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Land Use Relationships
in Rural-Urban Regions

Module 2

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D2.4.5

Economic Evaluation of the Land-Use Transport Relationship in the European Region

Costs and Benefits Related to Evaluation of Rapid Rail Investments on Urban Form and Development

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SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

Objectives

The current report has been prepared in the framework of PLUREL Work Package 2.4: Spatial Development Strategies and Scenarios (Planning Policy Options).

The objective of this Work Package (WP) is to develop scenarios as an input to the stakeholder-based scenario workshops undertaken in WP3.4. In line with this purpose, development scenarios for urban-rural region types have been determined by generic urban-rural region typologies in WP2.1 which assist in developing urban-rural region dynamics scenarios considering the existing and emerging driving forces for change and development in these regions. A generic methodology for the evaluation of the case study scenarios regarding implementation costs in the regions will be carried out in this report as part of the objectives of the WP2.4.

Methodology

The methodology utilised in this report is based on an international literature review to identify and prioritise a specific number of impacts and indicators for the economic evaluation of the sustainability of transport-land-use relationships in the Plurel Regions. In this respect, a generic methodology is developed and proposed for the scenario-based impact evaluation of rapid rail investments in the European Region, particularly in the Plurel case study areas. The land use impacts of a *do minimum* scenario is compared with a *with rail* scenario; the former implying a more dispersed urban growth compared to the more compact forms of urban development potentially achieved through the land development impacts of rapid rail investments. A Cost-Benefit Analysis (CBA) approach is the suggested methodology for the evaluation of the impacts of these two alternative scenarios.

Results

The report identifies four main types of criteria for the CBA evaluation of the impacts including direct impacts of transportation infrastructure provision, socio-economic impacts, transportation network effects, and energy and environmental impacts. The values and parameters for the appraisals of capital costs, public service provision costs, accident rates, vehicle operation costs, system operating cost and revenues, travel time and costs of carbon dioxide emissions and local air pollution are specified for the evaluation of rapid rail investments within a scenario analysis framework. The data requirements for the impact evaluation of the *with rail* and the baseline *do-minimum* scenarios are identified and given as follows:

Impacts/Indicators	Impact Evaluation Data Requirements of *With-Rail* Scenario vs. Baseline *Do-Minimum* Scenario
1. Capital Costs of Rail Infrastructure Investment	Direct construction cost estimates include the following: -Land acquisition costs -Civil engineering works -Railway infrastructure -Operational systems -Stations -Planning and design
2. Provision of Public Services	Future estimated numbers for new residential development (numbers of new housing units) in the case study area within the appraisal period specified for rapid rail investments
3. Accident Rates/Future Accident Risks	Three types of data are required: -The most recent data related to the *number of personal fatality, serious injury, and minor injury accidents along* the catchment area of the newly proposed rail line -Estimated numbers for future accident risks from the national and local accident rates and trends -Quantification of changes in the number of fatalities, serious injuries, and slight injury accidents due to a rapid rail investment by using country specific risk functions
4. Change in Road Vehicle Operation Costs	For the calculation of the economic benefits (costs) associated with vehicle operating costs, two types of data are required: -***Demand***: the number of private vehicles (cars) making a particular origin-destination trip for the *do minimum* scenario and the alternative *with rail* scenario (peak/off-peak traffic flow data for the baseline and alternative scenarios) -***Vehicle kilometres***-total change in vehicle kilometres from the local highway network for the *do minimum* and *with rail* cases
5. Change in Travel Time	Estimates related to; -*Travel time*-change in travel time for private vehicles (cars) in peak/off-peak traffic for the baseline and *with rai*l scenarios -*Demand*: peak/off-peak traffic flow data for the baseline and *with rail* cases
6. Rail Operating Costs and Revenues	-Expected operating pattern and service frequency of newly proposed rapid rail system -Key characteristics (route length, journey time, peak and off-peak headway etc.)
7. Change in Area Land Values	-Amount of greenfield/empty land within the catchment area of new rail line (in hectares). -Amount of other land-uses i.e. commercial, industrial, residential and mixed-uses within the zoning suitability for development catchment area of new rail line (in hectares).
8. Change in CO_2/Local Air Pollutants	-Total change in greenhouse gas emissions (i.e. CO_2 , in particular)/local air pollutants (NO_x, SO_2, $PM_{2.5}$ etc.) for the baseline and *with rail* cases.

The impact valuation methods are also identified for each impact and indicator and specified particularly for each EU country where relevant information is available. In this sense, values for traffic safety, travel time and carbon dioxide emissions are available for all the EU countries while vehicle operation costs are only provided for the UK given that vehicle operation costs are more generic and transferrable between the EU countries. Capital costs of transport infrastructure, system operation costs and revenues, public service provision costs, and area land values are highly case specific; and therefore, detailed information is required on these cost items for the valuation of the subject indicators. Therefore, some important issues on these case specific costs are highlighted in this report in general terms which will provide a base for future research regarding the valuation of these indicators.

Followed by the impact-indicator evaluation data requirements and valuation methods, CBA will be carried out utilising the Economic Net Present Value

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(ENPV) approach which computes NPV of marginal costs and benefits between baseline *do-minimum* and *with rail* scenarios. The ENPV formula is as follows:

$$ENPV = \sum_{t=0}^{n} a_t S_t = \frac{(b_0 - c_0)}{(1+r)^0} + \frac{(b_1 - c_1)}{(1+r)^1} + \ldots + \frac{(b_n - c_n)}{(1+r)^n}$$

Where S_t is balance of cash flow funds at time t comprising flow of benefits, b_t, and flow of costs, c_t; a_t is discount factor, r is discount rate, and n is the evaluation period. This is also used to produce a benefit-cost ratio and internal rate of return (IRR). The former is the ratio of the discounted aggregate net benefits (i.e. benefits minus costs) to the discounted investment costs. On the other hand, IRR is the rate of discount equating discounted net benefits to discounted investment costs. Finally, a common sensitivity testing criteria is specified for a number of indicators to test unexpected changes and uncertainties in the parameter values. This is a preliminary sensitivity analysis suggested in this report and more detailed analysis is required based on the characteristics of the transport infrastructure investment and the study area, both influencing the impact-indicator calculations and valuations.

Popular Science Description

The issues of transportation provision and land development have gained importance in many countries, and particularly the issue has become significant for regions with recent economic development such as Plurel case study areas. The rapid growth taking place especially in peri-urban areas has resulted in significant consequences on the development of the urban environment. Most of the cities have experienced dispersed or scattered type of development often referred to as ‘urban sprawl’ in contrast to their more compact structures which evolved until the 1950s. The sprawl type of development in the built-up area is generally associated with high social, economic and environmental costs. In this respect, sustainable urban development strategies and policies have gained importance among scholars, practitioners and policy makers to minimise undesirable impacts of sprawl type developments in the urban areas.

The literature has shown that rail transport systems can play a critical role in overcoming the problems posed by the dispersed or sprawl type development patterns (see Newman, 1995). These developments can provide high quality services in terms of reliability, speed, safety, and reduced travel time and act as a substitute for private car use. Consequently, rapid rail transportation has become a preferred policy approach for avoiding road congestion and other detrimental effects of urban sprawl. Considering that rapid rail systems are significantly costly investments and place a burden on the governments’ finances, an impact evaluation of rapid rail investments and land-use relationship is highly required not only for governments’ budgetary planning and control, but also for evaluating wider impacts of such developments on the general welfare. Given this framework, this report develops a generic scenario-based CBA methodology for the impact evaluation of rapid rail provisions on urban form and development for the EU countries, particularly for the Plurel Regions.

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Classification of Results / Outputs:

For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	(International literature + European case study level)
DPSIR framework: Driver, Pressure, State, Impact, Response	(Economic evaluation of the *impacts* of different transport-land-use relationships through the scenario analysis)
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	(Integrated system of transportation and land-use development)
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	(Yes, the indicators are scenario sensitive and since the scenario analyses are based on M1 modelling inputs, the present study is indirectly based on M1 modelling inputs)
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	(Inputs for the Cost-Benefit methodology in relation with the socio-economic assessment of the impacts of different transport-land-use relationships)
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	(Text, table, graph, Cost-Benefit evaluation formulae)

How many fact sheets will be derived from this deliverable:	**(1)**

Introduction

PLUREL Work Package (WP) 2.4: Spatial Development Strategies and Scenarios (Planning Policy Options).

The main purpose of this WP is to provide a case specific input to the stakeholder-based scenario workshops undertaken in WP3.4. In this vein, a number of development scenarios for rural-urban region types have been developed in relation with the generic urban region typologies proposed in WP2.1. Spatially-explicit scenarios depicting future spatial land use relationship development patterns have been carried out and evaluated leading finally to generic rural-urban region development typologies. Existing experience with the success of spatial policies at regional level are systematically analysed and projected onto the defined generic rural-urban region types.

By applying the typology of WP2.1, the existing and emerging driving forces for change and development will be considered with an aim of achieving policy option and rural-urban region pattern-driven generic scenarios to account the future dynamics of the driving forces. The relation of the response functions as rural-peri-urban-urban relationship analysis results referred to the generic rural-urban region types with the European rural-urban region classification derived in task 2 of WP2.1. This will allow transferring the results finally to the NUTS3 aggregates to be applied in M4 and M5 linked with the SENSOR SIAT.

Objectives of the Deliverable

The major objective of this deliverable is to evaluate the economic costs of major transport infrastructure provisions, particularly rapid rail investments linked with land use management or changes in organisation associated with alternative forms of development. The scenarios that are developed by utilising the MOLAND Model (Task 2 of WP2.4) will result in different activities with certain costs associated with implementing them in the regions (i.e. infrastructure, organisational costs).

Tasks 3 and 4 of WP2.4 will develop a generic methodology for the economic evaluation of the scenarios and estimate these internal economic effects at the administrational level of the region of different development strategies and discuss findings with the stakeholders of the case regions during the workshops of M3. Strong emphasis is placed on analysing the effects of different scenarios and planning strategies onto the rural sub-region of rural-urban regions. Dominant patterns of this will be derived for the relevant types of rural-urban regions.

The development scenarios (Task 2 of Wp2.4) and the economic evaluation of these scenarios (Task 3 of WP 2.4) will be discussed and tested by practitioners in the case study regions (M3) and finally serve as input to M4. They will be the basis for recommendations, planning tools and SIAT in M5.

