distribution of accessibility across regions is observed in the "after" situation.

7. Conclusions

This report, which is the output of Work Package 4 (Deliverable 5) of the CODE-TEN Project, comprises theoretical and empirical considerations on the choice of indicators to be used as the output terms of the methodology proposed for assessing strategic territorial impacts from Transport Projects. Since the actual impacts of the Trans-European Transportation Network are uncertain to a large extension, the indicators/models have to describe the regional distribution of socio-economic impacts of future infrastructure investments and transport system improvements in a comprehensive way.

In order to develop a model that is able to help the European decision-making process, the modelling outputs should be clearly linked with the policy goals.

This deliverable gives an overview about the aim of the CODE-TEN Project and the research carried out in the area of the WP4. This research provided a comprehensive list of accessibility indicators and a set of models related to the economic impact of transport infrastructure endowment. This survey made clear that the application of indicators and models is strongly conditioned by their data requirements, costs and delays.

One of the indicators found is suggested as a possible indicator for measuring demographic accessibility. Concerning indicators for assessment of the economic impacts of accessibility improvements that were researched, we conclude that the only that can be distinguished from the others by its appliance in the CODE-TEN, has a structure and data requirements that makes it not recommended for use in CODE-TEN.

Based on the above considerations the proposed methodology is relatively simple and its required data is believed to be available.

The main considerations that were made in the elaboration of such methodology are the following:

- A set of indicators is proposed for assessing change of demographic accessibility, reflecting changes for passengers and for freight;

- Economic accessibility improvements are handled as a potential for economic development, based on the reductions of transport costs in the relations with the other trading regions. The concept of Economic Accessibility is introduced to reflect this focusing on (potential) trade flows.

- Total Commercial Affinity between two regions (i, j) represents “the number of potential partners” (or potential intensity of trade) of region j as seen from i. This substitution of the variable “population” of region j by “Total Commercial Affinity between regions i and j” for the calculation of Economic Accessibility can be made for most of the usual types of accessibility index of a region.

Finally, a methodological proposal is presented for assessing the various alternatives of each corridor in the basis of the accessibility improvements they generate. This process shall be implemented in later phases of the CODE-TEN Project when the actual evaluations of the corridors are carried out.

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