Structure of the Deliverable

The first section of this deliverable is the research context related to the key objectives of the deliverable. The second section is an international literature review for the evaluation methodologies in assessing transport-land-use policies. In the third section, a generic CBA methodology is developed for the impact evaluation of rapid rail investments and land developments in the Plurel Regions. Finally, some key conclusions are provided.

1. Research Context

This research addresses the issue of development of a common CBA methodology for evaluating the transport/land-use relationship and contributes to the literature by refining the CBA approach in a rapid rail impact assessment resulting in a compact urban form in comparison with more dispersed forms of development. The principal feature of the paper is the comparison of the evaluation methods of transportation infrastructure obtained from a large number of international studies and the development of a common methodology for the scenario-based impact evaluation of rapid rail infrastructure investments across the EU countries. An EU Commission research programme i.e. EURET (European Research on Transport) constructed a basis for the common research on European transportation related issues; and thereby proposed a wide appraisal spectrum for the evaluation of transportation investments. In the EURET reports, it is noted that a majority of European countries rely on Cost-Benefit Analysis (CBA) in their national appraisal strategies, which provided a basis for generating common appraisal guidelines for the EU countries (see EURET Concerted Action 1.1., 1996). This is the starting point of this study which focuses on the Cost-Benefit Analysis (CBA) approach for evaluating the impacts of rapid rail investments and the consequential forms of urban development.

The structure of urban development in the European cities has changed its direction prior to a widespread population growth starting from the 1990s. This rapid growth taking place especially in peri-urban areas has resulted in significant consequences on the development of the urban environment. Most of the cities have experienced dispersed or scattered type of development often referred to as ‘urban sprawl’ in contrast to their more compact structures which evolved until the 1950s (EEA Report, 2006; UNFPA State of World Population Report, 2007). It is evident that global socio-economic forces interacting with the built environment; and the resultant improvements in accessibility and personal mobility are the main driving forces behind urban sprawl observed in European cities. The European Environment Agency (EEA) in 2006 reported that urban dispersal is now common in countries with high population density and economic activity such as Belgium, Netherlands, France, Southern and Western Germany; and also in regions experienced rapid economic growth such as Ireland and Poland.

Transformation from compact to more dispersed structures such as ‘urban sprawl’ has significant implications on the urban environment: The sprawl type of development in the built-up area is generally associated with high social, economic and environmental costs. Traffic congestion, automobile dependence, air pollution, social segregation, and decreasing quality of life are often cited as some of the most important problems faced by many large urban metropolitan centres (Boyle *et.al*, 2004; UN-Habitat Report, 2001; 2004). In an effort to address some of these problems, planners and policy makers have started to give greater significance on the issues of urban sustainable development and urban growth management within the context of sustainability. Here, the main concern is the search for the linkages between urban spatial structure and transportation systems which will achieve sustainable urban form and efficient transport provisions in the future.

Existing literature shows that the relationship between land-use and transportation is complicated since different factors such as urban structure, density, and city size are inputs which determine transportation demand, these in turn will affect the spatial structure, density, and size of the urban area (see Kenworthy and Laube, 1999). Considering this dynamic relationship in the land-use-transportation system, it can be claimed that sustainability of the urban form and efficient transport provisions are two closely interlinked issues. In this regard, sustainability often implies a policy approach minimising travel demand and prioritising an urban form in which different modes of transportation are available as an alternative to the private car. This should generate fewer car trips, and shorter trip lengths through the integration of land usage and transportation. Urban theory may suggest that a compact urban form is preferred to more dispersed patterns in terms of sustainable spatial development and transportation efficiency. This is related to the reduction in travel demand and travel time since most activities are closely located in a compact form (see Hillman, 1996; Bertaud, 2004). By contrast, there are also studies questioning the sustainability of compact form (see Rickaby, 1987; Breheny, 1995) and suggesting that decentralised or polycentric solutions can be as efficient. Reasons advanced for this include that multi-centred urban areas can provide significant transport benefits by locating residences close to employment centres (see Peng, 1997; Williams *et.al.*, 2000).

Related to these theoretical findings, planning research and practice has shown that rail transport systems such as metro-based systems can play a critical role in overcoming the problems posed by the dispersed or sprawl type development patterns (Vuchie, 1991; Newman, 1995; Thornblom and Bengtsson, 1997). Among the competing transit technologies are rapid rail, light rail, and express bus. These developments can provide high quality services in terms of reliability, speed, safety, and reduced travel time and act as a substitute for private car usage. Automobile-oriented planning policies in contrast tend to increase urban sprawl by improving accessibility to urban-fringe locations and by increasing the amount of land required for development (see Litman, 2008). Policies which support rail based transportation and pedestrian activities tend to encourage more compact and mixed developments. As a consequence of this, rapid rail systems such as metro-based transportation have become a preferred policy approach for avoiding road congestion and other detrimental effects of urban dispersal.

Given this framework, this report is aimed at researching emerging methods for the economic evaluation of the land development impacts of rapid rail investments in the context of sustainable urban development in the European Area, particularly the Plurel Regions.

2. Evaluation Methodologies in Assessing Transport-Land Use Policies

2.1. International Comparison of Evaluation Methodologies

The main goal of a transportation infrastructure evaluation is to estimate and evaluate costs and benefits of a given policy to achieve an efficient allocation of resources for optimising general social welfare (OECD, 2002). A Cost-Benefit Analysis (CBA) approach provides a basis for the evaluation of impacts of various transport projects and policy changes in a wide variety of the appraisal work. The Cost-Benefit methodology consists of a quantification of changes in user costs, infrastructure costs, and selected external costs. Evaluation criteria are expressed as monetary values, market prices and shadow prices which are then utilised for the valuation of benefits. Followed by the quantification of benefits through the planning scenarios horizon, benefits are discounted and compared according to criteria i.e. Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR) (see Pearce *et.al.*, 2006; Layard and Glaister, 1994; Brent, 2006).

Until recently, transportation projects have been subjected to a cost-benefit analysis by using a traditional approach where mainly user benefits were prioritised. Benefits are result from time savings, savings in operation costs, and from reductions in accidents. Traditional cost-benefit analysis is therefore strongly biased towards policies which focus on time savings, and reductions in accident and operation costs. Considering its narrow scope, a complementary cost-benefit framework has increasingly been introduced with the traditional approach, which enables a wider appraisal of transportation issues. Complementary analysis has introduced three main criteria including transportation network effects, environment effects and socio-economic impacts which were previously not included in the traditional CBA. The summary of the contents of this more comprehensive cost-benefit analysis is given in Table 1 together with the traditional CBA. The table indicated that traditional CBA ignores a significant number of external effects which is the main weakness in the standard CBA. Many recent studies in the literature try to identify and incorporate external effects into the standard CBA and can be examined under two main groups. These are 1) *General* Cost-Benefit studies and 2) *Specific* analysis on impact-indicator evaluation.

The first group of studies analyse the impacts of transportation networks on the structure of land development by applying a *general* CBA either in a qualitative or quantitative framework. Some examples of qualitative studies are in Haywood (1999); Bertolini (1999); Sutton (1999); Walton and Shaw (2003); Ryan and Throgmorton (2003); Handy (2005); and Donaldson (2005). In common, these studies questioned the effectiveness of transportation policies considering their impacts on land development

Table 1. Evaluation of Transportation Projects

Traditional CBA	**Complementary Analysis**
USER BENEFITS ***-Travel time*:** Time savings are valued on the basis of opportunity cost ***-Vehicle operating costs*:** Cost savings are identified according to the incremental cost of vehicles i.e. the costs that change with their use ***-Safety*:** Valuation is based on the risk analysis of user transport accidents associated with a project	**TRANSPORT NETWORK EFFECTS** ***-Induced travel:*** User benefits and costs are valued according to the impact of project in inducing new trips or causing changes to trip ends or trip times ***-Modal shift:*** Based on modelling and appraisal of modal shifts i.e. switches between travel modes e.g. road to rail ***-Reliability:*** It is related to variation and consistency in travel times and the reliability related to external factors ***-Quality of transport service:*** Ride quality, crowding, ambience, quality of information etc. are valued by using measures of willingness to pay **ENVIRONMENT EFFECTS** Environment is assessed considering the impacts on climate change, acidification, natural resources, biodiversity, air-water quality, noise etc. **SOCIO-ECONOMIC SPILLOVERS** The impacts of transportation infrastructure on the economy and the society are more widely. These impacts are assessed based on changes resulting from: ***-Employment*** ***-Efficiency and output*** ***-Social inclusion*** ***-Land use effect*** ***-Accessibility***

Adapted from: OECD, 2002

processes and the urban form. There is much literature on quantitative studies which follows the rules and principles of conventional CBA approach: Different country examples are given in Pearce and Nash (1973); Mills (1977); and Rus and Inglada (1997). The first two are examples of an economic appraisal of inter-urban road and motorway schemes in the UK while the third focuses on a CBA of rapid rail transportation in Spain. A common basis for the evaluation of these different modes of transport is the quantification of costs and benefits through a specified time horizon followed by discounted cash flow analysis resulting in NPV, BCR, and IRR.

The second group of studies focuses on *specific* indicators to measure and evaluate the costs and benefits of transportation provisions. In this group, there are analyses of the appraisal of transportation projects through examining the effects on real property prices, studies on relationships between transportation investments and land-use development. Relevant studies of this type include Sheppard and Stover (1995); Forrest *et.al.* (1996); Ryan (1999); and Debrezion *et.al.* (2007) which research the relationship between property values and transportation provisions. Studies incorporating accessibility dates back to Hansen (1959) with accessibility measures representing the movement of individuals and goods within the complex transportation-land use relationship. There are many contributions to Hansen’s derivations; and also many empirical studies based on the accessibility impacts of transportation provisions. Some examples can be found in Linneker and Spence (1991); Francisco and Martinez (1995);

Still *et.al.* (1999); Gutierrez and Gomez (1999); Martinez and Araya (2000); Geurs and Van Wee (2004); and Willigers *et.al.* (2007).

This body of literature incorporates scenario analysis into the accessibility appraisal of integrated transport-land use strategies. This is developed through deriving accessibility measures, and examinations of the transport-land-use relationship incorporating these accessibility measures on different land development scenarios. Geurs and Van Eck (2003), for example, dealt with accessibility impacts of different land-use scenarios by introducing comprehensive accessibility measures in their integrated transport-land use model for their study area of Netherlands. In a later work, Geurs *et.al.* (2006) carried out a similar analysis of accessibility impact evaluation of different land-use scenarios for the Netherlands Randstad Area. In contrast to conventional methods, they incorporated job-competition effects into their location- based and utility-based accessibility measures which is claimed to be theoretically more satisfying than infrastructure-based approaches in assessing the total accessibility benefits of integrated transport-land-use strategies. The study by Kwok and Yeh (2004) is another example for integrated transport-land use scenario analysis. Their contribution to previous work is to introduce the modal accessibility gap index which is related to the difference between accessibility indices of public and private transportation. This constructed a base for further studies aiming at analysing the issue of land use development in the context of transportation sustainability.

The literature examined above is relatively effective in quantifying the direct and external effects of transportation provisions on the urban environment. The evidence has shown that it is difficult to express some of the direct and indirect impacts either in monetary or non-monetary values. This may include safety and comfort within the selected transport mode and the associated accident risks; environmental impacts such as noise, air pollution, and climate change; social impacts such as social integration and exclusion; and the land-use impacts such as accessibility changes of the future land-uses. There are various attempts to overcome these difficulties such as incorporating the methods of Multi-Criteria Analysis-MCA (see Nijkamp and Blaas, 1993) into the CBA framework.

In contrast to monetary valuation techniques employed in CBA appraisal, the MCA approach assigns weights to results obtained from a wide variety of techniques, presumably including a high degree of subjective evaluation due to specific expert assessments. For example, Tsamboulas *et.al.* (1992) used an integrated Cost-Benefit (CB)-Multi-Criteria (MC) Analysis approach in their study which evaluates the impacts of rail investment projects in Greece. Tsamboulas and Mikroudis (2000) introduced a generalised methodological framework for the combination of MCA with CBA which is used for evaluating the impacts of transportation projects by giving specific priority to environmental impacts. Another study by Forslund and Johansson (1995) focused on the appraisal of national road programmes in Sweden by using a similar methodology of integrated CB-MC Analysis. They examine the effects of accessibility changes on the productive capacity of industries in order to explore how and why accessibility changes effect the productive capacities of different regions. Other country specific examples can be found in Gercek *et.al.* (2004); Banai (2006); and Sharifi *et.al.* (2006). There are also more general articles examining the impacts of transportation policies at the international and the European level (see Hey *et.al.*, 1997; Grant-Muller *et.al.*, 2001; and Janic, 2003), which will be examined in more detail in the next section.

2.2. Comparison of Cost-Benefit Methodologies in Europe

The appraisal of transport investment proposals became an important issue across the range of European Union (EU) countries prior to the admission of a 'common transport policy' by the European Commission (EC) in 1992. The most significant development in this EU policy focus was the establishment of the Trans-European Network (TEN) programme aiming at a more balanced development over the EU territory by giving importance to regional interconnection, interoperation and access to national and international networks. In relation with the TEN programme, there is wide variety of EU country examples concerning the appraisal of transport investment proposals either in country or regional/European levels. Bristow and Nellthorp (2000) reviewed the national appraisal frameworks for 14-EU countries which take part in one of the EC research projects i.e. the EUNET project (see Table 2).

The EUNET project reached to two key conclusions in analysing the national appraisal frameworks of 14-EU countries (see Grant-Muller *et.al.*, 2001): Firstly, the standard CBA approach is used widely among EU countries along with the use of multi-criteria analysis (MCA) and descriptive frameworks by some of the countries in the previous stages of project development. Secondly, the infrastructure investment appraisal is mainly based on a range of socio-economic and environmental objectives due to the fact that transport infrastructure is predominantly publicly owned in the majority of EU countries. Direct impacts including the 'construction costs', 'vehicle operating costs', 'time savings' and 'safety' are commonly agreed to be included in a CBA by placing a monetary value on each of them. The environmental impacts included in the evaluation process vary considerably across countries. Although noise and local air pollution are common in all evaluations, their methods of inclusion vary i.e. either monetary valuation or descriptive measures are used. The inclusion and coverage of socio- economic impacts also vary significantly across the countries with some countries including a wide range of impacts, with others excluding various impacts on the basis that they are not additional to the direct project costs and benefits.

In a later study, Odgaard *et.al.* (2005) reviewed the national appraisal practice in EU countries after the recent expansion of the EU to 25 countries in 2004. In line with Bristow and Nellthorp's (2000) findings, they stated that CBA is widely used in the assessment of transport projects along with the usage of other methods i.e. MCA, quantitative measures and qualitative assessments in a complementary framework. The authors also examined the inclusion of various impacts and indicators which are covered in each of the countries surveyed where CBA is used. These impacts and indicators are shown in Table 3, from Odgaard *et.al.* (2005).

Table 2: The Inclusion of Impacts and Evaluation Framework for 14-EU Countries

		AUS	BEL	DEN	FIN	FRA	GER	GRE	IRL	ITA	NRL	POR	SPA	SWE	UK
DIRECT IMPACTS															
Capital	Construction Costs	MCA	MCA					MCA			MCA				
	Disruption Costs		MCA					MCA							
	Land and Property Costs		MCA					MCA							
Recurring	Maintenance Costs	MCA	MCA					MCA			MCA				
	Operating Costs							MCA			MCA				
	Vehicle Operating Costs	MCA	MCA					MCA			MCA				
	Revenues	MCA						MCA							
	Passenger Cost Savings							MCA							
	Time Savings	MCA	MCA					MCA			MCA				
	Safety	MCA	MCA					MCA			MCA				
	Service Level							MCA							
	Information							MCA							
	Enforcement														
	Financing/Taxation							MCA							
ENVIRONMENTAL IMPACTS															
	Noise	MCA	MCA					MCA			MCA				
	Vibration		MCA												
	Air Pollution-Local	MCA	MCA					MCA			MCA				
	Air Pollution-Global	MCA	MCA					MCA							
	Severance	MCA													
	Visual Intrusion							MCA							
	Loss of Important Sites		MCA												
	Resource Consumption							MCA							
	Landscape	MCA													
	Ground/Water Pollution	MCA						MCA							
SOCIO-ECONOMIC IMPACTS															
	Land Use	**MCA**						MCA			**MCA**				
	Economic Development	**MCA**	MCA					MCA			**MCA**				
	Employment		MCA					MCA							
	Economic-Social Cohesion							MCA							
	International Traffic							MCA							
	Interoperability							MCA							
	Regional Policy		MCA					MCA			**MCA**				
	Conformity to Sector Plans		MCA												
	Peripherality/Distribution							MCA							

Key: CBA (Monetised Impacts) Measured Impacts Qualitative Assessment MCA: included in Multi-Criteria Analysis

Source: EUNET Project (Nellthorp *et.al.* 1998)

Table 3: The Inclusion of Impacts in CBA for 25-EU Countries

		Construction costs	Disruption costs	Costs for maintenance/ operation	Passenger transport time savings	User charges and revenues	Vehicle operating costs	Benefits to goods traffic	Safety	Noise	Air pollution-local/regional	Climate change	Indirect socio-economic effects
North-West	Austria	□	□	□	□	□	□	□	□	□	□	□	■
	Belgium	□	□	□	□	□	□	□	□	■	■	■	■
	Denmark	□	□	□	□	□	□	□	□	□	□	□	□
	Finland	□	■	□	□	□	□	□	□	□	□	□	■
	France	□	■	□	□	□	□	□	□	□	□	■	□
	Germany	□	■	□	□	■	□	□	□	□	□	□	□
	Ireland	□	□	□	□	□	□	□	□	■	■	■	■
	Netherlands	□	□	□	□	□	□	□	□	□	□	□	□
	Sweden	□	■	□	□	□	□	□	□	□	□	□	□
	Switzerland	□	■	□	□	□	□	□	□	□	□	□	□
	UK	□	□	□	□	□	□	□	□	■	■	■	□
East	Czech Rep.	□	■	□	□	□	□	□	□	□	□	□	■
	Estonia	□	□	□	□	■	□	□	□	■	■	■	■
	Hungary	□	■	□	□	□	□	□	□	□	□	■	■
	Latvia	□	■	□	□	■	□	□	□	■	■	■	■
	Lithuania	□	□	□	□	□	□	□	□	□	□	■	□
	Poland	□	■	□	□	□	■	□	□	□	■	■	□
	Slovak Rep.	□	□	□	□	□	□	□	□	■	■	■	□
	Slovenia	□	■	□	□	□	□	□	□	□	■	■	■
South	Cyprus	□	■	□	□	■	□	□	□	■	□	■	■
	Greece	□	□	□	□	□	□	□	□	■	□	■	■
	Italy	□	■	□	□	□	□	□	□	■	□	□	■
	Malta	□	□	□	□	■	□	□	□	■	■	■	■
	Portugal	□	■	□	□	■	□	□	□	■	■	■	■
	Spain	□	■	□	□	□	□	□	□	■	■	■	■

Key: ■ Measured quantitatively, qualitatively or not included □ Included with a money value

Source: Odgaard *et.al.* 2005

The common impacts and indicators throughout the 25-EU countries include those specified for the 14-EU countries plus 'maintenance and operation costs', and 'benefits to goods traffic'. Disruption costs, user charges and revenues, indirect socio-economic effects, and environmental impacts including noise, air pollution (local and/or regional levels) and climate are measured qualitatively, quantitatively or sometimes not included in the analysis depending on the country in which the project has taken place.

Other than these, there are also examples of broader international comparisons of transport project evaluation methodologies. Hayashi and Morisugi (2000) carried out research covering the national appraisal methods for transportation projects in the UK, USA, France, Germany and Japan. Their study concludes that all the countries utilise variations of CBA, some of which are complemented by MCA at different stages of project evaluations. The details of methodologies used and the impacts included in the evaluation process are given in Table 4. The authors concluded that all the countries share some common criteria parameters including travel time savings, safety and impacts on the environment. Time savings and safety are all included in the evaluation process by assigning a monetary value on each. Among the common environmental impacts are those of local air pollution, noise and landscape. In order to avoid double counting, the evaluation methods did not include regional economic impacts, with the exception of the UK, which considered the direct economic regeneration impacts, and in Germany, which estimated the employment effects of transport infrastructure construction and operation.

From the country examples summarised above, it is obvious that a wide variety of research approaches deal with the evaluation of transportation impacts on land use and environment. However due to obvious data difficulties, there are few studies with a capacity of incorporating all of the possible externalities into their analysis. This stems from the fact that it is difficult to quantify most of the impacts of transportation provisions. Some of the impacts and indicators can be represented in monetary values while others can be only expressed in a qualitative manner.

Table 4: Comparison of Impacts and Evaluation Methodologies for the UK, France, Japan, USA, Germany

		United Kingdom	**France**	**Japan**	**USA**	**Germany**
Methodology Used		CBA	MCA	MCA supplemented by CBA	CBA with MCA and other informal methods	CBA
Impacts and Indicators Included in Transport Project Evaluation	*Direct Impacts:*					
	-Travel Time Savings	░	░	░	░	░
	-Transport Cost Savings	NI	■	■	■	░
	-Safety	░	░	░	░	░
	Environmental Impacts:					
	-Global Impacts	■	░	░	NI	NI
	-Local air Pollution	■	░	░	■	░
	-Noise	■	░	░	■	░
	-Landscape	■	NI	NI	■	░
	-Water	■	NI	NI	NI	░
	-Biodiversity	■	NI	NI	NI	░
	Regional Economic Impacts	■	NI	NI	NI	░

Key: Measured quantitatively/qualitatively ■ Monetary value ░ NI: Not Included in the Evaluation Process
Adapted from: Hayashi and Morisugi (2000)

There may be also correlations among various indicators such as the positive correlation between land-use accessibility and land values, or the negative correlation between air pollution exposure and area property values. Considering the correlation effects, only a limited number of indicators should be selected in order to prevent the double counting problem in transport policy evaluations. Therefore, selection and confirmation of the most relevant indicators is an important stage within the project evaluation process.

In the literature, there are also various studies of CBA evaluating transportation policy changes and investment decisions by questioning the relevance of impacts and indicators included in the evaluation process. Table 5 summarises some of this empirical work which uses sensitivity analysis approach to evaluate the consistency of their results. As an example, Odeck (1996) focused on ex-post evaluation of the regional road investments in Norway, Janic (2003) carried out a MCA for the evaluation of high speed rail and air passenger transport across the European Region, and Gercek *et.al.* (2004) performed a MCA for analysing the alternative rail transit networks in Istanbul. These studies share a number of impacts and indicators which are similar to each other despite the existence of differences in their policy evaluation goals and appraisal methodologies. The common impacts included in these studies are: the cost of transportation infrastructure investments (land, development and capital investment costs), vehicle operation costs, travel time savings, and safety. All of these studies incorporated environmental impacts but with a substantial variation across countries. Energy consumption and local air/noise pollution levels are widely used in many of the studies while climate change indicators are not widely included. The inclusion of socio-economic impacts also vary significantly across the studies with some research including a wide range of impacts, and with others excluding these impacts due to the difficulties in data accessibility and problems in quantification.

In general, these studies conclude that it is important to consider all related impacts of transport policy changes in the evaluation process. However, specific emphasis should be given for the choice of number and type of criteria, and the indicators for particular criteria to be involved in the decision making process. The results of these studies show that considerable care should be taken in order to minimise the problem of double counting and to reduce the impacts of overestimation of benefits and costs in the transport policy evaluations. The studies summarised provide a background for impact-indicator evaluation in the Cost-Benefit methodology. The European Commission (EC) has set common guidelines for Cost Benefit Analysis of Transport Investment Projects. The most recent report was published by EC in 2008, which is a 'Guide to Cost Benefit Analysis of Investment Projects' for a contribution to shared European wide project appraisal guidelines in a broad conceptual framework (European Commission Final Report, 2008). This report provides a basis for the present study in generating a common methodology for the EU countries for CBA evaluation of the rapid rail investments and the urban form relationship. The methodology is examined in detail in the next section.

Table 5. Summary of the Selection Criteria for the Impacts and Indicators from Different Studies of CBA

Location, (Author, Year Published)	**Evaluated Transport Policy (Method of Evaluation)**	**Impacts and Indicators Included in the Evaluation**	**Results from the Selection of Relevant Impacts and Indicators**
Norway (Odeck, 1996)	Ex-post evaluation of regional road investments (CBA, logit analysis, socio-economic analysis)	*Direct Impacts:* -Construction costs (M*) -Vehicle (and systems') operation costs (M*) -Travel time savings (M) -Safety (M*) *Environmental Impacts:* -Local air/noise pollution (M) plus accident risks and climate change are evaluated in socio-economic analysis	-Benefit-Cost ratio (B/C) does not contain some very important environment elements because of the difficulties in monetary valuations. This implies that B/C does not take account of important issues such as distributional aspects, and if such effects are so great, then B/C as a ranking criterion should not be warranted (see Odeck, 1996: 138). -It can be suggested that quantification of more environmental effects in monetary terms will strengthen benefit-cost ratio as a ranking criteria (Odeck, 1996: 138).
Europe (Janic, 2003)	High-Speed Rail (HSR), Trans-Rapid Maglev (TRM), Air Passenger Transport (APT) (Multi Criteria Analysis-MCA)	*Direct Impacts:* -Construction costs (M*) -Vehicle (and systems') operation costs (M*) -Safety (M*) -Quality of transportation service (M) *Environmental Impacts:* -Energy consumption (M) -Local air/noise pollution (M) *Socio-Economic Impacts:* -Socio-economic growth (M) -Social inclusion (M) -Accessibility (M) -Traffic congestion (M)	- Sensitivity analysis indicates that the exclusion of various combinations of impacts from the evaluation of transport projects changes the results for project rankings. The reason is related to the existence of trade-offs between various interest groups. The cases considered in the sensitivity analysis comprise several criteria for users, community members, operators, investors and policy makers. -The results are highly sensitive to changes of inputs, and this raises the question of "choice of the number and type of criteria, and indicators for particular criteria to be involved in the evaluation process" (Janic, 2003: 509).
Istanbul, Turkey (Gercek *et.al.*, 2004)	Evaluation of three alternative rail transit network (i.e. RTN1, RTN5, RTN6) proposals (MCA)	*Direct Impacts:* -Construction costs (M*) -Vehicle (and systems') operation costs (M*) -Travel time savings (M) -Safety (M*) -Quality of transportation service (M) *Environmental Impacts:* -Climate change (M) *Socio-Economic Impacts:* -Accessibility (M)plus some other specified impacts related to system planning and policy criteria	-Sensitivity analysis was carried out for both 'trend' and 'master plan' scenarios by considering several cases which are related to 'financial criterion', 'economic criterion', 'system planning criterion', and 'policy criterion'. -The rankings of the alternative rail transit networks under both scenarios are sensitive to changes of the criterion included in the analysis. This result is consistent with Janic's (2003) conclusion that the selection of relevant criteria and indicators is important in the decision making process.

Key: (M): The impacts included in a CBA with a money value; ***** impacts that are common within all studies.

3. Methodology for Evaluating the Land Development Impacts of Rapid Rail Investments

3.1. Specification of Impacts and Indicators

Given the literature on the comparison of international and EU country examples for the transport policy evaluations, common impacts are specified for the appraisal of rapid rail investment projects and consequential land development impacts in the European wide area. The selection of related indicators are based on four main types of criteria including direct impacts of transportation infrastructure provision, socio-economic impacts, transportation network effects, and energy and environmental impacts. The list of the suggested impacts and indicators are summarised in Table 6. The impacts and indicators have been determined for this study on the following basis.

3.1.1. Direct Impacts

Costs and capital investments of transportation infrastructure constitute a significant part in project evaluations, and therefore, they are incorporated in all of the transport evaluation studies. The infrastructure costs of rapid rail projects will be included in CBA with a monetary value estimated on costs including: land, railway infrastructure, stations, civil engineering works, planning and design, and operational systems.

3.1.2. Socio-Economic Impacts

Transport infrastructure investments can contribute to economic growth by expanding the stock of capital, increasing labour productivity; and therefore, ensuring more efficient production (Aschauer, 1989; Munnell, 1992). As a result, real income levels and standard of living is expected to rise. Investment in transportation and other services is also important in encouraging socio-economic growth and in contributing to solving the problems of social exclusion and poverty. However, the literature indicates that the magnitude and significance of these effects are not clear (OECD, 2002: 18). In Banister and Berechman's (2000) explanation, there is little evidence that transport infrastructure investments at the regional level strengthen the local economy over longer term. The existence of some specific factors i.e. regional connectivity, network effects, and complicated trip patterns is the other problem which makes it difficult to perform the analysis of the socio-economic distribution of benefits (see Berechman and Paaswell, 2005).

Following this initial research and discussions on data availability indicating difficulties in the monetisation of specific impacts (due the existence of complicated relationships with the other impacts) and issues of double counting; some of the socio-economic impacts were eliminated from the analysis as shown in Table 6. For instance, socio-economic development benefits are not taken into consideration due to the fact that literature is not clear on the degree to which economic development benefits stems from the transportation investments (see for example, Knight and Trygg, 1977; Dyett *et. al.*, 1979; Cervero and Landis, 1997). The general argument in the literature is that

Table 6. Summary of Selected Impacts and Indicators for the Evaluation of Land-use Impacts of Rapid Rail Investments

Impacts/Indicators[1]	**Suggested Indicators/Impacts for the European Area**
1. Direct Impacts of Transportation Infrastructure Provision: -Transportation Facility Land Values -Development Costs/ Capital Investments -Adjacent Property Values	*Costs/ Capital Investments of Transportation Infrastructure (M)*
2.Socio-Economic Impacts: *a. Land Development Impacts:* -Green Space Preservation -Public Service Costs	*Costs of Providing Public Services (M)*
b. Transportation- Related Impacts: - Savings in Vehicle Operation Costs - Travel Time Savings - Reduction in Risk of Accidents - Comfort and Convenience - Traffic Congestion Effects	*Vehicle Operation Costs (M)* *Travel Time (M)* *Accident Costs (M)*
c. Socio-Economic Development Benefits: -Affordability (Housing) -Affordability (Transport) -Social Inclusion -Socio-Economic Growth -Land-Use/Transport Accessibility -Area Property Values	*Area Property Values (Q)*
3. Transport Network Effects: -Reliability/Quality of Transport Service -System Operating Costs	*System Operating Costs and Revenues (M)*
4. Energy and Environmental Impacts: -Climate Change Emissions (Greenhouse Gas Emissions) -Air/Noise Pollution Exposure - Energy Consumption	*CO_2 Emissions(M)* *Local Air Pollution (M)* *Local Noise Pollution (Q)*

Note: (M) denotes the indicators with a monetary value while (Q) representing the qualitative or quantitative assessment

benefits from economic growth are mainly represented in travel cost savings which results from improvements in the efficiency of the transportation system. Travel cost savings include the savings in travel times, vehicle operation costs and costs of accidents, reduction in traffic congestion etc. Some studies argue that the inclusion of economic growth effects will lead to double counting since "economic growth benefits are the manifestation of capitalised travel cost savings" (OECD, 2002: 19). OECD (2002) reports that only travel cost savings should be regarded as benefits from transport infrastructure investments unless perfect competition is satisfied within the markets. Based on the reasons explained above, socio-economic effects of rapid rail investments such as metro and high speed rail projects are represented by a limited number of impacts (see Table 6). These are defined as *transportation-related impacts*-including 'travel time savings', 'savings in accident and vehicle operation costs'; *development benefits*-including 'area property values'; and *land development impacts*-including 'public service costs'. Their details will be examined in the following sub-sections.

[1] Source: Janic, 2003; Litman, 2008.

(a) Travel Time Savings:

CBA is based on the assumption that users of the transportation system have a willingness to pay price/value for undertaking trips. Hence, if the travel time is shortened, they can appreciate the value of saved time having a positive effect in cost-benefit assessments. Savings in travel time is an important indicator in transport project appraisals due to the fact that it captures economic growth effects-stemming from travel time savings of labour; traffic congestion effects-reflecting the ease of travelling prior to a considerable transfer from private car usage to rapid rail-based transportation. Accessibility changes in land use-indicating savings in various travel costs and the resultant easiness of access reflect a shift from more dispersed developments to more compact urban form. Here it is important to mention that the direct short term effect of rapid rail projects is on existing travel pattern while the long term effect is potentially on urban development pattern.

(b) Savings in Accident Costs:

It is widely accepted that public modes of transport have lower accident rates than private car trips. Litman (2000) states for the Canadian case, the number of accidents per public transit vehicle is 5% of the corresponding rate for car travel trips. Among the alternative public transport modes, metro and other high speed rail systems can be considered as the most reliable ones due to the low likelihood of fatal accident occurrence. Therefore, a major shift from car-based transportation to metro-based systems can contribute to considerable amount of savings in (fatal) accident costs. Accident cost savings can also be considered as socio-economic benefits which contribute to social and economic well-being by reducing the injury and fatality rates and the resultant losses in labour force.

(c) Savings in Vehicle Operation Costs:

Vehicle operating cost savings are associated with user benefits indicating the shift of travel from private car to public transit-i.e. rapid rail transport in our case. At a minimum, the shift from private car to an efficient rapid rail-based system can save fuel and oil, which can be considered to have important impacts on energy consumption and environment pollution levels. In addition, there are costs of depreciation, insurance and parking which are increasing with car usage. In addition, there are increases in repair and maintenance costs, reductions in vehicle resale value, increases in parking and traffic costs etc. (see Litman, 2000).

(d) Area Property Values:

Empirical evidence has shown that introduction of a transit system results in increases in property values along the transport corridors (see for example, Armstrong, 1994; Benjamin and Sirmans, 1996; Nelson, 1998). These studies pointed out that the results presumably indicate the short term impacts of the introduction of a new transport system rather than the long term market effects. The degree to which increases in property values stems from transport investments is not clear due to the existence of other forces influencing real property markets. However, it can be suggested that transport impacts on economic development, on land-use and transportation accessibility; and the resultant effects on property markets are reflected in property values, despite the existence of price distortions and the imperfect knowledge in real property markets. It is also important to highlight is the existence of relocation effects stemming from local development captures the gain achieved by one area is lost by another area in the region implying a net zero effect at the national level. Therefore, it is suggested that effects on local development reflected in adjusted property values are not to be taken into account in CBA but can be evaluated separately subject to a qualitative assessment.

(e) Public Service Costs:

Dispersed or sprawl type of development necessitates providing public services to the low density population reflecting increases in infrastructure and public service costs (see Litman, 2008). Frank (1989) showed that municipal capital costs of residential service provision increased considerably with dispersed development. This can be a significant indicator in the CBA reflecting the change in public service costs following the shift from dispersed to more compact developments after the introduction of rapid rail-based transportation systems.

3.1.3. Transport Network Effects

Related to the transport network effects, the operating costs and revenues of the transportation infrastructure constitute a significant part in project evaluations, and therefore, they are incorporated in all of the transport evaluation studies examined previously. The system operating costs and revenues will be included in CBA with a monetary value based on cost and revenue estimates.

3.1.4. Energy and Environmental Impacts

It is widely accepted that changes in the climate system is effected by human-induced emissions i.e. greenhouse gas emissions such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Although transportation is not the only contributor to the rising levels of greenhouse gas emissions, it is the fastest rising contributor to the problem (Commission of the European Communities, 1990). The dramatic increase in the private vehicle ownership, which is also encouraged by the provision of large scale urban motorways, has led to air pollution, noise, and increasing amounts of transport-related energy consumption. In contrast, on average, rail produces less carbon dioxide per passenger and tonne kilometer than road transport.

Although there are examples of counter arguments, the general research has been in favour of compact urban form in comparison to the more dispersed urban developments largely on the grounds of transportation energy savings (see Breheny, 1995). Energy and environmental impacts i.e. energy consumption, air/noise pollution exposure, climate change emissions (greenhouse gas emissions) are all important for the Cost-Benefit evaluation process. Since energy consumption effects are also represented in vehicle operation costs, the only impact which will be monetised in the present analysis is the cost savings in carbon dioxide emissions. Based on data availability, local air/noise pollution can also be included in the CBA either by qualitative or quantitative evaluation.

3.2. Implementation of CBA for Impact Evaluation of Rapid Rail Investments

The impacts and indicators which were selected for the CBA can be quantified by utilising the appropriate country specific values published in various studies, reports and national project appraisal guidelines. In relation with these studies, the values and parameters for the appraisals of capital costs, public service costs, accident rates, vehicle operation costs, system operating cost and revenues, travel time and costs of carbon dioxide emissions and local air pollution involve a large number of working steps for which particular data input is required. Below is the brief explanation of the evaluation process.

3.2.1. Scenario Analysis for the CBA

Scenario analysis comprising a baseline scenario (reference scenario) which is compared with several alternative scenarios can construct a base for the impact evaluation of rapid rail investments in the European wide area. The research is based on the consideration of two scenarios: A baseline-*do minimum* and an alternative *with rail* scenario. According to the *do-minimum* scenario, it is assumed that the urban area would continue to grow with the present trends and there would be only sufficient maintenance and renewal investments to maintain the existing infrastructure. Therefore, rail services in future years would be broadly comparable to the current level leading to a dispersed urban form.

Considering land development impacts of rapid rail investments, it can be expected *with rail* scenario will generate more compact forms of urban development. By encouraging a transfer from private transport, rapid rail investments can assist in improving accessibility and land-use change which supports compact and mixed developments. The potential for efficiency and environmental impacts will be examined through the impacts and indicators specified in the previous sections for the European Region. The process of economic appraisal of the rapid rail investments in comparison with a *do minimum* scenario can be summarised by the following steps:

- Forecasting transportation demand with a transportation model consisting of:
    - Forecasts of future growth and land-use change (population, employment, economic activity, income)
    - Assumptions of the supply side of transportation activities
    - Assumptions and scenarios for external conditions

- Four stage method: trip generation, spatial distribution of trips, modal split and modal assignment

- Quantifying, where possible, incremental costs and benefits relative to the *do-minimum* scenario;
- Identifying unquantifiable impacts;
- Adjusting quantified costs and benefits for:
  - inflation
  - relative price changes
  - risk and optimism bias
- Undertaking sensitivity analysis;
- Calculating the net present value.

3.2.2. Specific Issues in Impact-Indicator Evaluation

In accordance with the estimations from the transportation model utilised in the subject country and the parameters/values specified for capital costs, accident costs, vehicle (and system) operation costs, public service provision costs, travel time, carbon dioxide emissions and local air pollution, Table 7 in the following page presents the related data requirements for the scenario analysis of *do minimum* and *with rail* cases. Based on the impact evaluation data given in Table 7, some specific issues in impact valuation methods are then explained.

3.2.2.1. Capital Cost Estimation of Rail Investments

A broad estimate of the capital costs for any rapid rail provisions is obviously obtained at project initiation stage. These estimates are expressed in constant prices and are generally built up using unit cost data, expert advice and experience of similar projects in the past. Given the inherent uncertainty at this stage, the detailed risk analysis is necessary to reduce uncertainty around the expected infrastructure costs of rapid rail projects.

In the literature, there are examples showing that cost escalations are common in transport infrastructure projects, particularly in urban rail projects. For instance, Flyvbjerg *et.al.* (2002) showed that transport infrastructure projects worldwide experience large construction cost escalations; and among them, rail projects incur the highest cost escalation. The average cost escalation for rail projects is 44.7%, followed by fixed-link projects (bridges and tunnels) by 33.8% and road projects by 20.4% (see Flyvbjerg *et.al.*, 2002). In a later study, Flyvbjerg *et.al.* (2004) also found that it is the length of the implementation phase which strongly leads to larger percentage cost escalations. Economic and demographic factors, technology, and differences between forecasted and actual operating service plans are considered as the main reasons for uncertainty in project cost estimations. This implies large underestimation of costs resulting in inflated figures and benefit-cost ratios from the CBA, which ends up with misleading conclusions in project evaluations (Flyvbjerg, 2007).

Table 7. Impact Evaluation Data for Rail-Based Infrastructure Investments: With-Rail vs. A Baseline Scenario Approach

Impacts/Indicators	**Impact Evaluation Data Requirements of *With-Rail* Scenario vs. Baseline *Do-Minimum* Scenario**
1. Capital Costs of Rail Infrastructure Investment	Direct construction cost estimates include the following: -Land acquisition costs -Railway infrastructure -Stations -Civil engineering works -Operational systems -Planning and design
2. Provision of Public Services	Future estimated numbers for new residential development (numbers of new housing units) in the case study area within the appraisal period specified for rapid rail investments
3. Accident Rates/Future Accident Risks	Three types of data are required: -The most recent data related to the *number of personal fatality, serious injury, and minor injury accidents along* the catchment area of the newly proposed rail line -Estimated numbers for future accident risks from the national and local accident rates and trends -Quantification of changes in the number of fatalities, serious injuries, and slight injury accidents due to a rapid rail investment by using country specific risk functions
4. Change in Road Vehicle Operation Costs	For the calculation of the economic benefits (costs) associated with vehicle operating costs, two types of data are required: -***Demand***: the number of private vehicles (cars) making a particular origin-destination trip for the *do minimum* scenario and the alternative *with rail* scenario (peak/off-peak traffic flow data for the baseline and alternative scenarios) -***Vehicle kilometres***-total change in vehicle kilometres from the local highway network for the *do minimum* and *with rail* cases
5. Change in Travel Time	Estimates related to; -*Travel time*-change in travel time for private vehicles (cars) in peak/off-peak traffic for the baseline and *with rai*l scenarios -*Demand*: peak/off-peak traffic flow data for the baseline and *with rail* cases
6. Rail Operating Costs and Revenues	-Expected operating pattern and service frequency of newly proposed rapid rail system -Key characteristics (route length, journey time, peak and off-peak headway etc.)
7. Change in Area Land Values	-Amount of greenfield/empty land within the catchment area of new rail line (in hectares). -Amount of other land-uses i.e. commercial, industrial, residential and mixed-uses within the zoning suitability for development catchment area of new rail line (in hectares).
8. Change in CO_2 Emissions/Local Air Pollutants	-Total change in greenhouse gas emissions (i.e. CO_2 , in particular) and local air pollutants (NO_x, SO_2, $PM_{2.5}$ etc.) for the baseline and *with rail* cases.

Practical methods for risk assessment and management in urban rail projects are provided in Flyvbjerg & COWI (2004) where UK transport projects were grouped and evaluated through the optimism bias up-lifts. The idea behind the optimism bias up-lifts is that the projects are classified into a number of distinct groups in order to "*establish a probability distribution for each group with the available data on actual budget increases in completed historical projects...This will provide the link between the observed ex-post cost increases for past projects and the required up-lift for a new project...*" which is referred to as 'optimism bias up-lifts' (Flyvbjerg & COWI, 2004: 10).

The optimism bias up-lifts specified for urban rail projects in the UK are given in Table 8. The table, for instance, shows that if the risk of cost overrun is less than 30 percent then an up-lift of 51 percent will be used for the correction of optimism bias in capital costs of urban rail projects.

Table 8. Capital Expenditure Up-lifts in Constant Prices for Urban Rail Projects

Types of Projects	Applicable optimism bias up-lifts				
	50% percentile	60% percentile	70% percentile	80% percentile	90% percentile
Metro Light Rail Busses on Tracks Conventional Rail High Speed Rail	40%	45%	51%	57%	68%

Source: Flyvbjerg & COWI, 2004: 32

Based on these studies, adjustments for optimism bias should be added to the initial cost estimations in any of the European countries where rapid rail projects are taken place. However, a detailed risk analysis can also reduce the uncertainty in cost estimations; and therefore, the need for optimism bias adjustments can be reduced. For the EU countries other than UK, HEATCO (2004) (a EC 6th Framework Research Programme) suggests an average of 34% capital expenditure up-lift for the rail projects based on the results in Flyvbjerg *et.al.* (2002) representing average cost escalations in Europe.

3.2.2.2. Valuation of Traffic Safety

It can be argued that any limited economic analysis underestimates the value of human life to family, society etc. However, for the purpose of this research an input based upon conventional economic statistics is used. The statistical value of human life (SVHL) has been determined using two methods: Human capital and stated preferences. The former method measures discounted loss of production due to the injury or death of the individual member of the workforce while the latter is used for estimating willingness-to-pay (WTP) values of individuals- indicating their preferences to reduce the risk of being injured or die in an accident. The human capital approach is distinguished by Weisbrod (1961) as to include two separate measures. The first is based on the discounted value of person's future lifetime production-measured by his earnings- under the assumption that production is equally valuable for everyone regardless of their consumption levels. Alternatively, a value of someone's life can be measured by the effects of his death on the welfare of the other people who would survive him. This second approach gives more importance on the consumption levels of the living population and measures the value of life by discounting the excess of person's expected future production over his future consumption. The components of the human capital approach were brought together into an overall value with the widespread application of willingness-to-pay methods.

Considering its wide usage, Grant-Muller *et.al.* (2001) identified some factors which may contribute to the variations of WTP values across the EU countries. These include: 1) income (per capita) variations among member countries influencing individual's WTP values for safety 2) cultural differences which have impact on both governments' attitudes and individual's tastes and preferences for accident reduction measures 3) inclusion or exclusion of some costs i.e. legal costs, other public sector costs etc. 4) differences in the nature of measurement methods i.e. problems of bias in WTP measures. Based on the existence of these factors, HEATCO (2004) suggests using the human capital measures and WTP studies carried out in the countries for which they are applied. In the absence of these estimates, the values suggested by another EC Research Project, UNITE can be applied (see HEATCO D:5, 2004: 88). The case studies in UNITE project are analysed by using the marginal external cost approach. These values depend on purchasing power, accident risk, and risk elasticity of the country that is examined. Considering these differences, UNITE project also set recommendations which allow adjustments to EU member countries of a common European set of values (see Lindberg, 2003). The adjusted values for the EU countries recommended by HEATCO are provided in Table 9.

Table 9. EU Values per Casualty (i.e. per person injured or killed) Avoided (2002 values, Purchasing Power Parity, factor prices[2])

Country	**Accident Type**		
	Fatality Million €	**Serious Injury Million €**	**Slight Injury Million €**
Austria	1.685	0.2301	0.0182
Belgium	1.603	0.2432	0.0157
Bulgaria	0.573	0.0789	0.0056
Cyprus	0.798	0.1055	0.0077
Czech Republic	0.932	0.1252	0.0091
Denmark	1.672	0.2069	0.0162
Estonia	0.630	0.0844	0.0061
Finland	1.548	0.2059	0.0154
France	1.548	0.2163	0.0162
Germany	1.493	0.2065	0.0167
Greece	1.069	0.1397	0.0107
Hungary	0.808	0.1084	0.0079
Ireland	1.836	0.2326	0.0178
Italy	1.493	0.1919	0.0147
Latvia	0.534	0.0723	0.0052
Lithuania	0.575	0.0785	0.0057
Luxembourg	2.055	0.3202	0.0193
Malta	1.445	0.1835	0.0137
Netherlands	1.672	0.2215	0.0179
Norway	2.055	0.2883	0.0207
Poland	0.630	0.0845	0.0061
Portugal	1.055	0.1410	0.0097
Romania	0.641	0.0871	0.0062
Slovakia	0.699	0.0964	0.0069
Slovenia	1.028	0.1335	0.0098
Spain	1.302	0.1618	0.0122
Sweden	1.576	0.2313	0.0166
Switzerland	1.809	0.2480	0.0191
United Kingdom	1.617	0.2089	0.0166

Source: HEATCO D:5, 2004. European Commission Final Report, 2008-refer to JASPER for Bulgaria and Romania

[2] Consumption and production are subject to a number of indirect taxes and subsidies. These are reflected in the calculation of market prices where "items are valued as if they are being traded in consumer markets with all indirect taxes and subsidies in place" (UNITE, 2001: 2). By contrast, in factor cost valuation, indirect taxation and subsidies are not taken into account. In principle, cost or benefit accounts could be expressed in either market prices or factor costs. Nevertheless, UNITE (2001: 3) noted that "the majority of the items on the cost side of the account are conventionally measured at factor costs, and this is the side of the accounts that will be used and studied the most...Therefore, factor costs are suggested to be used as a unit in the UNITE accounts". Based on this, factor costs will also be utilised in the current study for computing the costs and benefits.

Increasing values for future years will be based on estimation of country specific rate of growth in real GNP (or GDP) per person employed. In relation, HEATCO (2004) also recommended a default inter-temporal elasticity to GDP per capita growth of 1.0. In contrast to cross-sectional elasticity, inter-temporal elasticity to GDP considers underlying changes in both individuals' preferences and technology over time.

3.2.2.3. Vehicle Operation Costs

(a) Road Vehicle Operation Costs:

The unit vehicle operating costs are clearly dependent on the prices of goods within a region (i.e. price of oil, vehicle parts etc.), the transport network characteristics, and vehicle utilisation. However, operating cost relationships for road vehicles is more generic and transferable between countries (see HEATCO D:5, 2004). For instance, fuel and non-fuel consumption parameters for private car and busses can be computed by the following formulas in (4) and (5), respectively:

$$C= a + bV + cV^2+dV^3 \tag{4}$$

$$C= a_1 + (b_1/V) \tag{5}$$

where C is the cost in cents per kilometre, V is the average link speed in kilometres per hour, and a, b, c, d, a_1 and b_1 are the parameters defined for each vehicle category. As an example, UK values for fuel consumption parameters are shown in Table 10 for the year 2002. Post-2002 values can be computed by using the suggested growth factors[3] and are monetised by applying the market price of fuel in any specific country. The non-fuel cost formula in (5) can be adopted to the country case by using the Purchasing Power Parity (PPP) conversion, and then inflated to the post-2002 values by using the Consumer Price Index (CPI) for the related period. The non-fuel consumption parameters are given in Table 11 again representing the 2002 UK values.

Table 10. CBA Fuel Consumption Parameters in litres/km (2002, UK values)

Vehicle Category	**Fuel Parameters**			
	a	b	c	d
PETROL CAR	0.18804764	-0.00437947	0.00005068	-0.0000001691
DIESEL CAR	0.14086613	-0.00285222	0.00002867	-0.0000000693
AVERAGE CAR	0.17813952	-0.00405874	0.00004606	-0.0000001481
PSV	0.63466867	-0.01898970	0.00027431	-0.0000012161

Source: Department for Transport UK (2009)

Table 11. CBA Non-Fuel Consumption Parameter Values in pence/km (2002, UK values)

Vehicle Category	**Parameters**	
	a_1	b_1
AVERAGE CAR	3.030	19.048
PSV	24.959	569.094

Source: UK Department for Transport (2009)

[3] See Department for Transport UK (2009)

(b) Rail Operating Costs:

Railway costs can be analysed as fixed and variable costs. Fixed costs are incurred costs for operation, maintenance, and replacement which are independent of traffic volume changes. Variable costs, on the other hand, are those which depend on traffic volume. The elements of the variable unit operating costs for railways are specified by World Bank in its 1995; 2005 Infrastructure Reports, and given in Table 12 below:

Table 12. Elements of Rail Operating Costs

Cost Type	
• ***Vehicle Ownership Costs***	
Locomotives/Coaches	Replacement Cost
• ***Vehicle Maintenance Costs***	
Locomotives/Coaches	Unit cost/loco. Unit-km
	Unit cost/coach-km
	Unit cost/coach-year
• ***Transportation Costs***	
Train fuel	Unit cost (gross ton-km)
Train crew wages	Actual by cost centre
Locomotive crew wages	Actual by cost centre
Station operations	Unit cost/train-km
Billing	Unit cost/car load
Other	Unit cost/train-km

Source: Anderson (1995), World Bank (2005)

In relation with Table 12, rapid rail operating cost estimations require three main sets of data including:

-Crew Wages (drivers and operation staff, working time directives)
-Maintenance Costs (rolling stock, equipment, security, insurance)
-Power Usage Costs (power traction/auxiliaries, power depots and stations).

3.2.2.4. Value of Time

There are two categories of time that are involved for valuing travel time savings of passengers i.e. working and non-working, the former of which is related to commuting for working purposes while the latter is comprising all other non-working activities. Travel time is evaluated by standard values of time for each vehicle category assuming a constant marginal unit value of time regardless of the time saved and the variance of income levels of individuals. The valuation is based on three sources. First, cost saving approach, which considers wage rates as a measure of productivity loose or gain by the labour force, is selected as a minimum approach for the valuation of work time savings (see HEATCO, 2004). Second, a new methodology proposed by Hensher (1977) can be suggested to be used for the valuation of work travel time.

According to Hensher (1977), work trips have two components: a business component assuming that not all travel time is unproductive, and a private component presuming that not all savings are transferred to extra work but utilised for non-work purposes. Other than these, a further approach is based on the idea of willingness-to-pay (WTP) which is used for the valuation of both all non-work trips and the private component of work trips. Stated preference and revealed preference are the two methods used in WTP analyses for the purpose of generating a differentiated structure of values of time-both work and non-work.

In this study, national values for net average hourly wages for work time valuation are used, and for the non-work time valuation use the values in national value of time studies published in any country of interest. There are various countries that have already published national value of time studies including the Dutch national value of time studies 1986-1995 (Hague Consulting Group, 1996), Norwegian value of time study (Ramjerdi *et.al.*, 1997), national Swedish value of time study (Alger *et.al.*, 1996), value of time research in Finland (Pursula and Kurri, 1996) and the UK value of time study 1994 (Hague Consulting Group, 1994) (references derived from Wardman, 1998; Nellthorp *et.al.* 2001). Furthermore, HEATCO (2004) also identified national values for work and non-work travel time savings by utilising meta-analysis models to estimate the travel time values for each country (see Table 13). In the absence of country specific studies on national time values, the values derived from HEATCO meta-analysis can be used as shown in Table 13. In order to account for the income variations in the value of time savings across population, HEATCO (2004) also recommended a cross-sectional elasticity to income of 0.5 for work trips and 0.7 for non-work trips considering the absence of country specific values. For measuring future growth in value of time, it can be suggested using the annual growth rates in GNP per person employed for any country of interest.

Table 13. EU Values for the Travel Time (2002 values, € per passenger per hour, factor prices)

Country	Work Passenger Trips		Non-work Passenger Trips			
			Commute		Other	
	Bus	Car, Train	Bus	Car, Train	Bus	Car, Train
Austria	22.79	28.40	7.42	10.32	6.22	8.65
Belgium	22.03	27.44	7.07	9.84	5.93	8.26
Cyprus	16.92	21.08	7.32	10.18	6.14	8.53
Czech Republic	11.45	14.27	5.31	7.38	4.45	6.18
Denmark	25.31	31.54	7.82	10.88	6.56	9.12
Estonia	10.30	12.82	4.60	6.40	3.86	5.36
Finland	22.59	28.15	7.00	9.73	5.87	8.16
France	22.23	27.70	10.11	14.06	8.47	11.79
Germany	22.35	27.86	7.42	10.32	6.22	8.65
Greece	15.59	19.42	6.40	8.90	5.37	7.46
Hungary	10.85	13.52	4.66	6.48	3.91	5.44
Ireland	23.97	29.87	7.74	10.77	6.49	9.03
Italy	20.57	25.63	9.38	13.04	7.86	10.94
Latvia	9.41	11.73	4.20	5.85	3.52	4.90
Lithuania	9.29	11.58	4.09	5.69	3.43	4.77
Luxembourg	30.51	38.02	11.00	15.30	9.22	12.83
Malta	14.96	18.64	6.02	8.37	5.05	7.02
Netherlands	22.47	28.00	7.17	9.97	6.01	8.37
Poland	10.33	12.87	4.56	6.34	3.82	5.32
Portugal	15.52	19.34	6.18	8.59	5.17	7.20
Slovakia	9.92	12.36	4.25	5.91	3.57	4.96
Slovenia	15.08	18.80	7.42	10.33	6.22	8.66
Spain	17.93	22.34	7.87	10.94	6.59	9.18
Sweden	24.32	30.30	7.57	10.53	6.35	8.83
Switzerland	26.47	32.97	10.36	14.41	8.69	12.08
United Kingdom	23.29	29.02	7.69	10.70	6.46	8.98
EU (25 Countries)	**19.11**	**23.82**	**7.83**	**10.89**	**6.56**	**9.13**

Source: HEATCO D:5, 2004

3.2.2.5. Environmental Impacts

An environmental impact assessment will usually be required for any significant rapid rail infrastructure development in the European Region. In relation with this, three environment impacts are considered as given in Table 2:

- Global air pollution
- Local air pollution
- Noise pollution

Global air pollution which is mainly caused by carbon emissions can be calculated from the values attributed to the carbon dioxide by using the following three methods:

(a) *EU Emissions Trading Scheme (ETS) Futures Price:*
Through the establishment of the European Union Trading System (EU-ETS) for carbon dioxide emission permits, a price for carbon emissions has been developed. However, there are some problems with its usage for the valuation of transportation-related carbon emissions. In a study by Tol and Lyons (2008), the ETS is defined as a spot market and does not consider the expectations of the future. In addition, Curtin (2008) reported that EU-ETS covers approximately 41% of total EU carbon dioxide emissions which include only a limited number of sectors and exclude transport, housing, agriculture and waste sectors from the EU-ETS (World Bank, 2008).

(b) *Marginal Abatement Cost of Carbon:*
It is the cost of reducing emissions by one unit at a given emissions level (Stern, 2007). Marginal abatement cost of carbon is absolutely country specific since each country has its specific carbon dioxide reduction targets; and even in one country, targets may differ across various sectors (Maibach *et.al.* 2007).

(c) *Social Costs of Carbon(SCC):*
Tol and Lyons (2008) defined the social cost of carbon as the welfare loss due to a small increase in carbon emissions. This relates to the “net present value of climate change impacts over the next 100 years (or longer) of one additional tonne of carbon emitted to the atmosphere today” (Watkiss *et al*, 2005).Due to the uncertainty of future emissions and climate change, there is wide uncertainty among the SCC estimates. Kuik *et.al.*’s (2008) meta-analysis study is well known in the literature verifying this considerable variability across the SCC estimates. Since this is the case, for the post-2014 period,` Kilcullen (2008) suggested using the fixed carbon price of €39 per tonne which is the assumed average carbon price of the European Commission (EC)[4] in its Impact Assessment of the February 2008 Energy and Climate Change Policy Brief.[5]

[4] The packages of the Climate Policy Measures published by the EC on January, 2008 is mainly based on the design of the post-2012 EU-ETS for sharing the binding emissions reduction target between member states which is followed by the establishment of binding target for renewable and biofuels in transport for all member states (EC-Energy and Climate Change Policy Brief, February 2008).

[5] In EC’s Impact Assessment, the direct economic costs (investment, management and fuel costs) are estimated of the package at €91 billion or 0.58% of EU GDP in 2020. A carbon price of €39 was estimated to be appropriate for these objectives to be achieved (EC-Energy and Climate Change Policy Brief, February 2008).

There are additional key studies on climate change by INFRAS/IWW (1995), Cline (1992), Fankhauser (1994) and others having an estimate of €50 per tonne of carbon emitted (references were derived from Grant-Muller *et.al.*, 2001). However, sensitivity testing is suggested in these studies considering the existence of wide confidence intervals (see Grant-Muller *et.al.*, 2001). Alternatively, Kuik et.al. (2007) in the CASES Project points to the study performed by DEFRA (2005) as the most recent policy oriented study on the social costs of carbon. The CASES Project (2007) recommends using the carbon prices obtained by DEFRA (2005) as a central estimate for the price of global carbon emissions (see Table 14), which will be also considered for the current study. A sensitivity test is required for the shadow values of carbon tested with lower and upper estimates for each corresponding year as given in Table 14.

Table 14. Shadow Prices per tonne of CO_2 Emitted (2000 values, factor prices)

Year of Emission	Lower Values, €	Central Values, €	Upper Values, €
2000-2009	4	23	53
2010-2019	5	28	65
2020-2029	6	33	88
2030-	8	41	110

Source: CASES, D 3.2., 2007: 103-results based on DEFRA (2005)

Local pollution differs from global pollution in that it is caused by road transportation is absolutely case specific since it has impacts on human health and environment in local areas. The main pollutants (i.e. NO_2, PM_{10} and $PM_{2.5}$) are directly related with the number of vehicles travelling on each of the local roads; and therefore, the change in number of vehicles results in changes in concentrations of emissions in the affected areas. Willingness-to-pay methods are generally used for the valuation of the estimated damage. The evaluation can be based on the number of properties or people experiencing better or worse air quality in terms of the pollutants of NO_2, PM_{10} and $PM_{2.5}$ in relation with the *do minimum* and *with rail* scenarios.

The Impact Pathway Approach (IPA) was developed for the environmental impact evaluation in the ExternE[6] project series by the EC (1999; 2005). According to the IPA approach, a transport activity causes changes in concentrations of air pollutants, which have impacts on various receptors i.e. human beings, materials or ecosystems. This results in direct and indirect impacts on the utility of affected persons. The valuation of these welfare changes follows the willingness-to-pay (WTP) or willingness-to-accept (WTA) approaches for the damages to human health. For materials or crops, market prices can be used directly to evaluate the damages.[7] The IPA, in particular, summarises the general evaluation methodology for the costs of local air pollution in a specified area of interest.

In the ExternE projects, country specific impact and cost factors were calculated using the EcoSense software tool, and impacts and resulting costs occurring in Europe were calculated for increasing the existing emissions of NOx, SO_2, $PM_{2.5}$ and NMVOC (non-methane volatile organic compounds) by 10 percent in each

[6] Externalities of Energy

[7] The monetary values in the ExternE projects have been derived through meta-analysis (for mortality values) and by using the most robust estimates (see EcoSenseWeb, 2008).

country (see HEATCO D5, 2006). Impacts and costs were compared to those calculated for the reference scenario, which implies that the difference between both scenarios is caused by the additional emissions. Table 15 presents cost factors in € per tonne of pollutant emitted by road transportation in EU countries and these are suggested to be used for the current study.

Table 15. Cost Factors for Road Transport Emissions per tonne of Pollutant Emitted, (2002 Values, Factor Prices)

Pollutant Emitted	**NO_x**	**NMVOC**	**SO_2**	**$PM_{2.5}$**	
Effective Pollutant	**O_3, Nitrates, Crops**	**O_3**	**Sulphates, Acid Deposition, Crops**	**Primary $PM_{2.5}$**	
Local Environment				**Urban**	**Outside Built-Up Areas**
Austria	4,300	600	3,900	450,000	73,000
Belgium	2,700	1,100	5,400	440,000	95,000
Cyprus	500	1,100	500	230,000	20,000
Czech Republic	3,200	1,100	4,100	170,000	61,000
Denmark	1,800	800	1,900	520,000	54,000
Estonia	1,400	500	1,200	100,000	23,000
Finland	900	200	600	400,000	33,000
France	4,600	800	4,300	430,000	83,000
Germany	3,100	1,100	4,500	430,000	80,000
Greece	2,200	600	1,400	210,000	34,000
Hungary	5,000	800	4,100	150,000	54,000
Ireland	2,000	400	1,600	510,000	50,000
Italy	3,200	1,600	3,500	370,000	70,000
Latvia	1,800	500	1,400	80,000	22,000
Lithuania	2,600	500	1,800	90,000	28,000
Luxembourg	4,800	1,400	4,900	590,000	96,000
Malta (O_3 Estimated)	500	1,100	500	170,000	16,000
Netherlands	2,600	1,000	5,000	470,000	88,000
Poland	3,000	800	3,500	130,000	53,000
Portugal	2,800	1,000	1,900	210,000	37,000
Slovakia	4,600	1,100	3,800	110,000	49,000
Slovenia	4,400	700	4,000	220,000	55,000
Spain	2,700	500	2,100	280,000	41,000
Sweden	1,300	300	1,000	440,000	40,000
Switzerland	4,500	600	3,900	640,000	86,000
United Kingdom	1,600	700	2,900	450,000	67,000

Source: HEATCO D:5, 2005
Note: Cost categories included are: human health, crop losses and material damages

Regarding noise pollution, it can be stated that its measurement is difficult and expensive and highly dependent on local area conditions. In the context of rail based transportation, noise nuisance is likely to be associated with construction of the network, depot activity and with the continuous noise of passing trains affecting adjacent properties. Where modal switch is significant as in the case of *with rail* scenario, there may be significant implications for the change in the level of noise from road traffic, especially in the context of the number of cars and other traffic in locally affected areas. Noise is measured using a logarithmic scale. And again it can be evaluated in terms of properties subject to increases or decreases in noise. Hedonic price approach or stated preference techniques are widely used in the valuation of noise pollution.

3.2.2.6. Public Service Provision Costs

Among the problems related to urban sprawl, costs of public service provision is the one which requires further examination considering its negative impacts on the local public finances. In this respect, there is growing literature concerning the relationship between population size, density and the costs of providing local public services (for a complete literature review, see Carruthers and Ulfarsson, 2008). For example, the study by Buttner *et.al.* (2004), on the costs of local services in Germany confirmed that a low population density resulting from a dispersed development can increase the costs of some services such as roads, energy, water supply and cultural affairs. Sole-Olle and Rico (2008) have a similar conclusion for the public service provision costs in Spanish Municipalities. This study showed that with the expansion of the urban areas, public service provision costs initially increase as a result of the increase in road construction and general administration costs, and then, following a further increase in urban sprawl, costs continue to increase due to the higher provision costs in housing, local police, culture and community facilities.

The study by Carruthers and Ulfarsson (2008) utilised an econometric approach in order to examine the relationship between local public spending and some density measures in the US local governments. This study again provides an evidence of the positive impact of urban sprawl on the provision costs of certain local public services i.e. education, parks and recreational facilities, police protection and roadways. Despite the differences in their methodology and research areas, a common result from these studies indicate that dispersed expansion of population increases the costs of local public service provision.

Public service provision costs will therefore be utilised as an indicator for the cost-benefit evaluation of the *with rail* and *do minimum* scenarios indicating a negative cost impact of the more dispersed development compared to a compact urban form resulting from investments in rapid rail infrastructure. Public service cost estimations are case specific and can be identified as the costs of road construction, housing and community development, education, fire and police protection, water and electricity distribution, sewerage, and social and recreational facilities. Unit public service costs can be computed where data is available on each of these different cost items.

3.2.2.7. CBA Evaluations

A Cost-Benefit Analysis (CBA) approach which is based on a straight net present value calculation is considered appropriate for the evaluation of the transport and land-use impacts of rapid rail investments (in comparison with a *do-minimum* case) in the European wide area. In CBA, all costs and benefits are reduced to their present value and discounted at a standard rate over the pre-specified evaluation period through the formula given in (6) which is followed by the benefit-to-cost ratio (B/C) and Internal Rate of Return (IRR) formulas in equations (7) and (8).

$$ENPV = \sum_{t=0}^{n} a_t S_t = \frac{(b_0 - c_0)}{(1+r)^0} + \frac{(b_1 - c_1)}{(1+r)^1} + \ldots + \frac{(b_n - c_n)}{(1+r)^n} \tag{6}$$

$$B/C = \frac{\sum_{t=0}^{n} \left[(b_t) / (1+r)^t \right]}{\sum_{t=0}^{n} \left[(c_t) / (1+r)^t \right]} \tag{7}$$

$$IRR : \sum_{t=0}^{n} \frac{(b_t - c_t)}{(1+i)^t} = 0 \tag{8}$$

Here S_t is balance of cash flow funds at time t comprising flow of benefits, b_t, and flow of costs, c_t; a_t is discount factor, r is discount rate, and n is the evaluation period (see European Commission Final Report, 2008). This is also used to produce a benefit-cost ratio (B/C) and internal rate of return (IRR). The former is the ratio of the discounted aggregate net benefits (i.e. benefits minus costs) to the discounted investment costs. In practice, as a decision rule, benefit-cost ratio which is greater than 1 is acceptable for the evaluated schemes. On the other hand, IRR is the rate of discount equating discounted net benefits to discounted investment costs. The selection criterion for a policy or project is that IRR be greater than the selected rate of discount i.e. (r).

The social discount rates and project appraisal periods vary among countries reflecting the local variations in opportunity costs of capital, project risks, and lifetimes of rapid rail investments. UNITE project suggests use of a European social discount rate of 3% whilst it is mentioned in another EC project i.e. HEATCO that a rate of 5% is suggested by EC-DG Regional Policy (2002) (see HEATCO D:5, 2004). This implies use of a range of discount rates between 3% and 5% in cost-benefit analysis. The evaluation period of 40 years is suggested by HEATCO project as a default evaluation period as in the TEN-Transport Programme (i.e. planning and construction period plus 40 years of operational period). This is suggested to be used in the absence of information regarding the evaluation period in national appraisal guidelines.

Further to the calculation of cost-benefit indices within the CBA framework, there is an additional step that may influence the final valuation of the impacts of rapid rail investments: It is the sensitivity analysis approach which is mainly used for testing the effects of uncertainty in the value of indicators. Therefore, this approach can be used as a means of testing the robustness of the appraisal outcomes. The summary of sensitivity testing is given in Table 16.

Table 16. Summary of Sensitivity Testing

Factors and Impacts subject to Sensitivity Testing	**Sensitivity Test**	**Explanation**
Optimism-bias in capital costs	-optimism-bias uplift %	Original capital cost estimates will be tested to the capital costs with optimism-bias uplifts
Value of time	VTTS -20% VTTS +20%	*Uncertainty in National Value of Travel Time Savings (VTTS):* Appraisal results from national appraisal guidelines will be sensitivity tested to VTTS values +/-20 % of those national values
	VTTS -40% VTTS +40%	*Uncertainty in HEATCO Meta-Analysis Value of VTTS:* Appraisal results will be sensitivity tested to VTTS values +/-40% of the HEATCO values
	VTTS -10% VTTS +10%	*Uncertainty in Local WTP Value of VTTSs:* Appraisal results from local WTP survey should be sensitivity tested to the upper or lower limits of the 95% confidence interval of the local VTTS or +/-10% whichever is larger
Inter-temporal elasticity to GDP	$E_{\text{Inter-temporal}} = 0.7$ vs. $E_{\text{Inter-temporal}} = 1.0$	*Treatment of VTTS over time:* Inter-temporal elasticity to GDP per capita growth of 0.7 will be sensitivity tested to elasticity to GDP per capita growth of 1.0.
Elasticity to income for work trips	$E_{\text{VTTS, Income}}=0.5$ vs. $E_{\text{VTTS, Income}}=1.0$	*Treatment of VTTS based on income variations:* A cross-sectional elasticity to income of 0.5 for passenger work trips will be sensitivity tested to the cross-sectional elasticity to income of 1.0.
Accidents	Value of safety /3 Value of safety*3	Appraisal results will be sensitivity tested by using v/3 as low and v*3 as high sensitivity
Global air pollution	Year of Emission / Central Estimates (Lower, Upper): 2000-2009: 4, 53 2010-2019: 5, 65 2020-2029: 6, 88 2030-: 8, 110	*Uncertainty in costs of global carbon emissions:* Shadow values of carbon in Table 14 (central estimates) will be sensitivity tested tolower and upper estimates for each corresponding year
Social discount rate	3.5% compared to 3% 4.0% compared to 3% 4.5% compared to 3% 5.0% compared to 3%	Appraisal results from various discount rates will be tested to those computed by applying the base discount rate of 3%.

Adapted from: HEATCO: D5 (2006)

4. Conclusion

In conclusion, this research has explored the development of an adapted CBA approach to urban rail investment projects, which is to be used in the testing of various scenarios relating to urban form. This will allow the CBA process be used as a policy support tool in discussions of alternative development and investment decisions such as compact versus dispersed urban form. This approach is intended to allow for the development of an improved quantitative evidence basis for decisions on infrastructure spending. Through the identification of standard criteria for inputs and evaluation, this approach should assist in cross-national or cross-programme results analysis. In addition, it is possible that a variety of potential development scenarios can be developed and tested. Future research linked with this analysis will involve the testing of the model on two European cities with planned rail infrastructure investment.

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